AquaFish CRSP
Third Annual Report

1 October 2008 to 30 September 2009

AQUACULTURE & FISHERIES
COLLABORATIVE RESEARCH SUPPORT PROGRAM
MANAGEMENT ENTITY, OREGON STATE UNIVERSITY

USAID FROM THE AMERICAN PEOPLE

Oregon State UNIVERSITY OSU

AQUAFISH COLLABORATIVE RESEARCH SUPPORT PROGRAM

AQUAFISH CRSP THIRD ANNUAL REPORT

Program activities are funded in part by the United States Agency for International Development (USAID) under CA/LWA No. EPP-A-00-06-00012-00 and by participating US and Host Country institutions.

Disclaimers
The contents of this document do not necessarily represent an official position or policy of the United States Agency for International Development (USAID). Mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use on the part of USAID or the AquaFish Collaborative Research Support Program (CRSP). The accuracy, reliability, and originality of work presented in this report are the responsibility of the individual authors.

Acknowledgments
The Management Entity of the AquaFish CRSP gratefully acknowledges the contributions of CRSP researchers and the support provided by participating US and Host Country institutions.

Cover Photo
At markets in Bamako, Mali, fisheries products can at times appear to be in abundant supply. However, as this fish market vendor—a member of the *Feminine de la Conservation et de la Transformation des Produits de Pêche**—can attest, supplies usually do not meet the demand for fish. The AquaFish CRSP hopes to contribute to greater supplies of fish in Mali and the region through aquaculture and fisheries development activities conducted under the Mali Project, funded by USAID/Mali through an Associate Award. Photo by Jim Bowman (Mali Project Coordinator), Oregon State University.

*Women's Cooperative for the Processing and Marketing of Fishery Products

This publication may be cited as:
AquaFish Collaborative Research Support Program. December 2009, revised April 2010. Third Annual Report. AquaFish CRSP, Oregon State University, Corvallis, Oregon, 203 pp.

AquaFish CRSP Management Entity
College of Agricultural Sciences • Oregon State University
418 Snell Hall • Corvallis, Oregon 97331-1643• USA

CONTENTS

I. INTRODUCTION 1

II. PROGRAM HIGHLIGHTS 2

III. FISHELLANEOUS 5

IV. OVERVIEW OF RESEARCH PROGRAM STRUCTURE 21

V. RESEARCH & TECHNOLOGY TRANSFER ACCOMPLISHMENTS 27

VI. CORE RESEARCH PROJECT REPORTS 32

LEAD US INSTITUTION: AUBURN UNIVERSITY
HYDROLOGY, WATER HARVESTING, AND WATERSHED MANAGEMENT FOR FOOD SECURITY, INCOME, AND HEALTH: SMALL IMPOUNDMENTS FOR AQUACULTURE AND OTHER COUMMUNITY USES *32*

LEAD US INSTITUTION: NORTH CAROLINA STATE UNIVERSITY
IMPROVED COST EFFECTIVENESS AND SUSTAINABILITY OF AQUACULTURE IN THE PHILIPPINES AND INDONESIA *34*

LEAD US INSTITUTION: PURDUE UNIVERSITY
IMPROVING COMPETITIVENESS OF AFRICAN AQUACULTURE THROUGH CAPACITY BUILDING, IMPROVED TECHNOLOGY, AND MANAGEMENT OF SUPPLY CHAIN AND NATURAL RESOURCES *48*

LEAD US INSTITUTION: UNIVERSITY OF ARIZONA
DEVELOPING SUSTAINABLE AQUACULTURE FOR COASTAL AND TILAPIA SYSTEMS IN THE AMERICAS *55*

LEAD US INSTITUTION: UNIVERSITY OF CONNECTICUT–AVERY POINT
DEVELOPMENT OF ALTERNATIVES TO THE USE OF FRESHWATER LOW VAUE FISH FOR AQUACULTURE IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM: IMPLICATIONS FOR LIVELIHOODS, PRODUCTION AND MARKETS *63*

LEAD US INSTITUTION: UNIVERSITY OF HAWAI'I AT HILO
HUMAN HEALTH AND AQUACULTURE: HEALTH BENEFTS THROUGH IMPROVING AQUACULTURE SANITATION AND BEST MANAGEMENT PRACTICES *72*

LEAD US INSTITUTION: UNIVERSITY OF MICHIGAN IMPROVING SUSTAINABILITY AND REDUCING ENVIRONMENTAL IMPACTS OF AQUACULTURE SYSTEMS IN CHINA, AND SOUTH AND SOUTHEAST ASIA *78*

VII. MALI ASSOCIATE AWARD PROJECT 88

VIII. CAPACITY BUILDING 99

SHORT-TERM TRAINING *99*
LONG-TERM TRAINING *101*
OUTCOMES AND IMPACTS OF AQUAFISH CAPACITY BUILDING EFFORTS *105*
PROFESSIONAL CONFERENCES & SYMPOSIA *106*

IX. SYNTHESIS 121
DEVELOPMENT THEMES ADVISORY PANELS (DTAP) *121*
REGIONAL CENTERS OF EXCELLENCE (RCE) *126*
SYNTHESIS PROJECT (SP) *137*

X. MONITORING & EVALUATION 139
DTAP INDICATORS *139*
KEY DEVELOPMENT TARGETS: INDICATORS & BENCHMARKS *157*
USAID – DTAP INDICATORS CROSS-REFERENCING *168*
USAID IMPACT REPORTING *173*

XI. LESSONS LEARNED 184

XII. FINANCIAL SUMMARY 186

APPENDIX 1. PROGRAM PARTICIPANTS 189

APPENDIX 2. PERSONNEL CHANGES APPROVED IN THE REPORTING PERIOD 195

APPENDIX 3. LEVERAGED FUNDING 196

APPENDIX 4. LINKAGES 197

APPENDIX 5. ACRONYMS 200

I. INTRODUCTION

The mission of the Aquaculture & Fisheries Collaborative Research Support Program (AquaFish CRSP) is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. The United States Agency for International Development (USAID) looks at the AquaFish CRSP to "develop more comprehensive, sustainable, ecological and socially compatible, and economically viable aquaculture systems and innovative fisheries management systems in developing countries that contribute to poverty alleviation and food security."

This report describes the activities and accomplishments of the AquaFish CRSP from 1 October 2008 to 30 September 2009. USAID funds the AquaFish CRSP under authority of the Foreign Assistance Act of 1961 (PL 87-195), as amended. Significant funding is also provided by the participating US and Host Country institutions. The AquaFish CRSP is a partner of USAID's Economic Growth, Agriculture, and Trade (EGAT) Bureau's Office of Agriculture.

AquaFish CRSP 's cohesive program of research is carried out in selected developing countries and the United States by teams of US and Host Country researchers, faculty, and students. Now operating under its first USAID award, which was received on 29 September 2006, the CRSP is guided by the concepts and direction set down in the *Program Description*, which is funded under USAID CA/LWA No. EPP-A-00-06-00012-00. This award authorizes program activities from 30 September 2006 to 29 September 2011.

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 technical and programmatic activities at OSU are carried out by a Management Team (MT: Director and staff), which is supported in the task of program administration by advisory bodies. Management team personnel and advisory group membership during the reporting period appear in Appendix 1.

The AquaFish CRSP diverges from the previous Aquaculture CRSP in both organization and theme. Organizationally, this new CRSP is a Cooperative Agreement, with a Leader with Associates (LWA) term of reference. The LWA is a mechanism for allowing additional USAID funding to complement core activities. Core activities are funded by EGAT's Office of Agriculture at $8.9 million over five years. Associate Award activities under the Lead are estimated at an additional $3 million, although there is no obligation by USAID to fund these Associate Awards. There is currently one Asssociate Award focusing on aquaculture and fisheries in Mali, which is funded at $750K over three years (2007-2010). Thematically, the new AquaFish CRSP focuses on aquaculture with its core funds, and on both aquaculture and fisheries with its Associate Awards. The themes echo much of the sustainable aquaculture emphasis of the Aquaculture CRSP, since that earlier CRSP incorporated a farsighted and mindful approach.

II. PROGRAM HIGHLIGHTS

In Fiscal Year 2009, AquaFish CRSP managed seven core research projects and two program-wide projects operating at 15 US universities, in 20 countries, with over 300 collaborators. Below are programmatic comments and highlights for Fiscal Year 2009.

- AquaFish Management Team (MT) responded to a letter of Request for Proposals from USAID/OAA to raise the amount of AquaFish from $8,900,000 to $12,820,000. The proposed work presented additional activities to the existing program and will run concurrently. Objectives for increased funding, as stated by USAID in its letter of Request for Proposals of 14 July 2009 to Oregon State University, are: 1) to promote the extension of CRSP technologies through extension, commercialization, and partnership; and 2) to assess the impact and communicate the importance of CRSP research. Details of new and existing work slated for programming in FY2010 are outlined in the AquaFish CRSP Annual Work Plan 2009-2010 as submitted to USAID in September 2009 (available online at the AquaFish CRSP website).

- External NSF-style peer-review panels were conducted to evaluate projects submitted in response to two Requests for Proposals (RFP) from the AquaFish CRSP MT. The first RFP was for a project focusing on IEHA (President's Initiative to End Hunger in Africa) countries (RFP released November 2008). The second RFP was for 2009-2011 Continuation Proposals from the six existing projects (RFP released June 2009). The IEHA project was awarded to Auburn University for work in Uganda and South Africa. AquaFish CRSP currently manages projects in four IEHA countries: Ghana, Kenya, Mali (Associate Award), and Uganda.

- During this reporting period the AquaFish MT solicited a project submitted by a team of researchers from Oregon State University and Montana State University to assess impacts of the AquaFish CRSP core research. The review process is expected to be completed in January 2010.

- Six of the core research projects negotiated no-cost extensions (NCE) that extended their work under the *Implementation Plan 2007-2009* from 30 September 2009 through 31 December 2009 for five projects and through 31 March 2010 for one other. Contributing to the need for NCEs were a variety of natural and political events that include the following:
  - Severe flooding in Tabasco, Mexico during October–November 2007
  - Political turmoil in Kenya resulting from the 2008 presidential election
  - Sichuan earthquake in China in May 2008
  - El Niño warm water conditions on the Pacific Coast in 2009 that caused slower shellfish growth
  - Swine flu pandemic that began in the Spring of 2009 in Mexico

- The Management Team published the *Implementation Plan 2007-2009 Addendum* with work plan changes and additions (September 2009), the AquaFish CRSP Annual Work Plan 2009-2010 (September 2009), *Aquanews* (quarterly) and *EdOPNet* (monthly). Other publications produced by the Management Team include AquaFish CRSP Brochures (April 2009, September 2009) and posters for the following meetings and events:
  - Aquaculture America (AquaFish CRSP: February 2009)
  - Aquaculture America (Mali Associate Award Program: February 2009)
  - World Aquaculture Society-Veracruz, Mexico (September 2009)
  - Oregon State University Earth Day (April 2009)
  - Oregon State University Day (September 2009)

  All publications are available for download from the AquaFish website.

- In 2009, the AquaFish MT published an online compilation of abstracts from Aquaculture CRSP and AquaFish CRSP research, *The Collected Abstracts from 1996-2008*, available on the AquaFish website.

- The AquaFish MT organized and chaired the AquaFish CRSP Annual Meeting in Seattle,

prior to the Aquaculture America 2009 conference (February 2009). External evaluators were in attendance from World Wildlife Fund and University of Tasmania to assess project output.

- AquaFish CRSP Director Hillary Egna chaired the Aquaculture America 2009 session *International Aquaculture Development for the Poor*. Eight CRSP Host Country researchers presented updates on CRSP research in Cambodia, China, Ghana, Kenya, and the Philippines. Two US Lead PIs presented updates on project work in Mexico and Thailand. Former Aquaculture CRSP researchers were also in attendance and presented presentations on their current work.

- Initial arrangements were made during this reporting period for the CRSP Session at the 2010 World Aquaculture Society (WAS) Conference in March. This session is dedicated to the memory of AquaFish CRSP Host Country Lead PI, Dr. Yang Yi who passed away in July 2009 (See Fishellaneous, pp 5–20). The session, *Optimizing Small-Scale Aquaculture for the Poor: A Session in Honor of Dr. Yang Yi*, will feature 26 of Yang Yi's CRSP colleagues reporting on their research in Africa, Asia, and Latin America.

- AquaFish CRSP promoted the International Symposium on Aquaculture & Fisheries Education that was organized jointly by the Asian Fisheries Society (AFS), Asian Institute of Technology (AIT), and Shanghai Ocean University (SOU), and scheduled for 27–30 November 2009 in Thailand. CRSP researcher Yang Yi was a principal organizer for this event in his capacity as an AFS member.

- AquaFish CRSP promoted IIFET (International Institute of Fisheries, Economics & Trade), which has received past ACRSP support for its biennial conferences.

- AquaFish CRSP continued to provide leverage, establish research ties and help facilitate linkages between ongoing AquaFish CRSP projects and former Aquaculture CRSP researchers. Through their FY2009 quarterly reports, current AquaFish core research projects have reported over $620,000 in leveraged support (i.e. non-AquaFish CRSP funds that were acquired as a consequence of CRSP funding). For additional details, see Appendix 3.

- In October 2008, members of the Board for International Food and Agriculture Development (BIFAD) management team conducted a two-week field visit to Kenya. One of the AquaFish CRSP's major partners in Kenya, Moi University, had been selected by USAID and BIFAD to be included in the tour. Although the BIFAD team was unable to visit the university, Dr. Charles Ngugi, Head of the Department of Fisheries & Aquatic Sciences and a former ACRSP and current AquaFish CRSP Host Country PI, made a well-received presentation to the team at the UN Offices in Nairobi. In his talk, Dr. Ngugi demonstrated how new technologies have impacted the development and management of the aquaculture industry in Kenya dating back to the initial ACRSP partnership, which began in 1997.

- AquaFish CRSP continued its Library Donation Project, shipping boxes of scientific references, textbooks, and journals donated by Oregon State University to Host Country libraries.

- The AquaFish CRSP website intranet/extranet for the MT and project partners was developed and launched during this reporting year. This new, password-protected network features an on-line reporting system for US Lead PIs, a platform for distributing program-related information, and an interactive database system for managing research, outreach, and other data.

- The AquaFish CRSP website link was posted on SARNISSA's (Sustainable Aquaculture Research Network in Sub-Saharan Africa) webpage for Aquaculture Research Institutes. SARNISSA has also made many of the AquaFish CRSP publications available in the CABI Aquaculture Compendium, reaching out to over 1,000 SARNISSA registered stakeholders.

- The AquaFish CRSP MT continued to interact with other CRSP's on a variety of topics. The 2009 CRSP Council meeting was held in Washington DC in conjunction with the 157th meeting of BIFAD, and a joint USAID-CRSP Council Meeting. Additional communication among the CRSPs allowed for development of a CRSP brochure and website, as well as to lay the groundwork for a cross-CRSP information and clearinghouse.

- The Regional Centers of Excellence in Africa, Asia, and Latin America continued to build linkages and promote networking

opportunities. Highlights of their activities are included below.

- In Africa, RCE Lead Coordinator Charles Ngugi (Moi University) has been active building linkages with international and regional agencies including FAO, USAID Missions in Mali and Kenya, ANAF (Aquaculture Network in Africa), Fish Africa, NEPAD (New Partnership for Africa's Development), WIFIP (Women in Fishing Industry Project), and WorldFish to coordinate information dissemination and complement AquaFish CRSP research and extension efforts in IEHA countries. Among its other collaborative efforts, Dr. Ngugi has submitted a proposal to ASARECA (Association for Strengthening Agricultural Research in Eastern & Central Africa) for a project to enhance fish farmer-led enterprises for sustainable productivity and livelihoods in East Africa.

- Dr. Ngugi was invited by the Kenyan Ministry of Fisheries Development to participate in meetings dealing with development of the aquaculture sector under the Ministry's *Ocean & Fisheries Policy* that was officially announced in April 2009. As part of these activities, Dr. Ngugi participated, along with eight other CRSP-trained Kenyans — among them a fish farmer, researchers, extensionists, and Department of Fisheries officials — in the March 2009 FAO National Aquaculture Stakeholders Workshop which was held to develop a *National Aquaculture Development Strategy*.

- In Asia, Lead Coordinator Dr. Remedios Bolivar (Central Luzon State University) has promoted regional and international network opportunities for researchers and students through conferences and workshops — Philippine Fisheries Institutions Network (PhilFIN) Conference & General Assembly (October 2008), ISTA8 in Egypt (October 2008), Luzon Zonal Philippine Association for Graduate Education (PAGE) Convention (November 2008), Symposium on Catfish Aquaculture in Asia (December 2008), and International Symposium on Current Research Trends in Fisheries Biology (January 2009).

- In Latin America and the Caribbean (LAC), RCE Lead Coordinator Wilfrido Contreras-Sanchez (Universidad Juárez Autónoma de Tabasco) has promoted regional linkages and international collaborative research in tropical gar aquaculture and fisheries, involving Mexico, Costa Rica, Guatemala, Nicaragua, Cuba and the US. An international snook research network was recently created with the commitment to search for international funds and write multidisciplinary and multi-institutional proposals. Ronald Taylor from the Fish & Wildlife Research Institute (Florida) was named the first president of this new network. The RCE-LAC has also been very active in promoting tilapia and native cichlids among indigenous groups throughout Mexico and continues to communicate with former members of CRSP, including Dr. Maria Celia Portella regarding her tilapia research in Brazil.

• The ME continues to administer the "Mali Project" Associate Award (AA) for aquaculture and fisheries work in Mali, West Africa. This project, funded for three years by the USAID Mission in Mali, began 1 October 2007 and runs through 30 September 2010. During this reporting year, the project made great strides, including running eight short-term training courses for 122 participants, beginning on-farm fish culture trials with six participating farmers and rice-fish culture demonstrations with four participating farmers, and conducting the first-ever frame survey of Lake Sélingué.

III. FISHELLANEOUS

This year has a been a busy one with the six core projects completing the final stages of their investigations under the *Implementation Plan 2007-2009* and Mali Associate Award researchers completing their second full year of project trainings and activities. It has also been a sad year with the death of Dr. Yang Yi of Shanghai Ocean University in July 2009, a tragic loss to the entire CRSP.

Successes throughout all the projects can be seen in the achievements of the AquaFish CRSP researchers and their students. The following *Aquanews* clippings offer a view into the people and projects during this reporting period.

Host Country Principal Investigator Yang Yi

Yang Yi passed away in July 2009 at 46 years old. AquaFish CRSP lost a talented scientist and a great friend. Affliated with CRSP since 1992 when he started his doctoral degree program at the Asian Institute of Technology, Yang Yi was major figure in world aquaculture research. Although his career was cut short, Yang Yi's contributions to CRSP and to the larger world of aquaculture and rural development have been significant in number and far-reaching in their impact. To honor Yang Yi's memory, the CRSP is organizing a session at the upcoming 2010 World Aquaculture Society (WAS) Conference in March in dedication to his memory: *Optimizing Small-Scale Aquaculture for the Poor: A Session in Honor of Dr. Yang Yi*. Student scholarships and other tributes are currently under discussion. In addition, the *Aquanews* Summer-Fall 2009 issue was dedicated to Yang Yi and contains a number of articles, remembrances, and photos. The tribute by his project colleague, Dr. James Diana, is reprinted here from the Summer/Fall 2009 issue of *Aquanews*. The full issue is available on the AquaFish CRSP website.

Aquanews Clippings: Yang Yi

A Tribute to Yang Yi

— by Jim Diana

I sadly note the death of our dear friend and colleague, Dr. Yang Yi. He passed away at 2:41 a.m. on 31 July 2009 at Chengdu Huaxi Hospital, at the age of 46.

Yang Yi was an accomplished scholar, an excellent researcher, and an innovator in the field of aquaculture, especially in applying simple techniques to gain efficiency for small-scale farmers with limited incomes.

Yang Yi was born on 19 June 1963 in Chengdu, China, eldest of three boys born to Yang Chu and Peng Xuejing. He was raised in several locations throughout Sichuan Province and spent much of his formative years living with his grandparents, Yang Zhengqing and Hu Bingxian. His son, Yang Tongyun (Tony) is ten years old. His wife, Liu Yun, and son currently live in Chengdu and Shanghai.

Yang Yi was a bright young man and also a good athlete. At an early age, he was placed in a program to advance his volleyball skills. Later, he decided to focus more on academics. He received his BSc in Genetics from Sichuan University, China in 1985, and his MSc and Doctor of Technical Science degrees in Aquaculture from the Asian Institute of Technology, Thailand in 1992 and 1997, respectively.

One of the more interesting and engaging parts of collaborative research funded through USAID has been the opportunity for participants to work with and get to know collaborators from various countries. The relatively long time period during which we have been studying in certain regions has allowed many CRSP researchers to develop close friendships and very strong academic ties. This certainly has been the case for me, Kwei Lin, and Yang Yi. Yang Yi was a true product of the CRSP: his doctoral work was funded by CRSP projects, he served for years as a research investigator with the CRSP, and his most recent position was as host country principal investigator for the CRSP.

I first became associated with Yang Yi in the early 1990s, when he was a graduate student at the Asian Institute of Technology. He had moved to Thailand from his home country, China, to attend graduate school, and was working on a master's degree. AIT funding provided him an opportunity to conduct his graduate work on sex reversal of tilapia. He completed his master's degree in 1992 under the supervision of David Little.

In 1992, Yang Yi began a doctor of technical science program at AIT under supervision of Kwei Lin, and also became funded as the research associate for the CRSP project. At the time, Kwei was the host country PI at AIT. Kwei and I had been working for some time on projects combining cage and pond culture, with cage culture of pellet-feeding fish in the middle of a pond and open water culture of tilapia, based on the waste products from the cage-culture system. Kwei had developed a system for walking catfish in the cage and tilapia in the pond, and expanded it to local aquaculture extension organizations. This combination really piqued Yang Yi's interest and became the focus of much of his research career.

Yang Yi's dissertation work focused on co-culture of tilapia in cages and ponds. His basic premise was that one could grow large tilapia in cages using pellets, grow small tilapia in the open water using waste products to stimulate phytoplankton and zooplankton for tilapia consumption, and balance the two systems so the young fish from the ponds could be stocked in the cages for the grow-out to a large size. The system developed by Yang Yi is highly productive and integrated, using feed for all nutrient inputs and capturing as much of the nutrients in tilapia as possible.

My first prolonged exposure to Yang Yi was when he came to the University of Michigan in 1996-97 to complete a year of study abroad in our graduate program. He decided to focus on two main goals while at our university: learning to write and speak English more effectively, and learning more about statistics, experimental design, and modeling. He took coursework to help with these goals and also worked on writing his dissertation and publications from his dissertation while at UM. I had the pleasure of working regularly with Yang Yi during this time, helping him develop his writing skills. I did not realize then what a great investment this would be, because Yang Yi would then spend the next 12 years researching and writing excellent scholarly papers. He was an avid writer and published prolifically, mainly on results of the CRSP experiments. The limited time I dedicated to his program in 1996 has been reciprocated dramatically many times over.

Upon the completion of his doctorate, Yang Yi became a seconded faculty member at AIT, funded as a post-doctoral researcher by University of Michigan and the Aquaculture CRSP. He eventually became the host country PI when Kwei Lin retired from AIT in 2002, and advanced through the academic system at AIT, becoming assistant professor in 1999, associate professor in 2003, and chair of the Department of Aquaculture and Aquatic Resources Management in 2005. Yang Yi became a key faculty member at AIT, helping a very productive aquaculture training program produce a large and significant cohort of students who have established aquaculture programs throughout Asia. During his time at AIT he advised 4 PhD and 14 MSc students. Thanks in part to the involvement of devoted faculty like Yang Yi, the program at AIT at the time was one of the strongest aquaculture programs in the world, and certainly the strongest in training Asian students.

Even with his long-term involvement in Thailand at AIT, Yang Yi had always desired to return to his native China. In August 2007, he was hired as a professor at Shanghai Ocean University, as well as director of the Sichuan Aquacultural Engineering

and Technology Research Center in Chengdu. The research center is a part of Tongwei Group, the major feed producer for China, as well as an important aquaculture production and green technology company. Although his tenure at Shanghai Ocean University was short, he had already begun advising 2 PhD and 6 MS students.

Yang Yi was a great friend to many of us on the CRSP over the years. For example, when the World Aquaculture Society met in Beijing in 2002, Yang Yi organized several adventures for those of us visiting from out of country. I remember a trip to the Peking Opera, and another to eat Peking duck.

The trip to the opera involved over 50 people, who traveled on a bus to the venue. He was thrilled to show others his native country and his culture. He repeated this several times for me, making travel arrangements, introducing me to his parents and other family, and treating me like family. I have always been impressed with his willingness to work so hard to make people happy.

Yang Yi earned a number of honors during his academic career. He was the president of the Asian Fisheries Society since 2007. He consulted internationally in Egypt, Mali, Indonesia, and many other countries. He published broadly in the major journals in our field and took his research through the full circle of development, data collection, modeling, implementation, and publication.

Yang Yi was a great example of all the things collaborative research can do. It allowed him to develop his graduate program, which led him to an academic career focused on aquaculture, and eventually to becoming an expert in the field and president of a major society. Members of the CRSP should take great pride in his achievements, as he gave back even more to the field of aquaculture than he received from CRSP funding. Aquaculture has grown dramatically since the CRSP was initiated in 1982, and in large part, this growth has been due to the development of remarkable scientists like Yang Yi.

While I know it will happen, I cannot really imagine working on the CRSP projects without Yang Yi's presence. He was a great friend, colleague, and an inspiration to me. He will always be remembered by his aquaculture family, and he will be missed. God bless him and his family as we learn to go on without him. — *Reprinted from Aquanews, Summer/Fall 2009*

Aquanews Clippings: AquaFish CRSP Graduate Students

Jeanne Coulibaly

Originally from the city of Abidjan, Côte d'Ivoire, Jeanne Coulibaly is currently pursuing her doctorate degree at Purdue University in Agriculture Economics. Having obtained her undergraduate degree in biology and veterinary medicine from the University of Cocody in her hometown and the School of Veterinary Medicine in Dakar, Senegal, in 2006 Jeanne was awarded a Norman Borlaug LEAP fellowship to investigate dairy cattle and milk marketing in rural Côte d'Ivoire. Carrying this experience with her, she is now investigating "Optimal Marketing Strategies for Fish Famers in Kenya and Ghana" under the AquaFish CRSP. Her major professors at Purdue are Dr. William Masters and CRSP US Lead Principal Investigator, Dr. Kwamena Quagrainie.

In the Côte d'Ivoire, fish represent an integral part of the animal protein diet for a majority of consumers. With increasing pressures on the capture fisheries, fish stocks are rapidly declining and aquaculture is emerging as a sustainable industry for meeting the increasing demand for fish. These realities in the Côte d'Ivoire have drawn Jeanne to aquaculture and have led to her involvement with AquaFish CRSP research.

Jeanne's research focuses on developing the marketing organization of the aquaculture industry in order to encourage the growth and vitality of the industry. In Ghana and Kenya, where Jeanne's research is based, the majority of aquaculture production is small-scale, reliant on

the on-farm sale of fish. These farmers thus face many challenges, such as high transactions costs, low returns, and lack of market incentives. To foster the growth of these farms and increase the revenue for the farmers, Jeanne states that "Ghana and Kenya should include linking small-scale commercial farmers into the market chain of the established commercial aquaculture, capture fisheries and seafood markets through organized and collective marketing efforts." In her thesis work, Jeanne has focused on four objectives: 1) developing an aquaculture supply chain framework for farm-raised fish, 2) training small- and medium-scale fish farmers in the management of this supply chain, 3) building synergies between fish producers and fish vendors in order to improve product and service delivery, and 4) equipping farmers with the skills for group marketing, developing new markets, developing distribution and market networks, and identifying value-added opportunities.

In addressing these goals, Jeanne has developed a questionnaire that will be used to survey all the stakeholders that she is targeting to help guide her to their specific needs. She then plans to organize workshops on supply chain management, pricing strategies, and quality and cost effectiveness in post harvest value chains. Utilization of study groups for case-study opportunities will provide practical experience in value chain management. The development of brochures and manuals with information gained in the research will allow Jeanne's findings to continue aiding in the development of market strategies even beyond the time frame of her work.

With an expected completion date in January 2010, Jeanne plans on visiting Ghana and Kenya in the spring or summer of 2009. She expects her "research to result in a design of some efficient marketing strategies that will help famers to be more integrated into the marketing chain in order to enhance their welfare." Jeanne has a great interest in international development and plans to work in this sector so that she may help in addressing problems of poverty, market participation, and the sustainable management of natural resources. — *Reprinted from Aquanews, Winter 2009*

Margareth M. Kibodya

Margareth M. Kibodya is a graduate student from Tanzania, studying at the Sokoine University of Agriculture (SUA). She is currently working under AquaFish CRSP host country principal investigator Sebastian Chenyambuga to assess the potential uses of two local plants as a protein source in aquaculture feed. Her thesis work, *Assessment of Moringa oleifera and Leucaena leucocephala as Protein Supplements in Tilapia (Oreochromis niloticus) Diets*, will contribute directly to the AquaFish CRSP project with Purdue University, "Improving Competitiveness of African Aquaculture through Capacity Building, Improved Technology, and Management of Supply Chain and Natural Resources." The two plants, *M. oleifera* and *L. leucocephala*, could make aquaculture feed more readily available and allow for improved profits for small-scale farmers. Margareth's work will not only help to provide a more reliable source of feed, it could also help foster the growth of aquaculture in Tanzania.

Originally from the town of Iringa in the central part of Tanzania, Margareth graduated from Open University of Tanzania in 2006 with her bachelor's degree in Zoology. Due to her interest in fisheries and natural resources, Margareth started her work at SUA hoping to enhance the capacity of fish farming in her home country. Margareth's research has recently been completed, finding that *M. oleifera* and *L. leucocephala* can supplement soybean meal in fish diets at levels up to 25%. She is now in the process of finalizing her work.

With aquaculture growth in Tanzania limited in part by the availability of reliable feed sources, Margareth's research is helping to bring a broader awareness to the aquaculture community. In response, Margareth has noticed that aquaculture activities are being more widely embraced and new fishponds are emerging. Margareth hopes that her research will continue the expansion of aquaculture throughout Tanzania enhancing local economies through the use of their available resources. — *Reprinted from Aquanews, Summer/Fall 2009*

Ravi Lal Sharman

In November of 2008, Nepalese student Mr. Ravi Lal Sharman successfully completed his Master's degree in aquaculture from the Institute of Agriculture and Animal Sciences (IAAS) at the Rampur campus in Chitwan, Nepal. Having been inspired by AquaFish CRSP Project Leader Dr. Madhav Kumar Shrestha, Ravi decided to work on an AquaFish CRSP project looking at polyculture systems involving sahar and mixed-sex Nile tilapia. Ravi's thesis work, which started in 2007, specifically investigated the "Effect of sahar (*Tor putitora*) stocking on recruitment control, growth and production of mixed-sex Nile tilapia (*Oreochromis niloticus*) under a pond culture system."

It has become clear to Ravi that Nepal has great potential for aquaculture development. The country has vast amounts of natural water resources, a great diversity of high-value indigenous fish species, thousands of hectares of irrigated land, man-made ponds, and numerous wetlands and ditches. If these resources can be properly exploited and made productive through aquaculture, the benefit could be great for the country on many levels. However, Nepal currently lacks a number of essential elements for sustainable aquaculture development, preventing the full realization of their potential in this sector. The research of Ravi's major professor, Dr. Shrestha, incorporates Ravi's thesis work into the overall scope of the project to ultimately develop a polyculture system for sahar and Nile tilapia. Sahar is a very popular, high-value indigenous game fish in Nepal, whose numbers are currently declining due to fishing pressures.

Nile tilapia is the most important freshwater aquaculture species in Nepal. The polyculture system under development would use the sahar, which becomes piscivorous in high densities, to provide a production control method on the prolific breeding tendencies of mixed-sex Nile tilapia cultures. Culturing the two fish together would not only functionally improve the tilapia culture process, but would also supply an additional fish product for sale. Offering an alternative to the typical monoculture of mixed-sex Nile tilapia, this system has the potential not only to spur a whole new industry of small-scale culturists in Nepal, but could also help reduce fishing pressure on the already stressed wild sahar stocks.

Prior to his involvement with this AquaFish CRSP research, Ravi earned his bachelor's degree in agriculture from IAAS, where he received the Nepal Animal Science Association (NASA) Scholarship in 1996. The scholarship was in recognition of excellent performance in the Livestock Production and Management elective under the Department of Animal Science. After completing his Bachelor's degree in 1997, Ravi worked seven and a half years on a number of fishery development programs as a Fisheries Development Officer with the Directorate of Fisheries Development in the Nepalese Department of Agriculture. His primary responsibilities were in fisheries program planning, fisheries technology extension, program supervision and monitoring, fisheries technology verification, and fish seed production.

Having now completed his Master's program at IAAS, Ravi plans to return to his duties as a Fisheries Development Officer until he can secure funding for his PhD. He hopes to apply his new knowledge of aquaculture for the benefit of Nepalese fish farmers. Ravi hopes to inspire others like himself to continue following their interests and achieving their goals. — *Reprinted from Aquanews, Spring 2009*

BORLAUG LEAP FELLOW: MR. NHUONG VAN TRAN

With a diverse background in agriculture and aquaculture sciences, Nhuong Van Tran was recently awarded a Borlaug Leadership Enhancement in Agriculture Program (LEAP) Fellowship. Based at the University of California, Davis, this fellowship program is funded by USAID to enhance the quality of thesis research by graduate students from developing countries who show strong promise as leaders in agriculture related fields. The fellowship will allow Nhuong to conduct research for his PhD dissertation at Auburn University under the mentorship of his committee co-chairs, Dr. Conner Bailey and Dr. Norbet Wilson, and AquaFish CRSP Lead PI from the University of Connecticut, Dr. Robert Pomeroy. In collaboration with Dr. Pomeroy, Nhuong will be able to integrate his research with the AquaFish CRSP project in Cambodia and Vietnam, which focuses on enhancing trade opportunities for global fishery markets. Nhuong will also work with researchers at the WorldFish Center and The Research Institute for Aquaculture no.1 (RIA1) in Vietnam.

A Vietnamese student from Nghe An, Nhuong completed a BSc in aquaculture engineering, an MSc in Natural Resource Economics, and has over ten years of research experience with RIA1. In 2004 he received a grant from the International Institute for Fisheries Economics and Trade (IIFET) with supporting funds from the Aquaculture CRSP. This grant allowed Nhuong to attend the biennial IIFET conference in Tokyo to present the research he had been working on. It was this experience that inspired Nhuong to pursue his graduate studies in the US. When he received a three-year fellowship from the Ford Foundation in 2006, he started at Auburn University in the Department of Agriculture Economics & Rural Sociology in pursuit of a PhD in Agriculture Economics, an MS in Rural Sociology, and a statistics minor.

Nhuong's dissertation research entitled, "Impacts of Food Safety and Environmental Standards on Seafood Supply Chains from the South: Evidence from Vietnam," investigates the relationships between new food standards and the seafood industry of Vietnam. Approximately 90% of the exports from Vietnam go to countries in the North such as the US and Japan, where concerns for personal health and sustainability are increasing with regard to seafood production and consumption. These concerns are being realized in the form of new food safety and environmental standards for seafood in the global market. While these standards are intended to protect consumer health and improve the sustainability of seafood production, Nhuong realizes that they can also become non-tariff barriers (NTBs) to trade, potentially hurting small-scale aquaculture producers and seafood processors. Nhuong will complete his fieldwork in Vietnam, where he will conduct a series of surveys and interviews with over 100 fish farmers and other stakeholders in the seafood industry. Looking at this issue from a Northern perspective and from the Vietnamese perspective will help Nhuong understand whether these food standards will act as NTBs or serve as a catalyst to improve seafood and environmental quality in Vietnam and other similar regions.

In regards to his LEAP Fellowship, Nhuong says, "This fellowship will give me an excellent opportunity to use theories and knowledge that I learned from developed countries in diverse situations in developing countries, and to apply research instruments, methods, and innovative tools to analyze, evaluate, and address problems related to agricultural and rural development in Vietnam. I believe that my fellowship with the Borlaug LEAP Program will have practical impacts at a policy level in the Government of Vietnam to support sustainable agriculture development." —

Reprinted from Aquanews, Summer/Fall 2009

UNIVERSITY OF ARIZONA RESEARCH TEAM WINS EPA P3 AWARD

In April 2009, a team of interdisciplinary student researchers at the University of Arizona received the U.S. Environmental Protection Agency's People, Prosperity and Planet (EPA P3) award for their project "Development of Sustainable Integrated Aquaculture Systems with Assessment of Environmental, Social, and Economic Implications." Supported by AquaFish CRSP Lead US Principal Investigator Kevin Fitzsimmons, the team of three UA graduate students includes Mauricio Torres-Benavides, and AquaFish CRSP funded students Rafael Martinez-Garcia and Kyle VanderLugt.

The EPA P3 competition involves two phases that culminate with a final judging at the Annual National Sustainability Design Expo in Washington DC. With a focus on benefitting people, promoting prosperity, and protecting the planet, the competition encourages participants to apply technology in innovative ways to address environmental sustainability issues in both the developed and the developing world. This year $75,000 was awarded to each of the six teams with the best designs to help them to implement their projects in the field and in the marketplace.

The winning UA design is a hybrid hydroponics system, which the team named "re-circulating integrated agriculture aquaculture" (RIAA). With a 97% water conservation rate, RIAA combines aquaculture with agriculture, using the nutrient rich aquaculture effluents from fishponds to fertilize and grow crops. As the nutrient rich effluent water irrigates the crops, nitrogen and phosphorous are taken up by the plants and the nutrient-depleted water is collected from the runoff and re-circulated back into the fishponds.

With the success of their award winning system, the UA team has the opportunity to further develop their design and take it into the marketplace. Through ties with AquaFish CRSP, the team has made contact with researchers at the University of Tabasco (UJAT) in Mexico and will be taking the RIAA system to the rural community of Tacotalpa. The project is in the preliminary steps of its implementation stage. This summer the team visited their sites in Mexico to further assess feasibility. They also met with researchers from UJAT at the World Aquaculture Society Conference in Veracruz, Mexico. The team hopes that their design will provide the community with a sustainable agro-aqua system, which will avoid the need for inorganic fertilizers in their crops and supply a treatment mechanism for their aquaculture effluents. Furthermore, the new technologies can help to create new jobs and further develop the local economy. *— Reprinted from Aquanews, Summer/Fall 2009*

Aquanews Clippings: Core Research Projects

NORTH CAROLINA STATE UNIVERSITY

TILAPIA PODCASTS NOW AVAILABLE

Developed by our colleagues at the National Oceanic and Atmospheric Administration, North Carolina State University, and Central Luzon State University in the Philippines, the Tilapia Podcasts are now available through the AquaFish CRSP website. The podcast series is a development out of the North Carolina State University's "Practical Feeding Strategies" project providing useful information on tilapia aquaculture. Primarily aimed at tilapia farmers, hatchery managers and students in the Philippines, this podcast series is a broad new tool being used to share the most current information on tilapia aquaculture. It can be accessed wherever the Internet is available so these podcasts have applications in the global community as well.

The current podcast is a thorough book review by Chris Brown, CRSP US researcher involved in tilapia aquaculture in the Philippines. While displaying a slideshow of images of tilapia cultivation and research from around the Philippines, Brown provides an analysis and comparison of the two prominent textbooks in review: Tilapia Biology, Culture and Nutrition and Tilapia Culture. Podcasts to follow will provide information on alternative feeding methods that tilapia farmers can use. In January 2009, a workshop at Central Luzon State University was held to launch the podcast series. — *Reprinted from Aquanews, Winter 2009*

PURDUE UNIVERSITY

LOCAL PLANTS SHOW PROMISE OF NUTRITIONAL VALUE FOR TILAPIA GROWTH IN TANZANIA

In and around villages and towns in Tanzania, cattle, sheep and goats roam freely, grazing on various forages, such as *Leucaena leucocephala* and *Moringa oleifera*. These forage plants are excellent sources of digestible protein and could hold promise in addressing some of the protein needs in fish feed in Tanzania.
Tanzania is among sub-Saharan African countries where the government has embraced fish farming as a potential agricultural enterprise that could provide needed protein sources to its citizens. However, potential growth in the industry is limited by the availability of seed and feed.

Kajitanus Osewe, the Tanzania Deputy Director of Fisheries & Aquaculture, acknowledges that the lack of nutritious feed is a major hindrance to the development of the Tanzanian aquaculture industry. "There is no formulated feed available to fish farmers, and the few available ones are expensive," he said "Small-scale fish farmers rely solely on household food wastes, agricultural byproducts and wastes as major feed inputs in fish farming." The Aquaculture & Fisheries Collaborative Research Support Program (AquaFish CRSP) has therefore undertaken a study to examine the performance of two local plants as protein sources in feed, *L. leucocephala* and *M. oleifera*.

In his 1983 *Handbook of Energy Crops*, James Duke reports that the nutritional value of *L. leucocephala* is comparable to or even higher than that of alfalfa, and makes a better animal feed ingredient for sources of several amino acids than does copra. Duke reports that the leaves of *L. leucocephala* contain 2.9 grams protein per 100 grams edible portion while the leaves of *M. oleifera* contain 6.7 grams protein.

The study examined nine diet formulations all of which contained 40 percent protein source (soybean or *M. oleifera* or *L. leucocephala* leaf meal or mixtures of soybean and the leaf meals), 58% energy source (maize bran), and 2% mineral mix.

The fish were fed twice per day on the respective diets at a rate of 10 percent of body weight. The results indicate that dietary formulations consisting solely of *L. leucocephala* leaf meal and *M. oleifera* leaf meal as protein sources resulted in slower growth rate and smaller body size at 90 days than those fed solely on soybean meal as protein source. However, fish fed on a diet in which soybean meal was supplemented with *M. oleifera* leaf meal at 25 percent level had comparable growth rate and body size as those fed on a diet in which soybean meal was the sole source of protein. Diets in which 25 percent of soybean meal was replaced with *L. leucocephala* leaf meal, also showed growth rate and body size comparable to diets with soybean meal as the sole source of protein.

The study was conducted at Sokoine University of Agriculture in Tanzania. According to CRSP host country investigator, Sebastian Chenyambuga, the nutritional quality of leguminous multipurpose trees in Tanzania are usually maintained for most of the year, even in the dry season, because of prolonged production of green forage. "*Leucaena leucocephala* and *Moringa oleifera* are deep rooted and can access soil water and nutrients that are out of reach of most crops and forage species, and this enables them to produce and retain high-quality green forage throughout the year," said Chenyambuga.

Chenyambuga directed the study with assistance from Margareth Kibodya, a laboratory technician who is undertaking her masters degree in Management of Natural Resources for Sustainable Agriculture. Kibodya has been actively involved in research focused on an agro-forestry management

system that combines the growing of trees with the management of aquatic life––aquasilviculture. She evaluated *M. oleifera* and *L. leucocephala* as protein sources in tilapia (*Oreochromis niloticus*) diets as possible replacements for the relatively expensive soybean meal. The investigators believe that *L. leucocephala* leaf meal and *M. oleifera* leaf meal can be used in fish diets to substitute soybean meal at levels not more than 25 percent to reduce the cost of feed. — *Reprinted from Aquanews, Summer/Fall 2009*

UNIVERSITY OF ARIZONA

ISTA8: TILAPIA AQUACULTURE FROM PHARAOHS TO THE FUTURE

The Eighth International Symposium on Tilapia in Aquaculture (ISTA8), co-sponsored by the AquaFish CRSP, was held in Cairo, Egypt 12-14 October 2008. The event recognized the birthplace of tilapia aquaculture and home of the Nile tilapia on the 25th anniversary of the first ISTA held in Israel in 1983. The Cairo Convention Center was the venue for the conference and provided excellent facilities for simultaneous translations, concurrent sessions, and a trade show. The scope of the ISTA symposia has closely matched the growth of tilapia farming into a global industry of the second most commonly farmed fish in the world. From the first ISTA with several dozen participants, the ISTA's in Brazil, the Philippines, Mexico, and now Egypt have each drawn between 600 and 900 attendees. Hundreds of thousands of jobs have been created in the farming, processing, and selling of almost 3,000,000 mt of tilapia products per year. This enormous quantity of fish has been produced in many of the world's poorest developing nations, providing high quality seafood to their own people as well as the most highly developed markets. This fact was reflected in the diversity of attendees and presentations from 40 different countries.

The technical sessions included 112 presentations with each presentation having a paper also published in the proceedings. Papers on genetics, nutrition, fish health, processing and food safety, best management practices, marketing and value added products, certification programs, and regional reviews are included in the proceedings. Copies of the ISTA 8 proceedings are available from the World Aquaculture Society on-line bookstore (www.was.org) or from the co-Chairman, Dr. Hussein ElGhobashy helghobashy46@yahoo.com at the Central Laboratory for Aquaculture in Egypt. Most of the papers are in English with Arabic translations of the abstracts, and a few vice-versa. Keynote addresses included Saad Nasser's discussion of the State of Aquaculture in Egypt, Yang Yi's presentation on advances in pond management, Jesse Chappel's review of an integrated tomato and tilapia production system, Kevin Fitzsimmons' market review and description of new products, and description of the VitaFish recirculation system in Belgium by Jooste DeSmed. Other past and present CRSP participants included Remedios Bolivar and three others from CLSU-Philippines, Charles Ngugi, Karen Veverica, Khalid Salie, Chhron Lim, Pablo Gonzalez, Mario Hernandez, and several Egyptians, in addition to Yi and Fitzsimmons.

Other aspects of the conference included a Nile dinner cruise with tilapia on the menu to go along with classic Egyptian entertainment and a farm tour to the Egyptian Aquaculture Center, managed by Dr. Ishmail Radwan. The Center provided an extensive tour covering hatchery production, pond harvesting, and packing of fresh fish for Cairo and Alexandria markets. Egypt has become the second largest tilapia producer after China. One of the focal points of ISTA was the steps that are needed for Egypt to become a significant exporter of tilapia products.

Many people also took advantage of open periods to visit the Pyramids of Giza, the Sphinx, the Egyptian Museum, and Luxor where they could observe hieroglyphics of tilapia held in ponds during the Early and Middle Kingdoms of Egyptian history. Lunch and coffee breaks provided opportunities for discussions between delegates to compare results and projects.

Reverend Jan Heijne Award

The Tilapia International Foundation presented their award recognizing exceptional career service in support of poverty alleviation through tilapia aquaculture to Dr. Marc Verdegem from Wageningen University during the Nile dinner cruise. Named for Reverend Heinje, who organized and supported several tilapia farming

projects in developing countries with his congregation in the Netherlands, the award is presented at each of the ISTA events. Following tradition, the Ambassador from the Netherlands to the host country, Egypt in this case, presented the award. Dr. Verdegem has a distinguished record of development projects in Africa and Asia along with publications of research conducted in the field and at Wageningen. He also collaborated with the former PD/A CRSP.

Sponsors and Supporters

Egypt's Central Laboratory of Aquaculture Research in the Department of Agriculture and Land Reclamation was the ISTA host for the symposium. The American Soybean Association, World Fish Center, AquaFish CRSP, World Aquaculture Society, American Tilapia Association, US Agency for International Development, Intervet-Schering-Plough, ZooControl, and the Global Aquaculture Alliance provided additional support. An additional grant from the US Department of Agriculture-Foreign Agricultural Service supported participation from several scientists from Sub-Saharan countries.

ISTA9

The next ISTA has already been scheduled and will take place in Shanghai, China on October 15-18, 2010. Shanghai Ocean University (SOU) will host ISTA 9 at the same time as the Ninth Asian Fisheries Society meetings. SOU has an entirely new campus south of the Shanghai-Pudong International Airport in the master planned suburb of Lingang-Shanghai. The Howard Johnson's Hotel-Lingang will serve as one of the conference hotels along with the JinJiang Inn. Additional economical housing will be available in the graduate student dormitories on the SOU campus. ISTA 9 will also occur during the Shanghai 2010 World Expo. Many of our past sponsors have already agreed to co-sponsor the ISTA 9, along with additional support from the Chinese aquaculture industry. — *Reprinted from Aquanews, Winter 2009*

UNIVERSITY OF CONNECTICUT – AVERY POINT

ALTERNATIVE FEEDS FOR AQUACULTURE IN VIETNAM AND CAMBODIA

Aquaculture is growing rapidly in Vietnam and has the potential to do the same in Cambodia. Production of pangasiid catfish in the Mekong Delta of Vietnam alone exceeded 1 million metric tons in 2008. While some of the food provided to these fish, especially at the larger commercial farms, is pelleted feed from commercial feed mills, many small farmers still use "trash fish" from the Mekong in preparing feed by hand at the farm. In Cambodia, catfish culture is still at the small-farm stage and trash fish comprise the basic feed for the industry (which is considerably smaller in Cambodia than in Vietnam).

It may be more appropriate to refer to the fish used as feed in Cambodian and Vietnamese aquaculture as "small fish" rather than "trash fish." Trash fish implies fish with no direct value as human food. Unfortunately, that is not always the case for small fish taken from the Mekong River, as well as the Tonle Sap great lake in Cambodia. At least some of those small fish collected are juvenile stages of species that could grow up to be valuable human food. In addition, small fish have traditionally been taken by Cambodian fisheries for use in production of fish sauce, a fermented product that is popularly used in Cambodian cooking and can represent an important source of protein in the diets of some Cambodians. Finally, small fish are likely eaten directly by the poorest of the poor living along the river.

As aquaculture expands in Vietnam and Cambodia, the fish called snakehead is becoming popular to culture because of its high value in the market. There are two species currently being cultured, *Channa striata*, the snakehead murrel, and *Channa micropeltes*, the giant snakehead. While culture of these is permitted (and growing) in Vietnam, it is prohibited in Cambodia (except for some experimental work) due to dependence on small fish in their diet. While pelleted diets do not exist for snakehead in Vietnam and Cambodia, catfish culture does have commercial pellet diets available. Thus getting farmers to switch from small fish to pellets is a socioeconomic issue.

We are participating in the AquaFish CRSP project entitled "Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets". The project falls under the AquaFish project theme of "Enhanced Trade Opportunities for Global Fishery Markets" and consists of five investigations:

- Competition and Impacts between Use of Low Value/Trash Fish for Aquaculture Feed versus Use for Human Food
- Assessment of Diversity and Bioecological Characteristics of Low Value/Trash Fish Species
- Alternative Feeds for Freshwater Aquaculture Species
- Feed Technology Adoption and Policy Development for Fisheries Management
- Maximizing the Utilization of Low Value or Small Fish for Human Consumption through Appropriate Value Added Product Development

In particular, we are reporting on the third investigation, "Alternative Feeds."

Pelleted diets for freshwater fish must provide complete nutrition for a particular species in terms of the required amounts of protein, lipid, energy, vitamins and minerals. Piscivorous (fish-eating) fish like snakehead typically require high levels of protein in the diet, reflecting the high protein in their natural diet. The usual source of that protein in pellet diets is fishmeal, an international commodity made from species such as anchovy, herring, menhaden, capelin, etc. Fish nutritionists and aquaculturists worldwide are trying to replace fishmeal with plant proteins because of the high price of fishmeal, and to reduce the fishing pressure on the aforementioned species. At the University of Rhode Island (URI), we have been able to replace up to 40% of the fishmeal in diets for summer flounder *Paralichthys dentatus* with soybean meal, as long as certain essential amino acids and the non-essential amino acid taurine are included in the diet. Plant materials can sometimes include phytin, which interferes with mineral nutrition, so diets with protein sources such as soybean meal can often benefit from the addition of phytase, an enzyme that breaks down phytin.

Based on the URI work, we designed experiments to be done at Can Tho University in Vietnam on the replacement of fishmeal with plant proteins in diets for snakehead. In the first experiment, we replaced 0, 20, 30, 40, or 50% of the fishmeal in diets for *C. striata* with soybean meal plus essential amino acids (the 0% replacement was the control treatment using only fishmeal). For each of the replacement levels, we added either a) taurine, b) phytase, or c) neither. The results indicated that survival was statistically the same for all the treatments. Based on the growth results, however, we can say that soybean meal can replace fishmeal at the 30% level without addition of phytase or taurine and at the 40% level with the addition of phytase. Addition of taurine had no effect. In the second experiment, we replaced 0, 10, 20, or 30% of combined fishmeal and soybean meal (phytase added) in diets for *C. striata* with rice bran. Rice bran is more available in Vietnam than is soybean meal. Again there were no differences in survival. Growth was significantly better in the 10% rice bran diet than it was in the control (0% replacement), but there were no growth differences between the control diet and the 20% or 30% replacement with rice bran.

Our experiments are continuing, and we are encouraged by the results so far. In terms of replacement levels of fishmeal with plant protein, our results are similar to those of investigators working with piscivorous fish around the world. In order to demonstrate to farmers the utility of pelleted diets, we are currently examining the levels at which "small fish" can be replaced by pelleted diets. We will continue to present our results at annual meetings of AquaFish CRSP, at World Aquaculture Society meetings (results of the first experiment were presented at Aquaculture America in Seattle in February, 2009), and by direct outreach to the farmers in Vietnam as part of this project. The decline in fish production in the Mekong River and Tonle Sap system might be alleviated by the reduction of fishing for small fish for use in aquaculture. Development of alternative feeds to small/trash fish could also allow snakehead culture in Cambodia to proceed. — *Reprinted from Aquanews, Summer/Fall 2009*

UNIVERSITY OF HAWAI'I AT HILO

CHAME SEED PROJECT IN ECUADOR

Aquaculture diversification is nowadays a relevant practice along the Pacific Coast of the Americas. This region includes a magnificent ichthiological biodiversity that has allowed habitants of these areas to consume a variety of locally found fishes as part of their cultural background. In several particular cases, the demand for a species has promoted specific efforts towards production by aquaculture. As an example of this, we cite the pacific fat sleeper *Dormitator latifrons*, a species of interest to AquaFish The Pacific Fat Sleeper is a gobidae fish with a geographic range from southern California in the U.S. to northern Peru. Commonly known as chame in Ecuador, popoyote in Central America and southern Mexico and puyeque in northern Mexico, this fish has the potential to rival or replace tilapia as a culture species in the Americas. It is particularly suited for both coastal and wetlands areas. Despite its extensive range, it is only consumed in a few locations in Latin America, primarily in the Province of Manabi in Ecuador, and several locations in Central America and south Mexico.

In previous experiences with chame, this species was targeted for aquaculture development under a "Sustainable Coastal Communities and Ecosystems" (SUCCESS) project sponsored by EGAT/USAID in partnership with the Coastal Resources Center at the University of Rhode Island and the University of Hawaii Hilo with Ecocostas as the Ecuador partner. As a result of the experience from the SUCCESS project, researchers created a handbook, "Proyecto para la Conservación y Desarrollo del Estuario de Cojimíes (Sustainable Coastal Communities and Ecosystem Project -SUCCESS)" edited by Ecocostas. It is available on-line at Ecocostas.org Chame has a number of attributes providing for its considerable potential in sustainable aquaculture. The species is euryhaline, it reproduces naturally in ponds, has a high quality flesh, it has omnivorous/detritivorous feeding habits, exhibits rapid growth, is extremely hardy, can survive out of water for up to three days, and is easily sexed for mono-sex culture. Nevertheless, a major constraint on chame production by aquaculture in Ecuador is the fact that all chame stocked into culture units are captured from the wild.

The primary difficulty for the development of chame aquaculture is the current inability to produce juveniles in the laboratory. Thus, most of the research needed for the species should be directed towards understanding the variables involved with the onset of exogenous feeding. In relevant practical experiences from as early as 1982, several Ecuadorian researchers demonstrated that within a few hours after yolk sack absorption, there is a 100% mortality rate for the larvae, given that the onset of exogenous feeding has not been achieved. Other aspects related to reproductive biology, such as gonadal maturation in captivity and the mechanisms of phenotypic sex determination should be addressed as well.

Chame aquaculture is a viable possibility. As positive aspects, feeding requirements and grow-out conditions can be as extensive or intensive as desired depending on the level of production determined by the producer. Showing a satisfactory growth performance, the fish demonstrates low nutritional requirements, easily satisfied using agriculture by-products, organic waste, native aquatic vegetation, and low-cost formulated feeds. Although high-density stocking in pond culture has not been fully tested, heterogeneous growth could be difficult. Nevertheless, given that males seem to have faster growth rates, monosex culture could solve this.

To date, CRSP researcher, Dr. Gustavo Rodriguez, has compiled many references and practical experiences after a visit to Ecuador, outlining the most relevant necessities to contribute to a collaborative effort in chame seed research. A comprehensive effort towards the production of juveniles, as well as other husbandry aspects such as optimal salinity, fish density, and feeding requirements need to be addressed in order to effectively contribute towards the development of chame aquaculture in Latin America. — *Reprinted from Aquanews, Winter 2009*

UNIVERSITY OF MICHIGAN

JULY WORKSHOP IN CHINA

The AquaFish CRSP held a workshop on Aquaculture, Human Health, and Environment in Shanghai, China from 7–10 July 2009. Over 28 people attended, including faculty, students, and staff from all the CRSP Asian host country universities partnered with the University of Michigan project, as well as staff from the World Wildlife Fund. The atmosphere of the workshop was saddened by the deteriorating health condition of its creator, Professor Yang Yi, who could not attend the workshop. His health was constantly on our minds. Professors Liu Liping and Min Jiang substituted for Yang Yi and made the arrangements for hosting by Shanghai Ocean University. The workshop served as a wonderful venue for members of AquaFish CRSP research projects to review their progress, discuss future plans, and consider the relationship between their research program and needs within their countries.

The first day of the workshop presented an opportunity for each project to summarize their results to date. Altogether, ten presentations were made on the results of research conducted by CRSP institutions. The quality of these presentations was a clear indication of the high quality of faculty, staff, and students working on the CRSP, as well as the research questions in which they are engaged. There was a lot of discussion among CRSP participants about the kind of research being done in some countries and the kind that should move forward in other countries, as a result of the exchange of information and studies being conducted across the region.

The second day of the workshop focused on interaction among participants regarding the major issues related to aquaculture that should be a focus for our Asian research projects in the CRSP. This section was facilitated by Jim Diana. The first step of this process was for each individual to list on a piece of paper three issues they felt were important. Upon review of this list, we summarized the issues by various areas of work and combined similar areas into the overall list of research priorities. The priorities fell into four categories: aquaculture practices, fisheries, mitigating environmental impacts, and socio-economics. After compression of the topics, a total of 26 different areas of research were listed under these four categories.

Highest priority was given to studies on water quality and effluents, followed by microcystins, and a three-way tie for third place—sediment management, species introductions and impacts on indigenous species, and the quality of seed in hatchery management. Already, participants from different countries have agreed to sample algal material from their ponds and lakes and provide them for the studies on microcystins. Such cooperation will be an important component of integrating the CRSP across the regions of Asia in the next two-year implementation plan.

Upon completion of the prioritization of research goals, participants went on tours of Shanghai, including interaction at Shanghai Ocean University with the president of the university and several faculty members.

On termination of the workshop, several CRSP members traveled to Chengdu to visit Professor Yang Yi. While he was quite ill, we were able to speak with him for some period of time and to inform him of the results of the workshop, as well as plans for our proposal. These had been serious issues on Yang Yi's mind, and it was heartening to see him engaged in this area and interested in its outcome. Unfortunately, he passed from this world two weeks after the workshop ended. While he is no longer with us, he clearly has a spiritual significance to all members of the Asian community of the AquaFish CRSP. — *Reprinted from Aquanews, Summer/Fall 2009*

Aquanews Clippings: Mali Associate Award Project

MALI PROJECT: DEVELOPING SUSTAINABLE AQUACULTURE AND FISHERIES PRACTICES

With the population in West Africa projected to grow substantially in coming years, the tremendous pressures on their natural resources must be considered in order to alleviate poverty, ensure food security, and to develop an environmentally sustainable economy. The fishery and aquaculture sectors are a great asset to the national economy in Mali, as they provide for the growing demand locally consumed fish and provide an income for thousands of people. Declining fish stocks is becoming a critical issue in Mali as supply is far from meeting the demands of the local markets. Therefore, increasing aquaculture production and developing sustainable fisheries management are possibly the most promising alternatives to increase the overall supply of aquatic products.

In response to a request for assistance from USAID Mali, AquaFish CRSP is partnering with the Direction Nationale de la Pêche (Government of Mali) and collaborators from Moi University in Eldoret, Kenya, Shanghai Ocean University in Shanghai, China, and FishAfrica in Nairobi, Kenya to implement a project for the sustainable development of the aquaculture and fisheries sectors in Mali. The overall goal for the project is to improve the productivity and income of producers through facilitation of access to technologies and to increase the capacity of stakeholders involved in freshwater fish farming and capture fisheries management in targeted areas of Mali. A team of AquaFish Principal Investigators has identified three major themes to address through a South-South collaboration model in order to meet the goal of the project and to enhance the sustainability of the impacts.

Theme One is being headed by AquaFish Host Country PI, Dr. Charles Ngugi from Moi University, focusing on the advancement of freshwater aquaculture practices and technologies. In order to identify appropriate strategies for pond aquaculture and make them available for use. Theme One provides hands-on training in pond construction, fish propagation, and pond management.

Headed by AquaFish Host Country PI, Dr. Yang Yi from Shanghai Ocean University, Theme Two promotes the sustainable development of rice-fish aquaculture and fisheries. Field trials and training courses help evaluate appropriate adaptations for rice-fish systems' introduction into the irrigation systems in the Niger River Delta. Like Theme One, Theme Two is using training courses and field trials to make appropriate strategies available to the people on the ground.

Theme Three aims at building community and consensus towards a fisheries management plan in target areas of Mali in order to ensure the long-term viability and sustainability of capture fisheries. Nancy Gitonga from FishAfrica in Kenya is heading this portion of the project, and is getting the local fishing groups involved in the groundwork and the survey processes for the management of their fisheries. Initial frame surveys are being done in the Lake Sélingué area. Across the three themes, an emphasis is being placed on capacity building opportunities, sustainable solutions, and maximizing the benefits to the people of Mali without overexploiting their resources. Dissemination strategies have been determined for key stakeholder groups in order to ensure the highest level of communication and relevance, and to foster relationships for long-term cooperation. Already, a successful first training session was held in the fall of 2008, and another series of trainings and workshops are taking place in the first months of 2009. Collaboration across borders, seas, and language barriers makes this project valuable to the global community, using knowledge from where the expertise already exists to develop the systems where these skills are still needed. *— Reprinted from Aquanews, Winter 2009*

Optimism and Expectations Have Soared in the Aquaculture and Fisheries Industry in Mali

Following recent February 2009 trainings and workshops held there by the AquaFish CRSP Mali Project, Aquatic Resource Use and Conservation for Sustainable Freshwater Aquaculture and Fisheries in Mali. Prior to the trainings, news of the events was broadcast on national television and over the radio. On the first day of the trainings the Minister of Livestock and Fisheries in Mali opened the first workshop and attended an official luncheon. A number of other government officials also attended. The television and radio advertisements and the opening ceremonies generated a nationwide awareness and enthusiasm for the project.
The Project's first training session was held outside Mali in Shanghai, China in 2008 addressing Theme II, "Promoting Sustainable Rice-Fish Culture in Irrigated Systems," but the February trainings were the first to occur in Mali. Addressing the remaining two primary themes — "Advancing the freshwater aquaculture practices and technologies"(Theme I), and "Building community and consensus towards a fisheries management plan" (Theme III)— these CRSP trainings in Mali were a great success.

The Theme I training on pond construction and management took place in the capital city of Bamako and was led by Charles Ngugi, CRSP HCPI from Kenya. This workshop was originally planned to include 17 fish farmers, but enthusiasm and demand were so high that it was expanded to accommodate more participants, including five from the Regional Fisheries Directorates in Bamako and Koulikoro. In addition to training posters, Ngugi used several different topical training modules to accommodate a range of learning styles. Key topics covered included aquaculture planning, pond site selection, fish species selection, hatchery management, water quality management, and fish farming economics and marketing.
Peter Nzungi, also from Kenya, led the Theme III training, on behalf of Theme III leader Nancy Gitonga. This session took place at Lake Sélingué, where Peter trained both a group of supervisors and a group of enumerators on how to conduct a frame survey in two two-day sessions. Following the training sessions, Peter led the participants of both groups through an actual survey of the lake. The survey consisted of analyzing the fishing sites and fishing activities through the use of questionnaires distributed and filled out at two primary landing sites on the lake.

Both the Theme I and Theme III trainings were a great success, having imparted knowledge about basic aquaculture and fisheries management techniques and shed light on the potential for the growing industry in Mali. Two years ago, the Direction Nationale de la Pêche created the Fish Farmers Association in Mali, which meets frequently to discuss opportunities and challenges in their industry. However, this is the first time that these kinds of workshops have occurred in Mali in the aquaculture and fisheries sector. Promise of continuing the forward momentum of the project is high, as there is great confidence that the successful delivery of information will enhance the participants' abilities to effectively apply and share their new skills. *— Reprinted from Aquanews, Spring 2009*

Recent Trainings in Mali

The AquaFish CRSP Mali Project, "Aquatic Resource Use and Conservation for Sustainable Freshwater Aquaculture and Fisheries in Mali," successfully completed several key activities in recent months. These activities fall within the three themes of the project: Pond Culture, Rice-fish Culture, and Fisheries Planning.

Pond Culture: Theme I leader Charles Ngugi, with support from Héry Coulibaly, Mali Director of Fisheries and his technical staff, led two training courses for. The first of these was held in April, during which four Malians, Boureima Traore, Rokia Coulibaly, Mamadou Kane, and Seydou Toe travelled to Kenya to receive a series of short-term trainings. The trainings covered pond culture, including catfish propagation, tilapia sex reversal techniques, pond record keeping, and business plan development for aquaculture. Held at the Sagana Aquaculture Centre, the training consisted of practicals, lecture sessions, and a field trip. The second workshop, a two-week training course on hatchery management and propagation of catfish, took place in Bamako during late June. A total of 22 participants, including fish farmers,

Regional Fisheries Directors, technicians, and farmers, were trained through a combination of practicals and lecture sessions. Former CRSP graduate student James Mugo (Moi University) assisted Ngugi in these training courses. Following the conclusion of the short course in Bamako, Ngugi and Mugo worked with the four Malians trained in Kenya to set up and initiate a key Theme I activity, on-farm trials of alternative pond culture technologies, which will continue through mid January 2010.

Rice-Fish Culture: Building on experience gained during their short course in China last year, Alhassane Toure and Tieman Traore formed a farmers' group in the Baguineda irrigation area and held a workshop in which they presented techniques on rice-fish culture to potential participants. Liu Liping of Shanghai Ocean University and Wu Zongwen from the Tongwei Research Center in Chengdu went to Mali in June to make final arrangements for the demonstrations. Four farmers' rice fields were modified (excavation of fish sumps) for use as demonstration sites. These fields were stocked with catfish, tilapia, or a combination of tilapia and catfish. The rice-fish demonstrations ran through November 2009.

Fisheries Planning: Analysis of the data obtained during the Lake Sélingué frame survey conducted in February was completed and a full report was provided to the Direction Nationale de la Pêche (Héry Coulibaly) by Theme III leader Nancy Gitonga. Dr. Coulibaly's team had the report was translated into French to ensure its usefulness to fisheries planners in Mali. The information gained through this survey will be used during upcoming stakeholders' workshops as a basis for understanding the present status of the lake fishery and for working out future management plans. *— Reprinted from Aquanews, Summer/Fall 2009*

IV. OVERVIEW OF RESEARCH PROGRAM STRUCTURE

AquaFish CRSP is managed in a manner to achieve maximum program impacts, particularly for small-scale farmers and fishers, in Host Countries and more broadly. CRSP program objectives address the need for world-class research, capacity building, and information dissemination. Specifically, the AquaFish CRSP strives to:

- Develop sustainable end-user level aquaculture and fisheries systems to increase productivity, enhance international trade opportunities, and contribute to responsible aquatic resource management;
- Enhance local capacity in aquaculture and aquatic resource management to ensure long-term program impacts at the community and national levels;
- Foster wide dissemination of research results and technologies to local stakeholders at all levels, including end-users, researchers, and government officials; and
- Increase Host Country capacity and productivity to contribute to national food security, income generation, and market access.

The overall research context for the projects described in this *Annual Report* is poverty alleviation and food security improvement through sustainable aquaculture development and aquatic resources management. Discovery of new information forms the core of projects. Projects also include institutional strengthening, outreach, and capacity building activities such as training, formal education, workshops, extension, and conference organizing to support the scientific research being conducted.

Projects focus on one USAID-eligible country within a region, but have activities in nearby countries within the same region. All projects received USAID country-level concurrence prior to award. Non-concurrence meant that a project or investigation was not approved for funding, as was the case with an investigation that included Bangladesh. The USAID Mission in Bangladesh did not concur due to perceived management overload; the AMA CRSP was also denied the privilege of working in Bangladesh.

GLOBAL AQUAFISH CRSP PROJECT THEMES (GOALS)

A. Improved Health and Nutrition, Food Quality, and Food Safety
B. Income Generation for Small-Scale Fish Farmers and Fishers
C. Environmental Management for Sustainable Aquatic Resources Use
D. Enhanced Trade Opportunities for Global Fishery Markets

Each project has one AquaFish CRSP theme as its primary focus, but addresses all four themes in an integrated systems approach. The global themes of the CRSP are cross-cutting and address several specific USAID policy documents and guidelines.

AQUAFISH CORE RESEARCH PROJECTS STATS

Under the *Implementation Plan 2007-2009*, 38 investigations had been undertaken with a distribution by Systems Approach of 16 for *Integrated Production Systems* and 22 for *People, Livelihoods, & Ecosystem Interrelationships* (Table III-1). Five new investigations under the Auburn University Lead Project, which began 1 August 2009, were added to the *Implementation Plan 2007–2009 (Addendum).*

Table IV-1. AquaFish Core Research Projects by Systems Approach and Topic Areas*

SYSTEMS APPROACH	TOPIC AREA	NO.
Integrated Production Systems		
	Indigenous Species Development (IND)	4
	Quality Seedstock Development (QSD)	2
	Sustainable Feed Technology (SFT)	6
	Production System Design & Best Management Alternatives (BMA)	6
People, Livelihoods, & Ecosystem Interrelationships		
	Human Health Impact of Aquaculture (HHI)	5
	Technology Adoption & Policy Development (TAP)	3
	Marketing, Economic Risk Assessment, & Trade (MER)	5
	Mitigating Negative Environmental Impacts (MNE)	7
	Watershed & Integrated Coastal Zone Management (WIZ)	4
	Food Safety & Value-Added Product Development (FSV)	1
	Total	43

AQUAFISH CRSP TOPIC AREAS

Six core projects have work plans (investigations) organized around a number of specific areas of inquiry called Topic Areas. Current projects contain between five and eight investigations. Projects focus on more than one topic area in describing aquaculture research that will improve diets, generate income for smallholders, manage environments for future generations, and enhance trade opportunities.

A systems approach requires that each CRSP project integrate topic areas from both *Integrated Production Systems* and *People, Livelihoods and Ecosystem Interrelationships.* USAID also encourages the CRSP to address biodiversity conservation and non-GMO biotechnology solutions to critical issues in aquaculture. Each overall project describes a comprehensive development approach to a problem.

Projects were formed around *core program components*, as identified by USAID:

- a systems approach
- social, economic, and environmental sustainability
- capacity building and institution strengthening
- outreach, dissemination, and adoption
- gender integration

Topic Areas pertain to aquaculture and the nexus between aquaculture and fisheries. Some of the following topic areas overlap and are interconnected. Investigations in this *Implementation Plan* identify a single topic area that best describes each individual investigation. The text under each topic area is provided for illustrative purposes and is not prescriptive. Fisheries-only issues were not funded with core EGAT funds per guidance from USAID.

Topic Areas: Integrated Production Systems

- **Production System Design & Best Management Alternatives (BMA)**
  Aquaculture is an agricultural activity with specific input demands. Systems should be designed to improve efficiency and/or integrate aquaculture inputs and outputs with other agricultural and non-agricultural production systems. Systems should be designed so as to limit negative environmental impacts. CRSP research should benefit smallholder or low- to semi-intensive producers, and focus on low-trophic species for aquaculture development. Research on soil-water dynamics and natural productivity to lessen feed needs were fundamental to the Aquaculture CRSP; critical new areas of research may be continued. Interventions for disease and predation prevention must adopt an integrated pest management (IPM) approach and be careful to consider consumer acceptance and environmental risk of selected treatments.

- **Sustainable Feed Technology (SFT)**
  Methods of increasing the range of available ingredients and improving the technology available to manufacture and deliver feeds are an important research theme. Better information about fish nutrition can lead to the development of less expensive and more efficient feeds. Investigations on successful adoption, extension, and best practices for efficient feed strategies that reduce the "ecological footprint" of a species under cultivation are encouraged. Feed research that lessens reliance on fishmeal s/proteins/oils and lowers feed conversion ratios is desired, as is research on feeds (ingredients, sources, regimes, formulations) that result in high quality and safe aquaculture products with healthy nutrition profiles.

- **Indigenous Species Development (IND)**
  Domestication of indigenous species may contribute positively to the development of local communities as well as protect ecosystems. At the same time, the development of new native species for aquaculture must be approached in a responsible manner that diminishes the chance for negative environmental, technical, and social impacts. Research that investigates relevant policies and practices is encouraged while exotic species development and transfer of non-native fishes are not encouraged. A focus on biodiversity conservation, and biodiversity hotspots, as related to the development of new native species for aquaculture is of great interest. Aquaculture can be a means to enhance and restock small-scale capture and wild fisheries resources (Aquaculture-Fisheries Nexus Topic Area). Augmentation of bait fisheries through aquaculture to support capture fisheries is an area of interest, provided there are no net negative environmental effects.

- **Quality Seedstock Development (QSD)**
  Procuring reliable supplies of high quality seed for stocking local and remote sites is critical to continued development of the industry, and especially of smallholder private farms. A better understanding of the factors that contribute to stable seedstock quality, availability, and quantity for aquaculture enterprises is essential. Genetic improvement (e.g., selective breeding) that does not involve GMOs may be needed for certain species that are internationally traded. All genetic improvement strategies need to be cognizant of marketplace pressures and trends, including consumer acceptance and environmental impacts.

Topic Areas: People, Livelihoods, & Ecosystem Interrelationships

- **Human Health Impacts of Aquaculture (HHI)**

Aquaculture can be a crucial source of protein and micronutrients for improved human health, growth, and development. Research on the intrinsic food quality of various farmed fish for human consumption is needed—this might include science-based studies of positive and negative effects of consuming certain farmed fishes. Patterns of fish consumption are not well understood for many subpopulations. Human health can be negatively impacted by aquaculture if it serves as a direct or indirect vector for human diseases. There is interest in better understanding the interconnectedness of aquaculture production and water/vector-borne illnesses such as malaria, schistosomiasis, and Buruli ulcer and human health crises such as HIV/AIDS and avian flu.

- **Food Safety & Value-Added Product Development (FSV)**
  Ensuring high quality, safe, and nutritious fish products for local consumers and the competitive international marketplace is a primary research goal. Efforts that focus on reducing microbial contamination, HACCP controls and hazards associated with seafood processing, value-added processing, post-processing, and byproduct/waste development are of interest. Consumers and producers alike will benefit from research that contributes to the development of standards and practices that protect fish products from spoilage, adulteration, mishandling, and off-flavors. Certification, traceability, product integrity and other efforts to improve fish products for consumer acceptance and international markets are desired. Gender integration is important to consider as women are strongly represented in the processing and marketing sectors. (Aquaculture-Fisheries Nexus Topic Area)

- **Technology Adoption & Policy Development (TAP)**
  Developing appropriate technology and providing technology-related information to end-users is a high priority. The program encourages research that results 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. Areas of inquiry can include institutional efforts to improve extension related to aquaculture and aquatic resources management; science-based policy recommendations targeting poor subpopulations within a project area, or more broadly (for example, national aquaculture strategies); methods of improving access to fish of vulnerable populations including children (e.g., school-based aquaculture programs); science-based strategies for integrating aquaculture with other water uses to improve wellbeing, such as linkages with clean drinking water and improved sanitation. Policy initiatives that link aquaculture to various water uses to improve human health are needed. Additionally, social and cultural analyses regarding the impacts of fish farming may yield critical information for informing policy development.

- **Marketing, Economic Risk Assessment & Trade (MER)**
  Aquaculture is a rapidly growing industry and its risks and impacts on livelihoods need to be assessed. Significant researchable issues in this arena include cost, price, and risk relationships; domestic market and distribution needs and trends; the relationships between aquaculture and women/underrepresented groups; the availability of financial resources for small farms; and the effects of subsidies, taxes, and other regulations. Understanding constraints across value chains in local, regional, and international markets is of interest, especially as constraints affect competitiveness, market demand, and how to link producers to specific markets. (Aquaculture-Fisheries Nexus Topic Area)

- **Watershed & Integrated Coastal Zone Management (WIZ)**
  Aquaculture development that makes wise use of natural resources is at the core of the CRSP. Research that yields a better understanding of aquaculture as one competing part of an integrated water use system is of great interest. The range of research possibilities is broad—from investigations that quantify water availability and quality to those that look into the social context of water and aquaculture, including land and water rights, national and regional policies (or the lack thereof), traditional versus industrial uses, and the like. Water quality issues are of increasing concern as multiple resource use conflicts increase

under trends toward scarcity or uneven supply and access, especially for freshwater. Ecoregional analysis is also of interest to explore spatial differences in the capacities and potentials of ecosystems in response to disturbances. Innovative research on maximizing water and soil quality and productivity of overall watersheds is of interest. Pollution is a huge concern, as over 50% of people in developing countries are exposed to polluted water sources. Additionally, aquatic organisms cannot adequately grow and reproduce in polluted waters, and aquaculture may not only be receiving polluted waters, but adding to the burden. Rapid urbanization has further harmed coastal ecosystems, and with small-scale fisheries and aquaculture operations in the nearshore, integrated management strategies for coastal areas are also important. (Aquaculture-Fisheries Nexus Topic Area)

- **Mitigating Negative Environmental Impacts (MNE)**
  With the rapid growth in aquaculture production, environmental externalities are of increasing concern. Determining the scope and mitigating or eliminating negative environmental impacts of aquaculture—such as poor management practices and the effects of industrial aquaculture—is a primary research goal of this program. A focus on biodiversity conservation, especially in biodiversity "hotspot" areas, as related to emerging or existing fish farms is of great interest. Therefore, research on the impacts of farmed fish on wild fish populations, and research on other potential negative impacts of farmed fish or aquaculture operations is needed, along with scenarios and options for mitigation. **(**Aquaculture-Fisheries Nexus Topic Area)

ENVIRONMENTAL COMPLIANCE

The following **USAID environmental restrictions** apply to the projects and the overall program:

- Biotechnical investigations will be conducted primarily on research stations in Host Countries.
- Research protocols, policies, and practices will be established prior to implementation to ensure that potential environmental impacts are strictly controlled.
- All training programs and outreach materials intended to promote the adoption of CRSP-generated research findings will incorporate the appropriate environmental recommendations.
- All sub-awards must comply with environmental standards.
- CRSP Projects will not procure, use, or recommend the use of pesticides of any kind. This includes but is not limited to algaecides, herbicides, fungicides, piscicides, parasiticides, and protozoacides.
- CRSP Projects will not use or procure genetically modified organisms (GMO).
- CRSP Projects will not use, or recommend for use, any species that are non-endemic to a country or not already well established in its local waters, or that are non-endemic and well established but are the subject of an invasive species control effort.

TERMINOLOGY FOR INVESTIGATIONS

Investigations that generate new information form the core of projects. Each investigation is clearly identified as an experiment, study, or activity, based on the following definitions:

Experiment A scientifically sound investigation that addresses a testable hypothesis. An experiment implies collection of new data by controlled manipulation and observation.

Study A study may or may not be less technical or rigorous than an experiment

and may state a hypothesis if appropriate. Studies include surveys, focus groups, database examinations, most modeling work, and collection of technical data that do not involve controlled manipulation (e.g., collection and analysis of soil samples from sites without having experiments of hypothesized effect before collection).

Activity An activity requires staff time and possibly materials but does not generate new information like an experiment or a study. Conference organization, training sessions, workshops, outreach, and transformation and dissemination of information are examples of activities.

Investigations provide a transparent means for evaluating different types of work under the CRSP, be they quantitative, empirical, biologically-based, qualitative, policy-based, or informal. Each project was required to include at least one *experiment* or *study*. Projects were also required to include outreach *activities* such as training, formal education, extension, and conference organizing to supplement the scientific research being proposed.

General Research Priorities

All six projects address the following general research priorities:

- **Priority Ecosystems**
  Freshwater and brackish water ecosystems for aquaculture and aquaculture-fishery nexus topic areas. Marine ecosystems are also included in the aquaculture-fishery nexus topic areas.

- **Priority Species**
  Low-trophic level fishes; domesticated freshwater fishes; non-finfishes (e.g., bivalves, seaweeds); aquatic organisms used in polycultures and integrated systems; native species. Food fishes are a priority but species used for non-food purposes (e.g., ornamental, pharmaceutical) may also be included as a priority if they are a vital part of an integrated approach towards food security and poverty alleviation.

- **Target Groups**
  Aquaculture farms (small- to medium-scale, subsistence and commercial) and aquaculture intermediaries, policy makers, and others in host countries.

- **Key Partners**
  University, government, non-government, and private sector.

V. RESEARCH & TECHNOLOGY TRANSFER ACCOMPLISHMENTS

During this reporting period, AquaFish CRSP researchers have made advances in sustainable feed technology, seedstock, indigenous species development, human health, and environmental impacts. Work on marketing and trade, product development, and policy assessments has also led to significant achievements that directly improve the lives of the rural poor. Technology transfer has played a major role in building capacity at all levels of the aquaculture sectors in the countries where AquaFish CRSP projects are onging. The following highlights summarize many of the CRSP investigations underway during this reporting period.

Topic Areas: Integrated Production Systems

Production System Design & Best Management Alternatives (BMA)

- On-farm polyculture trials in Nepal with the indigenous game fish sahar (*Tor putitora*) and Nile tilapia (*Oreochromis niloticus*) have produced promising results. Sahar, a popular food and game fish for Bangladesh, India, Nepal, and Pakistan, is under threat from overfishing and habitat loss. Culturing sahar can help decrease fishing pressures on wild stocks. As a predatory fish, sahar offers the advantage in polyculture of controlling tilapia recruitment in aquaculture ponds. For small-scale, resource-poor farmers who are currently using a relatively low production, mixed-sex tilapia monoculture system, a sahar-tilapia polyculture can both help improve productivity and provide a new, desirable fish product. To date, trials have shown a stocking ratio of 1:16 sahar to tilapia as having the overall best performance. On the basis of these trials, cultured sahar is now available for human consumption by farmers, and tilapia production has improved 15%. — 07BMA02M

Sustainable Feed Technology (SFT)

- In the lower Mekong River Basin in Vietnam and Cambodia, aquaculture of snakehead, a carnivorous fish, depends largely on 33 different species of wild-caught, low-value freshwater fish species. Cost, availability, resource depletion, feed efficiency, and competition with food uses of the low-value fish have led to recommendations for alternative, locally sourced feeds. Experimental diets testing replacement of fishmeal (FM) at varying percentages have found the following dietary levels to have no negative effect on growth performance: 30% replacement with soybean meal (SM) or 40% replacement with SM and phytase or taurine supplements; 30% replacement of the SM-FM mix with rice bran; and 60% replacement with SM and a combined phytase and alpha-galactosidase supplement. Additionally, 50% of the fish fed to snakehead can be replaced with formulated feeds. This work is leading the way towards a more sustainable feed technology for snakehead aquaculture that will reduce pressures on a fishery that supplies an important food source for rural communities in the region. — 07SFT01UC

- For small-scale, rural tilapia farmers in the Philippines, feed is the most costly component, representing 60-80% of the total production cost. Reducing this cost requires either application of less feed or use of lower cost feeds. Findings in a series of studies on feed

reduction strategies and alternative protein sources show progress toward improved cost and feed efficiencies: (1) feed reduction strategies can significantly reduce the quantity of feeds consumed by about 55% without affecting the final weight, specific growth rate, and FCR (food conversion ratio); (2) fish fed at 50% satiation show comparable or even better results in terms of the production efficiency than control fish; 3) alternate protein sources (poultry meal, fermented, deboned meat-poultry byproduct, Nupro yeast extract) may serve as suitable substitutes for fishmeal in tilapia diets. — 07SFT02NC

- In Guyana, locally derived copra and shrimp meals are proving successful as lower-cost protein alternatives to fishmeal for tilapia and pacu farmers. Poultry by-products and brewers waste are also showing promise. This work is a collaborative effort that has brought together farmers' cooperatives (National Aquaculture Association of Guyana, Trafalgar Union Women's Cooperative for Tilapia) and a local feed mill (Maharaja Oil & Feed Mill) in trainings that focus on improved feed formulations and manufacture techniques with hammer mill and compression pelleting equipment. — 07SFT04UA, 07SFT05AU

- Tanzanian researchers found that leaf meal made from two local, native leguminous tree species — *Leucaena leucocephala* (LLLM) and *Moringa oleifera* (MOLM) — *can* replace costly soybean meal in tilapia diets. While growth performance is higher when fish are fed with soybean meal, lower cost and local availability of these leafmeals make them a suitable alternative for small-scale farmers. Due to rising prices, soybean meal and fishmeal have become prohibitively expensive. Of the two, MOLM-diets show higher fish productivity. As a result of this work, rural Tanzanian fish farmers can increase their profitability by using these locally available, low-cost protein sources for fish feed. — 07SFT06PU

Indigenous Species Development (IND)

- Culturing native oysters (*Crassostrea corteziensis*) safe for human consumption in the Pacific Coast estuaries located in the Mexican States of Sinaloa and Nayarit offer rural communities food security and income generation opportunities. Two CRSP studies have made considerable progress in developing suitable oyster culture technologies despite significant problems such as El Niño warm-water conditions and a serious oyster disease introduced from the East Coast of the USA, local flooding, and swine flu. CRSP researchers worked with women oyster growers on spat collection and grow-out in Santa Maria Bay. Market testing of the oyster is expected in FY10. Depuration of oysters relayed to a clean water site showed bacterial counts below allowable standards during neap tides. Work will continue with plans to develop a certified, depurated oyster product. Lessening dependence on introduced oysters (e.g., *Crassostrea gigas*) will benefit the community. The native oyster, particularly if depurated, offers a potential new product market. — 07IND03UH, 07IND04UH

Quality Seedstock Development (QSD)

- With tilapia seed production currently estimated to be over 1.2 billion annually in the Philippines, demand is expected to triple in the coming years. To meet the growing demand for quality tilapia seed, production improvements are essential. Preliminary work has focused on the relationship between broodstock age and seed production in the GIFT strain of Nile tilapia, which is the major strain farmed in the Philippines. Recent results show that broodstock ranging in age from eight months to two years can be used for tilapia seed production with no significant loss in final growout yield. For tilapia farmers this work will lead to technology improvements that will guarantee them improved seedstock quality at affordable prices. — 07QSD01NC

- Among the environmental issues in the artisanal fishery of Lake Victoria is the threatened status of the native sharktooth catfish, which is being depleted by Nile perch fishers who use it for baitfish. Farmed juvenile catfish sold as an alternative to wild-caught baitfish offer a sustainable solution. Farmers participating in an AquaFish CRSP project that trains them in both production and business techniques are now successfully selling baitfish in six

markets along the shores of Lake Victoria. The Bidii Fish Farmers Association stands out as a model farming cluster enterprise. Starting with 10 farmers in 2007, it has grown to 25 members, nine of them women. Through CRSP trainings, the group has developed a profitable catfish-baitfish business with sales to baitfish dealers and other farmers in need of seed stocks. Bidii farmers have also partnered with a Kenyan women's project (Women in Fishing Industry Project) to train women in pond construction and catfish breeding. The interest of other farmers in adopting the cluster model and enlisting the aid of successful farmers in setting up their clusters verifies the significant achievement of this work. — 07QSD02PU

Topic Areas: People, Livelihoods, & Ecosystem Interrelationships

Human Health Impacts of Aquaculture (HHI)

- Experimental work has identified chitosan-modified clay as an environmentally benign coagulant treatment to remove the toxin-producing cyanobacteria *Microcystis aeruginosa* from pond water. Under eutrophic conditions, blooms of this blue-green algae degrade water quality. Harmful levels of the microcystin toxin that have accumulated in tilapia affect food quality and food safety. This experimental work has also documented the lethal effects on other aquatic organisms such as the water flea (*Daphnia magna*) and red swamp crayfish (*Procambarus clarkii*) that are important contributors to aquaculture productivity. The coagulant treatment is suitable for use in aquaculture and offers a relatively simple, and environmentally benign, control option to maintain the health of tilapia ponds and ensure the food safety of pond-raised fish. — 07HHI01UM

- A two-part workshop on aquaculture sanitation for researchers, practitioners, and community stakeholders was conducted at Universidad Autónoma de Sinaloa–Culiacán in September 2008. Part I included a conference (19 presentations) and a one-day field trip for 36 stakeholders to a pilot site in Santa Maria Bay (Altata) for shellfish polyculture with oyster, pen shell, and shrimp. The Altata site is now targeted as a "shellfish growing water classification" by the State of Sinaloa and the Mexican Federal Government. Part II was conducted in Santiago Ixcuintla (Nayarit). Thirty-nine attendees participated in the conference (12 presentations) and two field visits to Pozo Chino and Boca de Camichin, both major oyster growing areas. Pozo Chino is projected as a "shellfish growing water classification" by the State of Nayarit and the Mexican Federal Government. — 07HHI03UH

- Forty-three attendees, representing educational, private sector and governmental institutions, participated in the Regional Workshop on Shellfish Culture & Sanitation held 28–30 September 2009 at UAS-C. Attendance by representatives of the Aquatic Sanitation Committees (ACS) for five of the Mexican States on the Pacific Coast was significant due to the ACS role in providing extension services to shrimp and bivalve producers. The workshop offered a networking opportunity for the various stakeholders. In this respect, the group's issuance of the "Declaration of Culiacán" — a public manifesto expressing the needs of the sector and requesting specific actions from industry and responsible government agencies — can be seen as a successful example of a newly established linkage. — 07HHI04UH

- The black cockle (*Anadara* spp.), which is native to the estuaries along the coast of Nicaragua, is aquaculture candidate that can potentially provide food and income to the rural poor. Market testing is completed. Next steps will focus on locating safe culture sites for depurated cockle production, establishing depuration rates, and field testing in the Asseradores Estuary. Community members are actively participating in the field research

studies, which empower them with the expertise to successfully build a livelihood on depurated cockle culture. — 07HHI05UH

Technology Adoption & Policy Development (TAP)

- AquaFish CRSP researchers have developed the first of a series of podcasts on tilapia aquaculture that is available for download from the CLSU computer center and North Carolina State University server and also through the AquaFish CRSP website. A diverse group of farmers, feed company personnel, local and regional government officials, journalists, and CLSU faculty, staff, and students attended the January 2009 workshop that launched the podcast. While most of the attendees were unfamiliar with online tools, they left the workshop with training on accessing the podcast as well as other online information sources on tilapia aquaculture. Media coverage also informed a larger population of this new outreach technology. For Filipino farmers, many of whom already have internet access, the podcast offers an easily obtained outreach tool with readily available information on tilapia production techniques. — 07TAP02NC

Marketing, Economic Risk Assessment & Trade (MER)

- AquaFish CRSP researchers trained small- and medium-scale fish farmers in Ghana and Kenya how to successfully enter urban markets. Trainings covered the importance of value chain, principles of supply chain management, principles of marketing, group marketing, developing new markets, and developing distribution and marketing networks. The goal is to engage these farmers in collective efforts to plan production, and manage supply and sales. Kenyan baitfish farmers (see Quality Seedstock Development: 07QSD02PU) using the cluster farming system are already achieving significant improvements in their marketing capabilities and assisting other farmers in adopting the collective model. — 07MER02PU

- Based on an assessment of export opportunities for tilapia in the Philippines, AquaFish CRSP researchers have documented supply chain constraints associated with the differing requirements between domestic and export markets. To establish a viable market relationship with foreign buyers, producers will need to supply higher volumes of larger and consistently sized tilapia as well as meet HACCP and EU accreditation protocols. CRSP recommendations that will go to government officials will assist them in tailoring production systems that can successfully compete in the various supermarket and specialty shop tilapia export markets — 07MER04NC

Watershed & Integrated Coastal Zone Management (WIZ)

- CRSP researchers have established that the current standing stock of oysters (~736 MT) cultured in the Boca de Camichin Estuary on the Pacific Coast of Mexico is below the maximum sustainable limit projected by the study (~1100 MT). The finding was presented to the Boca de Camichin management committee, a multi-institutional-governmental organization that is developing and implementing a management plan for the area. Based on recommendations, the Mexican government imposed a ban on establishing new oyster farms, which will ensure a sustainable oyster industry within the carrying capacity of the estuary. — 07WIZ02UH

Mitigating Negative Environmental Impacts (MNE)

- Small shrimp farmers in coastal areas of Indonesia (Banda Aceh) and the Philippines are now dealing with shrimp diseases and environmental degradation. These problems largely stem from their monoculture systems and are indicative of adverse environmental effects contributing to loss of mangroves and degraded water quality. To deal with these issues, workshop trainings have been designed to introduce farmers to more sustainable techniques incorporating seaweed culture into tilapia-shrimp polyculture and educate them in production and management practices that will improve productivity and control diseases. In Banda Aceh, workshops on soft shell mud crab farming as another polyculture option were also held as part of the tsunami recovery program. With an attendance of almost 300, trainees have been enthusiastic and requesting follow-up training. — 07MNE02NC

- Assessments of environmental and economic impacts of alien species in freshwater reservoirs in China (Taihu icefish: *Neosalanx taihuensis*) and Vietnam (Nile tilapia: *Oreochromis niloticus*) have led to recommendations to eliminate further stocking of these species. While alien species have contributed to economic development, their populations threaten native species biodiversity and development of sustainable local fisheries. — 07MNE03UM

- Based on an extensive study of the waste management strategies used by small-scale farmers in Hubei and Hainan provinces of China, farmer trainings have been conducted to promote two practices to reduce effluent and solid waste pollution for intensive carp, tilapia, and shrimp pond culture: (1) stocking density and (2) aeration as means to improve water quality and eliminate the need for flushing ponds. Farmers are becoming more environmentally aware and by adopting these simple water quality control measures, they will be taking a significant step toward improving the sustainability of their aquaculture industry. — 07MNE04UM

- AquaFish CRSP researchers have developed a novel use for life cycle assessment (LCA) — to evaluate the ecological footprint of three shrimp farming systems: (1) intensive farming for overseas export markets, (2) semi-intensive farming for export to the mainland, and (3) semi-intensive farming for local consumption. Their findings show that the main differences among the three scenarios are related to energy use, global warming, and eutrophication potential. Intensive farming showed the highest environmental impacts. — 07MNE05UM

VI. CORE RESEARCH PROJECT REPORTS

Annual reports submitted by each project cover the period from 1 October 2008 to 30 September 2009. Six of the core research projects negotiated no-cost extensions (NCE) that extended their work under the *Implementation Plan 2007-2009* from 30 September 2009 through 31 December 2009 for five projects (North Carolina State University, Purdue University, University of Connecticut–Avery Point, University of Hawai'i at Hilo, and University of Michigan) and through 31 March 2010 for one other (University of Arizona). Reports are printed as submitted by the Lead US PI. Abstracts replace progress reports for investigations where final investigation reports have been submitted. Final investigation reports are available from the ME and the AquaFish CRSP website. Due to their length and detail, they are not printed in this annual report.

LEAD US INSTITUTION: AUBURN UNIVERSITY

Hydrology, Water Harvesting, and Watershed Management for Food Security, Income, and Health: Small Impoundments for Aquaculture and Other Community Uses

Project Summary

Production constraints in Uganda and South Africa inhibiting development of aquaculture are associated with inefficiencies in (1) water availability and hydrological context, (2) seed and feed production, and (3) extension and outreach. Other challenges limit business enterprise opportunities and market development. Addressing the production constraints requires sustainable, cost-effective solutions that protect wetlands and promote biodiversity. Delivery of advisory and technical services through outreach and extension should focus on building the long-term knowledge base that will empower stakeholders to successfully grow the aquaculture sector.

This project is designed to build a knowledge base with research results and visible examples that work in the African context. Five investigations address a broad range of water management, production, credit, and extension issues: (1) watershed management practices to protect water quality (09WIZ01AU) (2) decision tools, techniques, and BMPs to assist in the proper siting and construction of ponds (09WIZ02AU); (3) data-based management recommendations for small-scale cage fish farmers (09BMA01AU); (4) assessment of commercial potential for small-scale aquaculture enterprises and availability of local markets (09MER01AU); and (5) training and outreach for local and regional farmers (09BMA02AU). The research goal is to develop integrative approaches for watershed management schemes that will serve multiple uses such as community water supply, aquaculture, livestock watering, and small-scale irrigation. Outreach and enterprise development addresses the livelihood issue by training a cadre of aquaculturists with the institutional knowledge to guide aquaculture development in the long term on a local and regional level. Inclusivity of women, who are significant players in small-scale aquaculture, will be emphasized in outreach and trainings.

USAID Focal Areas: Maximizing water and soil quality and productivity; Broadening market access; Increasing incomes; Enhancing productivity and livelihoods in marginal areas; Mitigating post harvest constraints

AquaFish CRSP Global Theme: Income Generation for Small-Scale Fish Farmers and Fishers

Host Countries: South Africa; Uganda (IEHA)

Project Participants

Auburn University
Joseph MOLNAR: US Lead PI
Claude E. Boyd: Investigator
Karen Veverica: Investigator

Alabama A&M University
James O. BUKENYA: US Co-PI

Gulu University
Nelly ISYAGI: HC Co-PI
Alfonse OPIO: Investigator

Makerere University
Levi KASISIRA: HC Lead PI
Monica Karuhanga BERAHO: Investigator
Theodora HYUHA: Investigator
Peter MULUMBA: Investigator

Stellenbosch University
Khalid SALIE: HC Co-PI

Uganda National Fisheries Resources Research Institute (NaFiRRI)
Gertrude ATAKUNDA: HC Co-PI
John WALAKIRA: Investigator

University of Georgia
E. William TOLLNER: US Co-PI

Investigation Progress Reports

Joe Molnar, US Lead PI

The Auburn University project with US and Host Country partners — University of Georgia, Alabama A&M University, Stellenbosch University, Makerere University, and Uganda NaFIRRI — began on 1 August 2009. The first two months of the project were devoted to organizing subcontracts, finalizing budgets, formulating MOUs, and otherwise putting the mechanisms in place to fund activities in the Host Countries and enable the expenditure of funds in support of the project objectives. Non-project funds from the State of Alabama, intended to encourage collaboration between Alabama A & M, Tuskegee, and Auburn University, enabled some of the investigators to make a preliminary visit to Uganda in July 2009 to make initial contacts with Gulu University and Makerere administrators and researchers. During the trip, we also visited key USAID personnel in Kampala and Gulu, as well as responsible officials in key counterpart projects. The project supported a meeting of US PIs in Heflin, Alabama in August, 2009.
For this two-month period, there was no investigation-specific work to report on the five investigations for this project, which include the following:

Investigation 1 (09WIZ01AU): Effects of Watershed and Aquaculture on Water Quantity and Quality in Small Catchments in South Africa and Uganda

Investigation 2 (09WIZ02AU): Evaluation of Surface Catchment Development and Sustainability for Multipurpose Water Needs in Uganda

Investigation 3 (09BMA01AU): Evaluation and Improvement of Production Technology in Uganda: Case Studies of Small-Holder Cage Culture in Watershed Reservoirs

Investigation 4 (09MER01AU): Market Assessment and Profitability Analysis of Aquaculture Enterprises in Uganda

Investigation 5 (09BMA02AU): Training and Outreach in Uganda and Surrounding Nations

LEAD US INSTITUTION: NORTH CAROLINA STATE UNIVERSITY

Improved Cost Effectiveness and Sustainability of Aquaculture in The Philippines and Indonesia

Project Summary

Rapid population growth and with it a heavy dependence on fish protein places food security as a high priority in the Philippines and the tsunami-devastated Aceh region of Indonesia. While aquaculture is increasing in importance, socioeconomic conditions, overfishing, and environmental damage threaten the livelihoods of small-scale fish farmers. Reducing costs and expanding income-generating opportunities requires improved production efficiencies, product quality, and sustainable farming options.

This project takes a multifaceted approach with a unifying objective to improve cost efficiencies and livelihoods for stakeholders throughout the production chain. Six research and extension investigations address various levels of the aquaculture production system: (1) improved hatchery technologies for improved tilapia seed quality (07QSD01C); (2) feeding strategies to reduce total feed (Milkfish: 07SFT03NC) as well as replace fishmeal with lower cost, alternative, local protein sources (Tilapia: 07SFT02NC); (3) podcasts as an extension tool to convey current production information to tilapia farmers (07TAP02NC); (4) targeted trainings on sustainable fish-shrimp-seaweed polyculture technologies for coastal shrimp farmers in the Philippines and the tsunami-devastated Aceh region of Indonesia (07MNE02NC); and (5) market analysis to assess the opportunities and constraints of expanding into tilapia fillet production for the export markets (07MER04NC). The feed studies include development of a rapid-test biomarker tool for scientists and industry personnel to check growth rate in tilapia and milkfish. This application addresses the USAID priority to advance aquaculture with appropriate biotechnologies. On another front, the podcast technology offers a powerful tool for informaiton dissemination. Internet access is expanding in developing countries such as the Philippines and its increasing popularity shows considerable promise for its use in extension.

USAID Focal Areas: Maximizing water and soil quality and productivity; Broadening market access; Increasing incomes; Enhancing productivity and livelihoods in marginal areas; Mitigating post harvest constraints

AquaFish CRSP Global Theme: Income Generation for Small-Scale Fish Farmers and Fishers

Host Countries: Indonesia; Philippines

Project Participants

NORTH CAROLINA STATE UNIVERSITY
Russell BORSKI: US Lead PI
Peter R. FERKET: Investigator
Upton HATCH: Investigator
Charles R. STARK: Investigator

AQUACULTURE WITHOUT FRONTIERS
Michael NEW: Collaborator

AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH
Michael Rimmer- Collaborator

BUREAU OF FISHERIES & AQUATIC RESOURCES
Nelson A. LOPEZ: HC Co-PI

C NN Aquaculture & Supply Company, Bangkok, Thailand
May Myat NOE LWIN- Collaborator

CENTRAL LUZON STATE UNIVERSITY
Remedios B. BOLIVAR: HC Lead PI
Wilfred JAMANDRE: Investigator
Emmanuel M. VERA CRUZ: Investigator

GIFT INTERNATIONAL FOUNDATION
Hernando L. BOLIVAR: HC Co-PI

SEAFDEC-AQD
Evelyn Grace T. DE JESUS-AYSON: HC Co-PI
Felix G. AYSON: Investigator
Nelson GOLEZ: Investigator
Anicia HURTADO: Investigator

UJUNG BATEE AQUACULTURE CENTER, BANDA ACEH
Hassan HASANUDDIN: HC Co-PI

UNIVERSITY OF ARIZONA
Kevin FITZSIMMONS: US Co-PI

US DEPARTMENT OF COMMERCE-NOAA
Christopher BROWN: US Co-PI

Investigation Progress Reports

Submitted by Russell Borski, US Lead PI

Investigation 1 - 07QSD01NC - Broodstock seed quality and fingerling production systems rearing for Nile tilapia in the Philippines

Tilapia seed production in the Philippines is estimated at over 1.2 billion annually with demand expected to triple. Methods to improve seed production are essential to meet the growing demand for tilapia. Little is known about the relationship between broodstock age and gamete production in the GIFT strain of Nile tilapia commonly cultured throughout the Philippines. We evaluated the effect of broodstock age on seed production of the GIFT Nile tilapia in hapas and on growout performance in ponds.

Treatments used in this study were based on the different ages of broodfish. Treatments were the following: Treatment I – 8-month old broodfish, Treatment II – 1-year old broodfish and Treatment III – 2-year old broodfish. Each treatment was replicated four times. Twelve (12) 2.5m x 10m x 1m fine mesh hapas were used for breeding. Thirteen males and 39 females broodfish at a 1:3 sex ratio were stocked in each breeding hapa. Significant differences were found among treatments ($P<0.01$) with respect to the initial size of male and female broodfish.

After 14-day breeding period, eggs, yolk-sac fry, and fry were collected. Treatments I and II had similar spawning rates of 41.0%. Treatment III showed a 24.4% spawning rate. With regards to the average seed production, Treatment I had the highest with 10,079 pieces followed by Treatment III with 9,464 pieces and Treatment II with 8,281 pieces. Statistically, no significant differences were found among Treatments ($P > 0.05$) in terms of spawning rate and average seed production.

We then investigated the effect of age of broodfish on the grow-out performance of Nile tilapia fingerlings in earthen ponds. Twelve (12) 500 m^2 ponds were stocked with sex-reversed Nile tilapia fingerlings of the GIFT strain. Each pond was stocked at 4 fish m^{-2}. Four treatments with three replicates are applied as follows: Treatment I – fingerlings produced by 8-month old broodfish, Treatment II – fingerlings produced by 1-year old broodfish, Treatment III – fingerlings produced by 2-year old broodfish and Treatment IV – equal combination of fingerlings from the three different ages of broodfish. After 120 days of culture, fish were

harvested, weighed, and counted. Gross yield, final weight and length of fish, and survival rates were calculated. Duncan Multiple Range Test (DMRT) was used for the comparison of means.

The extrapolated gross yield per hectare showed that Treatment IV had the highest gross yield with 4472.7 $\pm$ 619.1 kg ha^{-1} followed by Treatment III with 4045.3 $\pm$ 1039.8 kg ha^{-1}, Treatment II with 3719.3 $\pm$ 365.5 kg ha^{-1}, and Treatment I with 3667.3 $\pm$ 689.3 kg ha^{-1}. The treatments were not significantly different at 5% level of significance.

Fish in Treatment III had the highest average final weight and total length of 191.25 $\pm$ 33.56 g and 20.5 $\pm$ 1.09 cm, respectively. Treatment IV had an average final weight and total length of 182.41 $\pm$ 33.46 g and 20.2$\pm$ 1.12 cm, respectively, followed by Treatment I with average final weight of 162.86 $\pm$ 28.55 g and length of 19.5 $\pm$ 1.15 cm, and Treatment II with average values of 160.21 $\pm$ 1.32 g and 19.4 $\pm$ 0.17 cm. There was no statistically significant difference in terms of final mean weight and total length.

In terms of survival rate, Treatment IV obtained the highest survival with 70.0 $\pm$ 14.1 % followed by Treatment I with 61.3 $\pm$ 22.9 %, Treatment II with 61.0 $\pm$ 8.0 %, and Treatment III with 53.8 $\pm$ 4.6 %. Again, statistical analysis showed no significant difference among treatments ($P > 0.05$).

Collectively, these results suggest that younger broodstock produce greater quantities of seed that exhibit slower growth than older broodstock that produce fewer seed exhibiting greater growth rates. However, these trends are not statistically significant, suggesting that broodstock ranging in age from 8 months to 2 years can be used for tilapia seed production with no significant loss in final growout yield.

Investigation 2 - 07SFT02NC - Feeding Reduction Strategies and Alternative Feeds to Reduce Production Costs of Tilapia Culture

Study 1 - Growth Performance of Nile Tilapia (Oreochromis niloticus L.) in Ponds Using Combined Feed Reduction Strategies.

Feed is recognized as the most costly component of farming tilapia. It constitutes 60-80% of total production cost for small-scale, rural tilapia farmers in the Philippines. Tilapia production costs can therefore be reduced through either the application of less feed or of lower cost feeds. We conducted a series of studies to evaluate the utility of feed reduction strategies in reducing costs of tilapia farming. We also tested the potential for using alternative proteins.

In the first study we evaluated the growth performance of Nile tilapia (*Oreochromis niloticus* L.) in ponds using combined feed reduction strategies using commercial feeds. This study was done on-farm using ponds of 6 tilapia farmer cooperators in Nueva Ecija, Central Luzon Philippines. The treatments were as follows: Treatment I – a combined feed reduction regime consisting of 60 days delayed feeding, 30 days alternate day feeding, followed by 30 days daily feeding at a sub-satiation level of 67% and Treatment II – control fish fed at 100% of fish biomass based on standard feeding schedules typically employed by farmers. This study was composed of two (2) treatments and replicated six (6) times. Two ponds were employed for each cooperator, one for the reduced feeding (Treatment I) and the other for normal feeding (Treatment II) group, with a total of 6 ponds/group.

Twelve (12) ponds ranging from 586 – 1,280 m^2 were stocked with sex-reversed Nile tilapia fingerlings at 4 fish m^{-2}. Fish were fed twice daily throughout the experiment. Fish sampling was done every two weeks for the measurement of fish weight and length. After 120 days of culture, the stocks were harvested by getting the bulk weight, the survival rate, and the gross fish yield of all the stocks. Other parameters were also determined such as FCR, SGR, quantity of feeds consumed by the fish, and daily fish gain in weight and length. The data were analyzed using T-test.

The performance of the fish stock with regards to mean initial and final weight and length, daily gain in weight and length, specific growth rate, and feed conversion ratio did not differ significantly between groups (P>0.05). Mean survival rate, gross yield, and quantity of feeds consumed were significantly lower in fish under the feed reduction regimen. Survival rates were also low in the control, the Treatment II group. Using a combination of feed reduction strategies significantly reduced the quantity of feeds consumed by about 55% without affecting the final weight, specific growth rate, and FCR of the fish stock. However, extrapolated gross yield was significantly lower in this group relative to fish fed at normal rates. This may have been due in part to the 30% lower survival rate obtained in the Treatment I group (32% average) versus fish fed a normal regimen (49% survival rate). It is uncertain what led to lower survival rates in both groups, but the presence of catfishes and mudfishes may have contributed. Tissue (liver) samples were obtained and are currently being measured for insulin growth-like factor 1 (IGF-1) to ascertain if IGF-I might serve as a marker for growth rates in the field.

Study 2 - Reduction of the Daily Feed Ration on the Grow-out Culture of Nile Tilapia (Oreochromis niloticus L.) on Farm.
In previous work we found that alternate day feeding reduces feed costs without negatively affecting performance of fish stocks. In our second study, we assessed if reduction in the daily feed ration by 50% might be effective in reducing feed requirements without altering growout performance of Nile tilapia. Two (2) treatments were used in this study. Treatments were as follows: I – Daily ration based on fish biomass divided by half; II – Daily feeding with 100% amount of feed based on fish biomass. The study involved six (6) farmer-cooperators within Nueva Ecija who participated in this study; two (2) ponds, one for each treatment group, were used for each cooperator. Fingerlings were stocked in ponds at 4 fish m^{-2}. The fingerlings were fed daily based on fish biomass according to the feeding strategy indicated for the treatments.

After the 120-day culture period, growth and production performance of the fish stock were assessed. Fish fed with the daily ration divided by half obtained a mean final weight ($\pm$SEM) of 123.57 $\pm$ 15.71 g, daily weight gain of 1.03 $\pm$ 0.13 g, mean final length of 17.6 $\pm$ 0.61 cm, gain in length of 15.2 $\pm$ 0.61 cm and specific growth rate of 5.03 $\pm$ 0.18 %. These values were significantly lower ($P < 0.05$) than those of fish fed at 100% of the computed daily ration, which had a mean final weight of 148.95 $\pm$ 13.06 g, daily weight gain of 1.24 $\pm$ 0.11 g, mean final length of 18.9 $\pm$ 0.56 cm, gain in length of 16.5 $\pm$ 0.61 cm and specific growth rate with 5.46 $\pm$ 0.13 %. On the other hand, Treatment I had a better FCR with 1.0 $\pm$ 0.06 as compared to Treatment II with 2.1 $\pm$ 0.38 ($P<0.05$). No significant difference was found in terms of the mean survival as well as the mean extrapolated gross yield among treatments ($P >0.05$). Along with these insignificant differences in the grow out production, mean quantity of feeds consumed in fish fed at half the daily level was 56% less than those fed at full levels (2588.0 $\pm$ 121.75 kg, Treatment I versus 5928.7 $\pm$ 178.06 kg ha^{-1}, Treatment II; $P < 0.05$).

These results suggest that growth performance is lower in fish fed at 50% satiation relative to those fed at 100 % satiation. However, fish fed at 50% satiation showed comparable or even better results in terms of the production efficiency than control fish. Despite having consumed considerably less feed and showing substantial improvements in feed conversion, the survival and extrapolated yield of stocks fed at 50% satiation was not significantly impacted relative to fish fed at 100% satiation.

Study 3 - Effects of Fermented Mechanically Deboned Meat Poultry by-Products, Poultry Meal and Nupro Yeast Extract as a potential protein source substitution for Fish Meal in Tilapia feed formulation.
Fishmeal is the most costly ingredient in fish feeds and its reduction or elimination from tilapia feeds has the potential to reduce costs of tilapia production. We evaluated other protein sources as a substitute for fishmeal in tilapia diets in tank trials using sex-reversed male Nile tilapia. Fish were either fed a balanced tilapia diet (32% crude protein, 7% crude fat) containing 6% fishmeal (FM), or diets in which fishmeal was substituted with other protein sources; fermented mechanically deboned meat-poultry byproduct (MDM), Nupro yeast extract (NUP), or poultry

meal (PM). Fish were raised in recirculating freshwater tanks for 105 days beginning at an average body weight of approximately 90 g (N = 2 tanks/group with 35 fish/tank). A separate group of smaller fish (56 g, N = 1 tank/group, 35 fish/tank) was also tested. The data presented represent that from the replicated groups containing larger fish, although the smaller fish responded virtually identically to the different diets as that of the larger fish. Fish fed the PM-based diets achieved a similar final mean body weight as fish fed the FM-based diets (mean ± SEM; PM, 437 ± 1.26 g versus FM, 448 ± 1.31 g). Final mean weight was significantly greater in fish fed FM and PM than those fed MDM (411 ± 11.29 g) and NUP (422 ± 1.43 g) diets. Body lengths did not differ among the groups. There also was not a significant overall effect of the different diets on specific growth rates: PM (3.29 ± 0.007 % BW/day), FM (3.39 ± 0.005 % BW/day), MDM (3.03 ± 0.082 % BW/day), and NUP (3.15 ± 0.007 % BW/day). Collectively, these results suggest that alternate protein sources may serve as suitable substitutes of fishmeal in tilapia diets and could ultimately provide cost savings while reducing dependence on fishmeal derived from capture fisheries.

Investigation 3 - 07TAP02NC - Internet-based Extension Podcasts for Tilapia Farmers in the Philippines

A podcast was made using multimedia computer software (Garage Band, Apple Inc.). The podcast has an 18-minute vocal track evaluating two popular tilapia culture reference texts, Lim and Webster (eds., 2006) and El Sayed (ed., 2006). Recorded vocal analysis of the utility of these reference materials is accompanied with a series of ~ 60 photographs of tilapia farming and cultivation centers in the Philippines, along with a musical soundtrack. The podcast was circulated internally and reviewd by AquaFish CRSP and the US Department of Commerce. Following extensive editorial revisions the podcast was formally approved by the US Department of Commerce. See http://web.mac.com/poptard/Site/Podcast/Podcast.html

The podcast was subsequently uploaded on iTunes U (University) on the North Carolina State University (NCSU) server, which is configured to collect data in order to quantify the number of podcast uses or "hits" (See:
http://deimos.apple.com/WebObjects/Core.woa/Browse/ncsu.edu.1784740579.01784740581
Use of the podcast on the NCSU server has been brisk; figures supplied by system administrators indicate that this podcast was downloaded 139 times over the single one-month period of July 2009.

A second podcast was assembled to address the nutritional value of tilapia, and about 35 hours of labor was invested. Regrettably, the portable computer on which it was stored was stolen with the nutritional podcast on the hard drive at ~ 90% completion; future podcast work will be backed up on a secure desktop machine. Additional podcasts were consequently put on hold, beginning with one on the subject of feeding strategies that enable farmers to reduce the cost of growing tilapia without compromising production.

A workshop for farmers and students was held in Luzon at the Freshwater Aquaculture Center during the second week of January 2009. This workshop launched the tilapia podcast and provided extension activities to promote students and fish farmers to use online information in their tilapia culture work. The workshop also provided information and presentations on alternative feeding strategies for farmers. The workshop was very well attended, with approximately 84 registered participants at the Phil-Sino Center for Agricultural Technology at Central Luzon State University. Participants included various members of the farming community, feed companies, government representatives (local and regional), media, and university students, staff and faculty. Drs. Bolivar, Brown, and Borski addressed the group with introductory information on the subject and methodology of podcasting, a demonstration to introduce the tilapia podcast, and presentations on alternative feeding strategies for tilapia farming. Questions, discussion, and social activities filled out the two-day Tilapia Podcasting Workshop. An apparent majority of the participants were initially unfamiliar with podcasting. The workshop was met with considerable enthusiasm and the podcast was loaded on

computing facilities at CLSU. The activities were subsequently featured in two articles, "Tilapia Podcast in the Web" and "Tilapia Feeding Strategies for More Income" by Dr. Sosimo Ma. Pablico, respectively published in the March and April 2009 in the Agriculture Magazine of the Manila Bulletin (ISSN 0118-857-1).

Investigation 4 - 07SFT03NC - Alternative Feeding Strategies to Improve Milkfish Production Efficiency in the Philippines

Milkfish is the largest finfish aquaculture industry in the Philippines. Milkfish are grown in brackish water ponds and seawater cages with seawater culture. Feed represents around 60% of the costs for milkfish culture. A series of experiments was therefore conducted to test the effects of different feeding regimes on growth of milkfish. In tank studies using flow-through seawater, milkfish fed the usual ration of 10% average body weight (ABW) on alternate days did not grow as well as milkfish fed the same ration daily. On the other hand, ABW of milkfish subjected to 2-week alternate starvation and refeeding cycle was comparable to the control group that was fed daily, suggesting that compensatory growth mechanisms are at work. Milkfish subjected to a 4-week starvation and refeeding cycle attained final ABW that was significantly lower than the control. An experiment was also conducted to compare growth of milkfish fed a ration of 10% or 7.5% of body weight. Results show that growth of milkfish was not affected by reduction of the ration to 7.5% of the body weight. Thus, a lower feeding ration can be given to milkfish without compromising yield.

Another experiment was conducted to assess the effects of different feeding regimes on growth of milkfish in a simulated marine cage environment. Results generally reflect the results of the tank experiment. Milkfish fed on alternate days did not grow as well as milkfish fed daily. However, milkfish subjected to a 2-week alternate starvation and refeeding cycle did not exhibit compensatory growth of comparable magnitude as was observed in tanks. This could be due to the presence of algae growing on the nets and of plankton in the water that the fish can feed on. Prolonging the starvation period did not enhance the compensatory growth response.

Meanwhile, SEAFDEC AQD has improved the milkfish grow-out feed formulation to better suit marine cage culture conditions. The SEAFDEC milkfish grow out feed has been tested in marine cage production systems and has shown better FCR than commercially available feeds. The new feed was subsequently used in the cage experiments to test if reduced feeding strategies might reduce production costs.

Based on the results of the tank experiments, an experiment was conducted to compare the effect of starvation and refeeding cycles on milkfish production in an intensive culture system in marine cages. Six units of 5x5x3m cages were stocked with milkfish fingerlings at a stocking density of 35 fish/m^3. Fish in 3 cages were fed daily while fish in the other 3 cages were subjected to 2-week starvation and refeeding cycles. Data after 3 starvation and refeeding cycles are summarized as follows:

PARAMETER	**TREATMENT A** (Fed daily, control) Mean ± SEM	**TREATMENT B** (2-week starvation and refeeding cycles)
Initial ABW (g)	18.88 ± 3.92	22.87 ± 7.51
Final ABW (g)	185.13 ± 17.43	140.50 ± 31.08
% Weight Gain	166.25 ± 13.98	117.62 ± 29.56
Survival Rate (%)	91.22 ± 9.52	66.51 ± 15.26
Biomass Harvested (kg)	484.40 ± 83.20	231.93 ± 57.83
Total Feed Consumed (kg)	1067.49 ± 108.07	582.82 ± 109.25
FCR	2.29 ± 0.29	2.60 ± 0.37

Although, statistically insignificant, data indicate that fish on the cyclic feeding regime (3 series of 2-week fasting/refeeding cycles) have a 25% lower average body weight (ABW) and weight gain than animals fed the standard daily feeding regime. Total biomass harvested was lower in fish on the cyclic feeding regimen. Average survivorship was also lower in fish on the cyclic regimen, largely a result of one replicate that exhibited 60% mortality. Collectively, these results suggest that unlike that observed with tank cultured fish, repeated cycles of fasting and refeeding is ineffective at producing fish of comparable yield as those fed daily under cage culture conditions. Industry FCR values normally range from 2.9 or higher. Our results further confirm that reformulated SEAFDEC growout feeds produce marketable fish with better FCRs than that reported for standard commercial diets, which should provide a significant cost savings in the production of milkfish in seawater cages.

Brackishwater pond experiments are currently in progress to compare the effects of three feeding regimens: fish fed daily (control, A), fish fed on alternate days (B), and fish that are subjected to cycles of 2 weeks starvation followed by 4 weeks of refeeding (C). Since there were only 6 ponds (800 sqm) rather than 9 as originally anticipated, treatment groups could only be run in duplicate. Each pond was stocked with 350 fish and during each sampling, 40 fish are collected by seining. Only one cycle of feed restriction/refeeding has been completed. Data thus far suggest that as in the tank experiments, alternate day feeding results in lower weight gain compared to fish fed daily. The effect of 2-week starvation and 4-week refeeding relative to daily feeding is inconclusive at this juncture of the experiment.

Investigation 5 - 07MNE02NC - Training in Sustainable Coastal Aquaculture Technologies in Indonesia and the Philippines

Shrimp monoculture in Indonesia and the Philippines has led to a decline in mangroves, degradation of water quality, diseases in shrimp, and low prices due to over-production. The aim of this investigation is to provide training and techniques through a series of workshops for more sustainable shrimp farming that incorporates culture of seaweed and tilapia-shrimp polyculture. Outside of the three workshops already reported in Aceh, Indonesia and Visayas (Guimaras) region of the Philippines, we have completed two additional workshops demonstrating alternatives to monoculture of shrimp in affected communities of the Visayas and Luzon regions of the Philippines. The first workshop provided training on nursery and growout of seaweed and was held in Punta Punting, Sabang, Sibunag, Guimaras, Philippines, on November 12, 2009. This AquaFish CRSP USAID workshop was led by Anne Hurtado of SEAFDEC and involved the participation of 44 seaweed growers, including 16 women, and 3 SEAFDEC staff. This workshop was supplemental to those outlined in the original project work plan that was requested by the seaweed farming community. It provided training on the distribution, biology-ecology, farming, crop management/diseases, post-harvest, marketing and product applications of seaweed (*Kappaphycus cottonii*) in a region previously impacted by a 2006 oil spill. The second workshop held at the Golden Sunset Resort in Calatagan, Batangas, Philippines (Luzon Region) was held on January 15-16, 2009 and included 47 participants from Central Luzon State University, North Carolina State University, University of Arizona, SEAFDEC, Philippines Bureau of Fisheries and Aquatic Resources, local government officials, feed companies, and 24 seaweed, tilapia, and shrimp growers. Lectures included fundamentals on sustainable shrimp farming; culture system, management and nutrition; tilapia-shrimp polyculture and seaweed farming and polyculture. Information was provided on pond preparation and fertilization, feed formulation, and shrimp culture with emphasis on biosecurity and disease control. An integrated shrimp-mollusc-seaweed culture in a recirculating water system was highlighted to prevent disease outbreak. A hands-on preparation of feeds, and native agar extraction was conducted.

A third series of supplemental workshops on soft shell crab farming was held in Aceh province of Indonesia at BBAP Ujung Batee (Aceh Besar) on July 21, 2009 and at Kota Langsa (Aceh Timur) on July 23, 2009. These workshops were part of the Aquaculture Rehabilitation Project in Aceh Indonesia and included the participation of 40 farmers, 8 fisheries/aquaculture specialists

from BBAP, Ladong Fisheries School, and JFPR; and 11 fisheries/aquaculture government specialists from Dinas Kelautan, Perikanan dan Pertanian Kota Langsa (Fisheries staff of Kota Langsa and Aceh Timur districts). Due to disease outbreak associated with shrimp culture, farmers in Aceh are interested not only in polyculture techniques for more sustainable shellfish/fish culture, but in alternative crops. Soft shell mud crabs are a lucrative product that can be grown in polyculture with existing aquatic crops. However, problems with high mortality and the methodology for producing soft shell crabs remain a concern. Specifically, some farmers remove walking and swimming legs and claws to produce softshell crab. This technique has been met with considerable ethical concern and is inconsistent with the religious and social values of the community of Aceh. It also results in excessive stress and mortality to the crabs. A series of workshops was conducted by Ms. May Myat Noe Lwin (C NN Aquaculture & Supply Company, Bangkok-Thailand), a volunteer with Aquaculture Without Frontiers (AwF), with cooperation from AquaFish CRSP staff and various local government and college staff. The workshops were supported by AquaFish CRSP, Aquaculture Without Frontiers (AwF), the Australian Centre for International Agricultural Research (ACIAR), and the Directorate General of BBAP Ujung Batee. Ms May Myat Noe Lwin along with help from an AquaFish CRSP graduate student provided training on natural methods of producing softshell mud crab, similar to techniques on her own farm in Thailand; crab biology, design and lay out of soft shell farming, stocking techniques, inspection, feeding and feed, water management, pond preparation, processing and packing, and also business planning and management. Collectively, these and the other workshops on seaweed and fish polyculture were met with considerable enthusiasm with frequent requests for follow-up training.

Investigation 6 - 07MER04NC - Implications of Export Market Opportunities for Tilapia Farming Practices in the Philippines

Literature review and secondary data collection were initiated (Jamandre and Hatch) in anticipation of HC travel (Borski and Hatch) in January 2009. A list of industry experts with whom interviews will be conducted in the Philippines was compiled. To provide better "best procedures" to trace the requirements of exports, supermarkets and other niches of tilapia, the Supply Chain (SC) research method was adopted. An exploratory survey was completed in December 2008 and January 2009 and the study area involved Pampanga, Metro-Manila, Laguna, Batangas, Bulacan, and Nueva Ecija. The primary focus was identification of major SC players, e.g., fish processing plants, fish farms, fish markets/buyers, institutional buyers, hypermarkets, and exporters. Key potential interviewees were identified, particularly major supply chain players.

One of these preliminary inquiries conducted prior to HC travel illustrated SC constraints. Monthly volume requirement of one exporter in Pampanga were 60 tons/month of whole (chilled) tilapia with an average size of 800 g -1 kilogram. Export was not sustained because of contract breachment by growers, who normally sell their fishes (200-250 grams per fish) in traditional markets at competitive price levels. Consistency and/or uniformity of size and economies of scale were the constraints faced by farmers, thus resulting in the contract termination. Export requirements have substantial differences from traditional markets that farmers typically use.

During HC travel, January 9-23, 2009, Hatch and Jamandre conducted follow-up interviews and surveys in the areas previously identified with the addition of Bataan. Government experts of the Food Division of the Department of Trade & Industry and the Fisheries Development Support Division of the Bureau of Fisheries & Aquatic Resources indicated that prospective foreign buyers of tilapia in Taiwan and Korea had expressed interest in obtaining supplies from Philippine fish growers, but no solid commitment had been reached at that time. In addition to trade and export promotions, government agency efforts have tended to center on the formation and strengthening of fisherfolks production/marketing associations to meet generally accepted export standards and protocols. These standards often vary in important ways based on the destination, e.g., Korea, Japan, European Union, or US. Also, based on many

negative experiences with cooperatives in the Philippines and other developing countries worldwide, recently these associations tend to have looser arrangements than their predecessors. Government supply and utilization tilapia data further corroborated that export experience by Philippine growers prior to 2006 was quite insignificant. This picture has changes somewhat in the last couple of years when tilapia exports reached 50 MT in 2007 and 300 MT in 2008.

Fresh fish and seafood sections of hypermarkets and supermarkets are the major domestic outlets for live and fresh tilapia with sizes ranging from 300-500 grams. Typically, these markets require monthly volumes ranging from 500 to 1,000 kilograms; a level substantially above the quantities produced by Philippine growers. This need for a consistent, high volume is an important constraint and is a crucial reason for producer/marketing associations mentioned above. Filleted, smoked, and other processed forms of tilapia are also offered through these market outlets. By-products of filleting including head, belly, and skin are usually sold to specialty shops and restaurants. These markets have not specified any volume requirements since the common arrangement is by consignment. These smaller, specialty markets are a part of the supply chain that individual producers can successfully use.

Monthly prices of fresh tilapia at both retail and wholesale levels show a seasonal pattern with relatively constant prices for most of the year; the exception is the last quarter of the year associated with the Christmas holiday season and social events in the Philippines. In this peak season, tilapia are often harvested and sold at sizes well below minimum market size, e.g., 5-6 pieces per kilogram, imposed throughout the rest of the year.

The varying requirements of the above market niches are likely to have important implications and provide significant opportunities for adjusting the aquaculture production systems to target these windows:

(1) Exports require relatively bigger and consistent size and volume of tilapia. Producers must also pass the HACCP and EU accreditation protocols.

(2) Supermarkets and specialty shops require variable sizes depending on the targeted product form. For fillet, fish size ranges from 300-500 kg each; for smoked, any size but preferably 250-350 grams each; for butterfly fillet, sizes ranges from 45-70 grams; and for dried tilapia, sizes ranges from 30-35 grams.

Presentations and Publications

Table VI-1. Presentations

Title	Authors	Type	Event	Date	Location
Growth Evaluation, Sex Conversion Rate and Percent Survival of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings in Earthen Ponds.	Bolivar, R. B., Bolivar, H. L., Sayco, R.M. V., Jimenez, E.B. T., Argueza, R.L. B., Dadag, L. B., Taduan, A. G. and Borski, R. J.	Paper	8th International Symposium on Tilapia Aquaculture	12-14 October 2008	Cairo, Egypt
Characterization of Serum and Glucocorticoid Induced Kinases (SGK) in a teleost fish, the Mozambique tilapia (Oreochromis mossambicus).	Johnstone III, W.M., Baltzegar, D.A. and R.J. Borski	Paper	Society of Integrative and Comparative Biology	3-7 Jan 2009	Boston, MA, USA
Cloning and regulation of hepatic leptin mRNA expression by nutritional status in hybrid striped bass (Genus *Morone*). Society of Integrative and Comparative Biology. Jan 3-7, Boston, MA.	Won, E.T., Baltzegar, D.A., Picha, M.E., and R.J. Borski	Paper	Society of Integrative and Comparative Biology	3-7 Jan 2009	Boston, MA, USA
Claudin mRNA expression in Mozambique tilapia (*Oreochromis mossambicus*) gill tissue: implications for osmoregulation and salinity adaptation	Baltzegar, D.A., Ozden, O. and R.J. Borski	Paper	Society of Integrative and Comparative Biology	3-7 Jan 2009	Boston, MA, USA
Compensatory Growth: Mechanisms and Applications for Improving Production Efficiency of Fish.	R.J. Borski	Seminar	Southeast Asian Fisheries Development Center	27 January 2009	Iloilo Philippines
SEAFDEC AQD RD&E initiatives towards sustainable aquaculture Development	E.G. de Jesus-Ayson	Seminar	Faculty of Fisheries, Hokkaido University	06 February 2009	Hakodate, Japan
Grow-out Performance of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings From Different Hatching Systems.	Bolivar, R. B., Jimenez, E.B. T., Sayco, R.M. V., Argueza, R.L. B., Bolivar, H. L., Dadag, L. B., Taduan, A. G. and Borski, R. J.	Paper	Aquaculture America 2009	14-18 February 2009	Seattle, WA, USA
			21st Agency In-house Review of Completed and On-going Research and Development Projects	29 May 2009	Science City of Muñoz, Nueva Ecija, Philippines

Table VI-1. Presentations

Title	Authors	Type	Event	Date	Location
Effect of Temperature on the Growth and Survival of Nile Tilapia (*Oreochromis niloticus* L.) Fry Reared in Hapas.	Bolivar, R. B., Jimenez, E.B. T., Sayco, R.M. V., Argueza, R.L. B., Bolivar, H. L., Dadag, L. B., Taduan, A. G. and Borski, R.	Paper	Aquaculture America 2009	14-18 February 2009	Seattle, WA, USA
			21st Agency In-house Review of Completed and On-going Research and Development Projects	29 May 2009	Science City of Muñoz, Nueva Ecija, Philippines
Eye Color as a Predictor of Social Dominance in Nile Tilapia (*Oreochromis niloticus*).	Vera Cruz, E. M., Bero, R.M., Bolivar, R. B. and Borski, R. J.	Paper	Aquaculture America 2009	14-18 February 2009	Seattle, WA, USA
Alternative feeding strategies to improve milkfish production.	De Jesus-Ayson, E.G. and Borski, RJ	Paper	Aquaculture America 2009	14-18 February 2009	Seattle, WA, USA
SEAFDEC AQD RD&E thrusts and services	De-Jesus-Ayson, E.G.	Talk	Fisheries Forum	26 March 2009	Iloilo City, Philippines
Growth Performance of Nile Tilapia (*Oreochromis niloticus* L.) in Ponds Using Combined Feed Reduction Strategies.	Bolivar, R. B., Vera Cruz, E. M., Sayco, RM. V., Jimenez, EB. T., Argueza, RL. B. and Borski, R. J.	Paper	21st Agency In-house Review of Completed and On-going Research and Development Projects	29 May 2009	Science City of Muñoz, Nueva Ecija, Philippines
Effect of Age of Broodfish on the Grow-out Performance of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings in Earthen Ponds.	Bolivar, R. B., Bolivar, H. L., Jimenez, E.B. T., Sayco, R.M. V., Argueza, R.L. B. and Borski, R. J.	Paper	21st Agency In-house Review of Completed and On-going Research and Development Projects	29 May 2009	Science City of Muñoz, Nueva Ecija, Philippines
Reduction of the Daily Feed Ration on the Grow-out Culture of Nile Tilapia (*Oreochromis niloticus* L.) on Farm.	Bolivar, R. B., Vera Cruz, E. M., Sayco, R.M. V., Jimenez, E.B. T., Argueza, R.L. B. and Borski, R. J.	Paper	21st Agency In-house Review of Completed and On-going Research and Development Projects	29 May 2009	Science City of Muñoz, Nueva Ecija, Philippines
Initiatives of SEAFDEC AQD on stock enhancement and important lessons learned.	De Jesus-Ayson, E.G	Seminar	Second Meeting of the Regional Advisory Committee on Fisheries Management in Southeast Asia	2-4 September 2009	Bangkok, Thailand.
Overview of Department Programs R&D	De Jesus-Ayson, E.G	Seminar	R&D Review of Progress and	16-18	Iloilo, Philippines

Table VI-1. Presentations

Title	Authors	Type	Event	Date	Location
activities: Marine Fish, Crustacean, Seaweeds Strain Improvement, Abalone and other Mollusks, Smallholders' Freshwater Aquaculture, Aquatic Ecology			Planning Workshop, SEAFDEC AQD, Iloilo, Philippines	September 2009	

Table VI-2. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Growth Evaluation, Sex Conversion Rate and Percent Survival of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings in Earthen Ponds	Bolivar, R. B.	Proceedings	Proceedings of the 8th International Symposium on Tilapia Aquaculture, 2008	Vol I: 403-413	Published	2008
Characterization of Serum and Glucocorticoid Induced Kinases (SGK) in a teleost fish, the Mozambique tilapia (*Oreochromis mossambicus*)	Johnstone III, W.M.	Journal	Integrative and Comparative Biology	49:E87-E87	Published	2009
Cloning and regulation of hepatic leptin mRNA expression by nutritional status in hybrid striped bass (Genus *Morone*)	Won, E.T	Journal	Integrative and Comparative Biology	49:E184	Published	2009
Claudin mRNA expression in Mozambique tilapia (*Oreochromis mossambicus*) gill tissue: implications for osmoregulation and salinity adaptation	Baltzegar, D.A.	Journal	Integrative and Comparative Biology	49:E9	Published	2009
Grow-out Performance of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings From Different Hatching Systems	Bolivar, R. B.	Conference Abstracts	Aquaculture America 2009	Abstracts CD	Published	2009
Effect of Temperature on the Growth and Survival of Nile Tilapia (*Oreochromis niloticus* L.) Fry Reared in Hapas.	Bolivar, R. B.	Conference Abstracts	Aquaculture America 2009	Abstracts CD	Published	2009
Eye Color as a Predictor of Social Dominance in Nile Tilapia (*Oreochromis niloticus*)	Vera Cruz, E. M.	Conference Abstracts	Aquaculture America 2009	Abstracts CD	Published	2009
Effect of Temperature on the Growth and	Bolivar, R. B.	Agency Review	21st Agency In-house	na	Published	2009

Table VI-2. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Survival of Nile Tilapia (*Oreochromis niloticus* L.) Fry Reared in Hapas			Review of Completed and On-going Research & Development Projects			
Growth Performance of Nile Tilapia (*Oreochromis niloticus* L.) in Ponds Using Combined Feed Reduction Strategies	Bolivar, R. B.	Agency Review	21st Agency In-house Review of Completed and On-going Research & Development Projects	na	Published	2009
Effect of Age of Broodfish on the Seed Production of GIFT Strain of Nile Tilapia (*Oreochromis niloticus* L.).	Bolivar, R. B.	Agency Review	21st Agency In-house Review of Completed and On-going Research & Development Projects	na	Published	2009
Effect of Age of Broodfish on the Grow-out Performance of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings in Earthen Ponds	Bolivar, R. B.	Agency Review	21st Agency In-house Review of Completed and On-going Research & Development Projects	na	Published	2009
Reduction of the Daily Feed Ration on the Grow-out Culture of Nile Tilapia (*Oreochromis niloticus* L.) on Farm	Bolivar, R. B.	Agency Review	21st Agency In-house Review of Completed and On-going Research & Development Projects	na	Published	2009
Grow-out Performance of Nile Tilapia (*Oreochromis niloticus* L.) Fingerlings From Different Hatching Systems	Bolivar, R. B.	Agency Review	21st Agency In-house Review of Completed and On-going Research & Development Projects	na	Published	2009
Plasma ghrelin and growth hormone regulation in response to metabolic state in hybrid striped bass: Effects of feeding, ghrelin and insulin-like growth factor-I on *in vivo* and *in vitro* GH secretion.	Picha, M.E	Journal	General & Comparative Endocrinology	161:365-372	Published	2009
cDNA cloning and isolation of somatolactin in Mozambique tilapia and effects of seawater acclimation, confinement stress, and fasting on its pituitary expression	Uchida, K.	Journal	General & Comparative Endocrinology	161:162-170	Published	2009
Fingerlings From Varied Systems Deliver Similar Growout Performance	Bolivar, R.B.,	Journal	Global Aquaculture Advocate	September/October: 96-98	Published	2009

Table VI-2. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Milkfish R&D in the Philippines	De Jesus-Ayson, E.G.	Book Chapter	Milkfish Aquaculture	na	in press	2009
Milkfish hatchery and nursery production in the Philippines	De Jesus-Ayson, E.G	Book Chapter	Milkfish Aquaculture	na	in press	2009
Salinity Regulation of Lactotroph Cell Proliferation and Apoptosis in the Euryhaline Teleost, the Tilapia (*Oreochromis mossambicus*). General and Comparative Endocrinology	Strom, C.N	Journal	General & Comparative Endocrinology	na	submitted	2009

LEAD US INSTITUTION: PURDUE UNIVERSITY

Improving Competitiveness of African Aquaculture Through Capacity Building, Improved Technology, and Management of Supply Chain and Natural Resources

Project Summary

Most sub-Saharan African nations are net food importers due to rapid population growth, low agricultural productivity, high post-harvest losses, environmental degradation, political conflicts, and periodic natural disasters such as floods and droughts. National governments are currently addressing this issue, primarily focusing on poverty eradication and food security. Aquaculture offers one resource alternative both for producing fish as food and for generating income. While wild-caught fish has been an important food resource in Africa, demand and over-exploitation of natural fisheries strengthens the need for a strong aquaculture sector.

Among the critical elements for building a viable and sustainable aquaculture economy at both the rural and national levels, is an enhanced capacity in value chain and aquatic resource management. Five investigations in this project address several key aspects with an agribusiness focus: (1) development of aquaculture supply chain for fish farmers in Ghana and Kenya (07MER02PU), (2) development of catfish fingerling production as baitfish for the Lake Victoria commercial fisheries in Kenya (07QSD02PU); (3) assessment of pond effluent effects on watersheds and development of BMPs for fish farmers in Ghana (07WIZ01PU); (4) development of local fish feeds in Tanzania (07SFT06PU); and (5) on-farm verification of tilapia-catfish culture in Tanzania (07MER03PU). The goal is to vitalize rural entrepreneurship by dealing with the whole chain of activities, beginning from management of natural resources, production and marketing of fish fingerlings and food fish to transportation and retail sales. With these activities linked, rural communities will benefit through employment and income generation opportunities that will, in turn, create demand for other products.

USAID Focal Areas: Maximizing water and soil quality and productivity; Broadening market access; Increasing incomes; Enhancing productivity and livelihoods in marginal areas; Mitigating post harvest constraints

AquaFish CRSP Global Theme: Income Generation for Small-Scale Fish Farmers and Fishers

Host Countries: Ghana (IEHA), Kenya (IEHA), Tanzania

Project Participants

PURDUE UNIVERSITY
Kwamena QUAGRAINIE: US Lead PI
Jennifer DENNIS: Investigator

KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY
Stephen AMISAH: HC Co-PI
Gifty ANANE-TAABEAH: Research Assistant
Selina Naana EGYIR: Research Assistant
Akwasi Nana OSEI: Research Assistant
Richard PENDLETON: Research Assistant
Afua Serwaah Akoto PREMPEH: Research Assistant

MINISTRY OF NATURAL RESOURCES & TOURISM, AQUACULTURE DIVISION
Kajitanus OSEWE: HC Co-PI

MOI UNIVERSITY
Charles NGUGI: HC Lead PI
Julius MANYALA: Investigator

MOI UNIVERSITY (continued)
Duncan SIJE: Research Assistant

SOKOINE UNIVERSITY OF AGRICULTURE
Sebastian CHENYAMBUGA: HC Co-PI
Nazael MADALLA: Investigator

UNIVERSITY OF ARKANSAS AT PINE BLUFF
Rebecca LOCHMANN: US Co-PI
Carole ENGLE: Investigator

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY
Emmanuel FRIMPONG: US Co-PI

WOMEN IN FISHING INDUSTRY PROJECT
Jennifer ATIENO: Collaborator

Investigation Progress Reports

Submitted by Kwamena Quagrainie, Lead US PI

07MER02PU - Developing Supply Chain and Group Marketing Systems for Fish Farmers in Ghana and Kenya.

Background information and data on fish marketing were collected from primary and secondary sources. The primary data were obtained through a survey using structured questionnaires, personal communications, and observations in Ghana and Kenya. Information was gathered from fish retailers, fish producers, and agents connected to the marketing of fish products. The questionnaires elicited information on quantities supplied and demanded, prices, mode of distribution, challenges encountered, etc. Retailers were selected randomly for the survey from Accra and Kasoa markets in Ghana and from Nairobi and Kisumu markets in Kenya. Fish producers were also chosen randomly for the interview. Both owners of very large commercials fish farms and small-scale fish farms were interviewed in both Ghana and Kenya. Information gathered from personal communications came from officials at the ministry of fisheries in the two countries, Host Country project directors, and other personnel with more insights and in-depth understanding of the supply chain for fish. Observations were also made from the locations visited to provide first-hand knowledge of the flow of fish products from producers to consumers.

Secondary data were obtained from sources such as annual reports on the fisheries sector, fisheries policy and development strategies, national production statistics, imports and exports of fish, and other fisheries project reports. These documents provided some background information and understanding of the environment and macro-economic fish policies prevailing in the host countries.

Two workshops were conducted on June 15 and 22, 2009 in Kenya and Ghana respectively. Participants at the workshops included fish farmers, fisheries officers, fish processors, and fish traders. The training curriculum covered the importance of value chain, principles of supply chain management, principles of marketing, group marketing, developing new markets, and developing distribution and marketing networks.

The activity proposed a supply chain framework for small-scale and medium-scale commercial fish farmers in Ghana and Kenya to enhance their access to and integration into urban fish markets for better returns. The arrangement for marketing farmed fish in the two countries followed two distribution chains — a short chain from farm gate to neighboring markets and a long chain to distant markets. The nature of the marketing arrangement depended on the scale of production, proximity of production points to urban markets, and size of fish. Some changes in the marketing pattern were proposed, especially changes in the volume and supply consistency of tilapia sold by the small-scale and medium-scale fish farmers. These fish farmers traditionally operated independently but given their scale of production, they needed to be

taught and encouraged to engage in collective efforts to plan production, and manage supply and sales. By improving on the current cluster farming system in Kenya and fish farming associations in Ghana, fish farmers could utilize their collective organization to develop strategic assembly location points for collective sales, and also minimize their marketing risks by benefiting from government programs and engaging in contracting with both input suppliers and fish buyers.

07QSD02PU - Development of Small-scale Clarias Fingerlings as Bait for Lake Victoria Commercial Fisheries in Western Kenya.

The artisanal fishery of Lake Victoria, Kenya has been degraded by environmental deterioration, and the stock of sharptooth catfish (*Clarias gariepinus*) in the Lake has been drastically reduced because wild-caught catfish juveniles are used as bait. Trawling for Nile perch (*Lates niloticus*), as previously practiced, is now illegal and the majority of fishers have resorted to long-line fishing using hooks live-baited with catfish fingerlings. Therefore, the focus of this study was to encourage the production (farming) of catfish fingerlings for use as bait, thus reducing exploitation of wild stocks and conserving the aquatic diversity of Lake Victoria. *Clarias gariepinus* has many attributes that make it an ideal aquaculture species. This includes rapid growth, high reproductive potential, general hardiness, resistance to diseases, ability to adapt their feeding habits, and tolerance to overcrowding and adverse environmental conditions. By providing the necessary technical assistance in propagation, production, general pond husbandry, and marketing, the development of catfish fingerlings as baitfish would transform existing and potential small-scale fish farming from subsistence production into commercial and profitable enterprises.

Fish farmers were first organized into farmer groups or clusters. Each cluster was registered with the government and an operational account opened for the group. Farmers received training in hatchery management, seed production, hatchery production techniques including broodstock collection, fertilization and spawning techniques, incubation and hatching, egg treatment, larval rearing and mass catfish fry production, fish nutrition and feed, fish health management, and transportation of live fish. Fish farmers also received some training on record keeping, market development and analyses, leadership skills, and communication.

From the training received, the clusters procured good quality broodstock of *C. gariepinus* for production. Farmers now practice either the semi-natural or artificial method of spawning the brood fish. After spawning, the brood fish are removed and the fertilized eggs are left to develop. Hatchlings are kept in hapas or PVC tanks for 2-3 weeks before they are transferred to nursery ponds. The larvae are reared for 14-21 days, then moved to protected nursery ponds or hapas hung in nursery ponds for another 21-30 days before they are sold as baitfish.

The Vihiga cluster (on the western side of Lake Victoria) specifically made excellent progress and was able to design and implement a comprehensive program where both experienced and new farmers realized the full potential of fingerling production. Sales among the Vihiga cluster showed a progressive transformation of baitfish farmers towards commercialization and profitability. Clusters developed business plans and marketing plans and successfully established marketing channels with baitfish traders. The traders obtain supplies of baitfish from both the wild and aquaculture. Bait traders are mainly women and operate in organized groups or as individuals operating from the beaches along the Lake. The price of farmed baitfish both on-farm and at end-market depend on the supply and demand, and in particular the abundance of wild-caught catfish juveniles from the lake.

07WIZ01PU - Characterization of Pond Effluents and Biological and Physiochemical Assessment of Receiving Waters in Ghana.

Only a small portion of the nutrients in feed is retained in cultured fish biomass. The remainder is lost to the pond system as uneaten feed, faecal solids, and dissolved nutrients. The use of farm waste as fertilizers and feed can also result in elevated microbial levels in ponds. In

addition, earthen ponds generate high amounts of inorganic solids, especially during harvest. With the suite of variables present in pond water, high concentrations of effluent could have undesirable effects on receiving stream ecosystems. The first objective of this investigation was to characterize potential quality of pond effluents in central Ghana and to investigate possible effects on receiving streams.

During the summer of 2009, water samples were taken from 36 ponds in 12 farms and from receiving streams within 100m upstream and downstream of farms. For each farm, a reference site, designated as the closest stream of approximately the same size as the receiving stream that is not influenced by aquaculture activity, was also sampled. Water samples were then analysed for total fecal coliforms, fecal streptococci, settleable and suspended solids, total phosphorus (TP), total nitrogen (TN), and five-day biochemical oxygen demand (BOD_5).

Preliminary results indicate pond water concentrations of suspended and settleable solids of 5 - 6 times higher than that of receiving and reference streams. BOD_5, TP, and TN also recorded concentrations of 2 - 3 times that of receiving streams. Concentrations of fecal coliform were only significantly lower in reference streams while fecal streptococci were uniformly moderately high in all systems. Our results suggest that pond effluents could be detrimental to the receiving water but the effects will depend on management practices such as frequency and volume of effluents released.

Aquatic biota are the most reliable signals of the long-term effects of habitat and water quality alteration. Water chemistry alone is not as reliable since it is altered only briefly after pond effluents are released into a stream. The response of receiving water to habitat and water quality alterations may be detected from changes in abundance and richness of fish and macroinvertebrates using bioassessment techniques.

This second component of this study was conducted in the summer of 2009 to investigate the biological effects of aquaculture ponds on receiving streams in the Ashanti Region of Ghana. Fish and macroinvertebrate samples were collected 50 to 100m upstream and downstream of 12 fish farms, and also from 12 reference streams. A total of 28 different fish species were identified within the study area and analysed using metrics of assemblage structure and function. Preliminary statistical analyses were performed using repeated measures ANOVA and paired sample t-tests.

Preliminary results suggests no significant differences in fish species richness between upstream and downstream ($p > 0.05$), or reference stream and downstream ($p > 0.05$) of receiving waters. Mean species richness was 3.9, 3.8, and 4.0 for upstream, reference, and downstream sites, respectively. Macroinvertebrate and guild-based analyses are ongoing and should provide additional insight into the interactions between ponds and receiving streams in the study region. These analyses are expected to be completed in October 2009 and the results will be reported in the final report.

Pond aquaculture depends heavily on the quality of the natural aquatic environments that often serve as the source of water, nutrients, and seed for the production system, and also as a conduit for effluent during harvest, overflow, or at the end of the production cycle. The nature of interaction of pond operations with the aquatic environment, whether positive or negative, depends to a large extent on the management practices that are employed on fish farms.

Development of best management practices (BMPs) for pond aquaculture will be informed by an understanding of the relationship among prevailing practices, the quality of pond effluents, and the integrity of receiving streams.

The increasing intensification of pond aquaculture in developing countries, which entails higher inputs of feed, seed and fertilizers, would generally be reflected in deteriorating pond and

receiving water quality and integrity in the absence of good management practices. We studied the relationship among management practices, the quality of potential pond effluents, and receiving stream water and biotic integrity in the Ashanti and Brong Ahafo regions of Ghana as the third component of this investigation. Thirty-two fish farmers participated in the intensive survey with questionnaires, accompanied by biological and water quality investigations of a subset of the farms and their receiving and reference streams in Summer 2009.
Preliminary results show a positive relationship between the practices of water reuse and top effluent releases and downstream fish abundance and species richness. Additionally, these practices correlated negatively with the levels of nitrogen and phosphorus in ponds and receiving waters downstream of ponds. These results, though preliminary, suggest some practices that may help minimize effects of ponds on the aquatic environment and sustain intensive and semi-intensive pond aquaculture in Ghana.

Complete analysis and final results are expected in October 2009. Plans for a major outreach activity in the form of a 2-day workshop on pond aquaculture BMPs that will bring farmers researchers and policy makers together to train farmers, discuss, and share data is being planned. This workshop is scheduled for the fourth week of November 2009 to be hosted by the KNUST CRSP team in Ghana and attended by the VT PI.

07SFT06PU - Development of Locally Available Feed Resource Base in Tanzania.

Soybean meal has been recommended as the substitute for fishmeal in fish diets because of its high protein content and relatively low price. However, small-scale fish farmers in sub-Saharan Africa have not adopted it because of its high price and limited supply. Thus, there is a need to look for cheap alternative protein sources from locally available feed resources. This study was carried out to evaluate the effects of substituting soybean meal with either *Moringa oleifera* leaf meal (MOLM) or *Leucaena leucocephala* leaf meal (LLLM) on pond water quality and growth performance of tilapia. Furthermore, the study assessed whether the replacement of soybean meal with leaf meals increases profit in tilapia farming. Nine diets were formulated and all of them contained 40% protein (soybean or MOLM or LLLM or mixtures of soybean and the leaf meals), 58% energy source (maize bran) and 2% mineral mix. Diet 1, diet 2, and diet 3 contained, respectively, LLLM, MOLM, and soybean as sole protein sources. In diet 4, diet 5, and diet 6 LLLM replaced soybean at the levels of 25%, 50% and 75%, respectively. In diet 7, diet 8, and diet 9 soybean meal was replaced with MOLM at the levels of 25%, 50% and 75%, respectively.

Two concrete tanks were allocated for each diet and 40 fingerlings were stocked in each tank at a rate of 2 fingerlings/m^2. The fingerlings were of mixed sex and had mean (± se) weight of 3.1 ± 0.24 g. The fish in the tanks were fed daily on the respective diets at a rate of 10% of body weight for 90 days. Body weights and length of the fish were measured at the start of the experiment and then at day 30, 60, and 90. Pond water temperature, dissolved oxygen (DO) and pH were measured at weekly intervals for the whole experimental period. Water temperature ranged from 27.7 to 28.5 ^{0}C, DO was between 8.7 and 11.3 mg/l and pH ranged between 7.68 and 8.18. The growth of fish was significantly ($P \leq 0.001$) influenced by diets. Fish on diet 3 showed the highest average growth rate (GR) (0.76 ± 0.07 g/d), lowest average feed conversion ratio (FCR) (2.7), and highest mean body weight (72.06 ± 1.25 g) and length (11.83 ± 1.90 cm) at 90 days. These were followed by the fish on diet 7 (GR = 0.57 ± 0.06 g/d, FCR = 2.8, mean body weight at 90 days = 47.43 ± 1.17 g, and length = 11.25 ± 1.7 cm). Fish on diet 1 had the lowest GR (0.37 ± 0.03 g/d), mean body weight (37.79 ± 1.13 g), and length (9.60 ± 1.4 cm). Fish on diet 2 had the next lowest values (GR = 0.38 ± 0.03 g/d, body weight = 41.92 ± 1.21 g, and length = 10.30 ± 1.4 cm).The economic analysis indicated that the diets which contained MOLM and LLLM as sole sources of protein resulted in profits while the diet which had soybean meal resulted in a loss. The profits decreased as the proportion of soybean meal increased in the diets. It is concluded that the use of MOLM and LLLM in place of soybean increased profit, although the yield of Nile Tilapia was low. The study also revealed that MOLM is relatively better than LLLM as a protein source for tilapia diets.

07MER03PU - On Farm Verification of Tilapia-catfish Predation Culture.

In Tanzania fish farming is dominated by the culture of Nile tilapia (*Oreochromis niloticus*) in earthen ponds under mixed-sex culture. The emphasis on culturing Nile tilapia is due to their better characteristics that include fast growth, short food chain, efficient conversion of feed, high fecundity, tolerance to a wide range of environmental parameters, and good table quality. However, the mixed-sex culture system is faced with a problem of uncontrolled reproduction which results in overpopulation in the ponds. Consequently, most ponds in the country yield only small-sized tilapia, making fish farming appear to be an unprofitable enterprise. Introduction of predator species that feed on fry and fingerlings in the ponds has been recommended as a method to control the population. Predator species such as African catfish (*Clarias gariepinus*) have been used for this purpose in several countries. This study is being carried out to compare the production performance of mixed culture of tilapia and catfish, culture of mixed-sex tilapia, and culture of all-male (or predominantly male) tilapia.

Seven farmers from Mkuyuni village are participating in this study. The farmers were selected based on their willingness to participate. The farmers were given guidance on pond preparation and were given some basic farm inputs such as pipes and spades. The farmers started preparing the ponds in April 2009 and finished in June 2009. On July 1, 2009, all farmers were provided with tilapia fingerlings. The fingerings were stocked in the ponds at a rate of 20 fingerlings per $10m^2$. The number of fingerlings per farmer ranged from 450 to 900 depending on the size of the pond. The farmers were provided with concentrated feed comprised of 40% protein source (soybean), 58% energy source (maize bran) and 2% mineral mix. They were instructed to feed the fish in their ponds at a feeding level of 5% of body weight. The African catfish were supplied to the farmers after 45 days (i.e. on August 15, 2009). Two catfish were stocked for every 20 tilapias per $10m^2$. Both tilapia and catfish are being monitored by measuring body weight, body length, and body width at monthly intervals. In addition, the water quality parameters are also monitored by measuring dissolved oxygen, pH, and temperature of water in the ponds. The experiment will be conducted for five months, and it is expected to be completed on November 30, 2009.

Presentations and Publications

Table VI-3. Presentations

Title	Authors	Type	Event	Date	Location
Evaluating Pond Aquaculture Effluents Through Biological Assessment of Fish and Benthic Macroinvertebrate Assemblages in Receiving Waters	Emmanuel Frimpong, Stephen Amisah	Paper	Aquaculture America 2009	02/2009	Seattle, WA, USA
Catfish-*Clarias gariepinus* Fingerlings as Bait for Lake Victoria Commercial Fisheries	Charles Ngugi, Kwamena Quagrainie	Paper	Aquaculture America 2009	02/2009	Seattle, WA, USA

Table VI-4. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Analysis of the use of Credit facilities by small – scale fish farmers in Kenya	Kwamena Quagrainie	Journal	Aquaculture International	Ref: Doi 10.1007/s.10499-009.9252-8.	Accepted	03/15/2009
Determinant of aquaculture information sources for Ghana small-scale fish famers	Kwamena Quagrainie	Journal	Aquaculture Research	Vol. 40, 1516-1522	Accepted	03/1/2009
Growth performance, survival feed utilization and nutrient utilization of African catfish (Clarias gariepinus) larvae co-fed Artemia and micro-diet containing freshwater atyid shrimp (Caridina nilotica) during weaning	Victoria Boit	Journal	Aquaculture Nutrition		Accepted	08/1/2009

LEAD US INSTITUTION: UNIVERSITY OF ARIZONA

Developing Sustainable Aquaculture for Coastal and Tilapia Systems in the Americas

Project Summary

While the rapid growth of aquaculture has been a boon to many developing countries, its environmental impacts have been considerable. Demand for fishmeal for aquaculture feed has grown to be a significant percentage of global markets. Effluents from aquaculture farms have contributed to eutrophication of receiving waters. As the economic and social importance of aquaculture products grows, it is imperative that scientists in both producing and consuming countries collaborate to develop diets and production systems that mitigate environmental impacts and reduce demands on limited resources. To protect the native fisheries of Latin America from overexploitation and to meet rising demands through aquaculture, successful techniques to culture native species are needed.

This project links a series of research investigations and activities that focus on innovative approaches to waste control, sustainable feed technology, and indigenous species development by (1) exploring research progress on multiple use and polyculture systems with marine macroalgae (seaweed) in an international workshop held in conjunction with the World Aquaculture 2009 conference (07BMA03UA); (2) developing techniques to produce quality eggs and seedstock of native snook (07IND01UA) and improving seedstock quality of native cichlids (07IND02UA); (3) developing technologies using bacterial degradation, catalysis with TiO_2 and UV to eliminate methyltestosterone (MT) from hatchery effluent (07MNE06UA); (4) determining the food safety of leafy vegetable crops grown with aquaculture effluents (07HHI02UA); (5) testing locally available protein sources to replace fishmeal in diets for tilapia and pacu (07SFT04UA, 07SFT05UA). Under this project, AquaFish CRSP also is sponsoring the 8th International Symposium on Tilapia in Aquaculture (07TAP03UA). This work will help to improve the knowledge and capacity of producers, fisheries officers, and extensionists who provide technical services. Experimental results will be transferred in trainings and outreach. Professional-level meetings will offer opportunities for information exchanges of current research and for networking among members of the international aquacultural research community.

USAID Focal Areas: Improving nutrition and health; Maximizing water and soil quality and productivity; Increasing incomes; Improving food quality, processing, and food safety; Enhancing productivity and livelihoods in marginal areas

AquaFish CRSP Global Theme: Environmental Management for Sustainable Aquatic Resources Use

Host Countries: Guyana, Mexico

Project Participants

University of Arizona
Kevin M. FITZSIMMONS: US Lead PI

American University of Beirut
Imad SAOUD: Collaborator

BIOTECMAR C.A., Venezuela
Raul RINCONES: Collaborator

Central Lab Aquaculture Research, Egypt
Ahmed Said DIAB: Collaborator

Delaware State University
Dennis McINTOSH: Collaborator

Department of Fisheries
Pamila RAMOTAR: HC Co-PI
Kamila SINGH: HC Investigator
Vivek JOSHI: HC Investigator

Instituto Sinaloense de Acuacultura, Mazatlan
Roberto AROSEMENA: HC Co-PI

Texas Tech University-Lubbock
Reynaldo PATINO: US Co-PI
Bibek SHARMA: Research Assistant

Universidad Autonoma de Tamaulipas
Pablo GONZALES ALANIS: HC Co-PI
Mauricio A. ONDARZA: HC Investigator

Universidad Juarez Autonoma de Tabasco
Wilfrido CONTRERAS-SANCHEZ: HC Lead PI
Alfonso ALVAREZ-GONZALEZ: HC Investigator
Mario FERNANDEZ-PEREZ: HC Investigator
Arlette HERNANDEZ FRANYUTTI: HC Investigator
Ulises HERNANDEZ-VIDAL: HC Investigator
Gabriel MARQUEZ COUTURIER: HC Investigator
Rosa Martha PADRON-LOPEZ: HC Investigator
Salomon PARAMO DELGADILLO: HC Investigator
Beatriz A. HERNANDEZ VERA: Research Assistant
Isidro LOPEZ RAMOS: Research Assistant
Alejandro MCDONAL-VERA: Research Assistant
William RODRIGUEZ-VALENCIA: Research Assistant

Investigation Final & Progress Reports

Submitted by Kevin Fitzsimmons, Lead US PI

07BMA03UA - Co-sponsorship of "Second International Workshop on the Cultivation and Biotechnology of Marine Algae: An Alternative for Sustainable Development in Latin America and the Caribbean" (*Final Report Summary)*

Abstract: At the 2009 World Aquaculture Society Meetings in Veracruz Mexico (25-29 September), we organized and co-chaired a workshop the Second International Workshop on the Cultivation & Biotechnology of Marine Algae. As part of our support for this workshop, we provided transportation and registration funding for four participants. The workshop itself included nine presentations and a panel discussion. As a follow-up to the workshop, we collected the presentations and converted to PDF's for posting on a conference website.

07SFT04UA - Utilization of Local Feed Ingredients for Tilapia and Pacu Production

Tilapia and pacu production in Guyana has been limited by the availability and cost of fish feeds. Imported feeds are prohibitively expensive and domestically manufactured feeds are nearly expensive based on the use of imported fish and soybean oil meals. The Guyana Aquaculture Association and the primary feed mill, Maharaja Mills, requested assistance to determine the potential of using locally available ingredients in formulated diets for tilapia and pacu. As a first step we held a workshop with the mill operator, local fish farmers and government fisheries officers to develop a list of potential ingredients that were available in Guyana. The second step was to collect samples of the ingredients and conduct proximate and nutritional analyses of the ingredients to determine the nutrient characteristics of the locally available ingredients. During this time we also met with some of the local suppliers of the various ingredients to determine costs and availability of ingredients.

Once the nutrient analyses were completed we entered the data into feed formulation software and began to manipulate the formulations to evaluate the quality and cost for a number of

theoretical diets. The nutrient analyses and feed formulation software were shared with our partners (hosts PI, feed mill management, and aquaculture association members) to consider a variety of diet formulations. In June 2009 we returned to Guyana to work out some experimental diet formulations to test at the Mon Repos Center.

In addition to this program we also spent time with tilapia farmers who preferred to manufacture feeds on site with on-farm ingredients only. One farm purchased an inexpensive hammer mill and compression pellet mill in order to make their own formulated feed. We worked with this farm to provide hands-on training on the various mills, proper drying and handling of fish carcasses to make fish meal, and handling and storage of pellets. The eventual conclusion of the work was directed toward development of pelleted diets by the feed mill and on farm diets for testing in the associated investigation.

07SFT05UA - Local Ingredients Substituting for Fishmeal in Tilapia and Pacu Diets in Guyana

In the associated investigation, 07SFT04UA, *Utilization of Local Feed Ingredients for Tilapia and Pacu Production*, we developed a list of locally available ingredients that could be used in formulated diets for pacu and tilapia. This list included cassava meal, palm oil cake, copra meal, shrimp meal, brewery waste, and poultry by-product meal. After compilation of the list, developed during visits to various producers and processors in Guyana, we collected samples and returned the samples to the US. We conducted proximate and nutrient analyses and loaded the values into feed formulation software. We developed a series of potential fingerling and growout diets utilizing local ingredients.

Our primary goal was to find suitable substitutes for the expensive fishmeal and soybean oil meal in the formulated feeds. This desire is based on both the cost of imported ingredients and the greater availability of agricultural by-products produced in Guyana. We wanted to not only stimulate the aquaculture industry, but also benefit other agricultural ventures by developing markets for some of their by-products.

We developed experimental and control diets for both fingerling tilapia and for growout. The control diets included 50% fishmeal in the fingerling diet and 27% in the growout diet. The experimental diets replaced fish meal in both diets with shrimp and poultry by-product meals in various percentages.

The feed trials were recently completed but the analyses are not completed. We will conclude the statistical analyses and report the results in January 2010.

07IND01UA. Development of snook (Centropomus spp) seed production technology for application in aquaculture and restocking of over-fished populations

This specific project has been severely impacted by climatic changes in the coasts of Tabasco. The absence of storms has limited broodstock availability with 2009 particularly bad for snooks. Very few spawning events were reported in the wild and several induced females did not respond to treatments. We are planning on conducting a final trial in January 2010. Several attempts were conducted with adults from both species *Centropomus parallelus* (fat snook) and *C. undecimalis* (common snook). However, due to severe problems caused by consecutive flooding events in 2007 and 2008, more attempts have been conducted with fat snooks.

Objective 1: To develop techniques for the production of good quality snook eggs.

In the present Project there have been several activities, including the preparation of experimental areas in the coast station in Jalapita, Centla, Tabasco, and the Tropical Aquaculture Laboratory at UJAT. We have collected several wild organisms to develop techniques for the production of good quality snook eggs. As part of the results, we were able to evaluate the dose effectiveness for oocyte maturation. Effects were evaluated before and after 24 hours of the injections. An incremental increase in oocyte diameter was shown with the doses tested. This experiment was repeated in order to determine the possibility of

spawning with the tested doses. For this, we also observed incremental increases in oocyte diameter for the tested females.

In experiment 2 we obtained spawnings in almost all hormone treated females. An increase in oocyte diameters was observed in all cases. We found no differences among treatments with hormones. Fertilization rates were on average 85.66 and 99.5%. Hatching rates varied between 85.81 and 93.56%. The greatest initial length in larvae was found in the 100 μg/kg treatment.

Objective 2. To develop techniques for the production of snook seed. For this study we carried out two trials, the first using a recirculating system composed of 15 cylinder conical tanks connected to two square tanks (500 L each) used as reservoir, centrifugal pump, sand filter, electronic chiller, and UV lamps. For the second trial, we used a static system with 100% water exchange per day. For both trials, a complete randomized experimental design was implemented using as a variable factor the initial stocking density of larvae. Five treatments were used (T1: 20 larvae/L, T2: 40 larvae/L, T3: 60 larvae/L, T4: 80 larvae/L, and T5: 100 larvae/L) run in triplicate. Embryo and yolk-sac larvae were obtained from an induced spawning of fat snook (*Centropomus paralelus*) in Jalapita, Tabasco. Cholesterol implants (200 μg of LHRH per fish) were used to obtain the fertilized eggs. Fertilized embryos were transported to the Laboratorio de Acuicultura Tropical DCBIOL-UJAT. For the first trial, yolk-sac larvae were stocked using a total volume of 15 L per tank. Meanwhile, for the second trial we stocked embryos in square plastic tanks using 5 L. The feeding schedule during the trials included only a supplement of green microalgae (*Nannochloropsis* sp.) and rotifers (*Brachionus plicatilis* at 10 rotifers/mL) for 7 days after yolk absorption. At day five after hatching, the evaluation of total length was obtained by sampling 5 larvae per tank. Our preliminary results showed that fertilization rate was 87.5%, and hatching rate was 80%. For both trials, the highest total length was obtained for larvae stocked at 60/L, where we found rotifers in the guts. However, after day 8 post hatching, all larvae died. We are considering repeating this experiment in February 2010.

Objective 3. To conduct an international workshop on snook biology and culture.
The Second International Symposium on Snook Biology and Culture was conducted. Researchers from the US (Texas, Florida and Louisiana), Mexico and Brazil participated in this symposium. Four pre-symposium workshops were conducted ("Estimation of Snook age from otoliths": Allyse Ferrara, Nicholls State University; Louisiana, USA; "Recirculating systems in aquaculture": Quenton Fontenot, Nicholls State University; Louisiana, USA. "Fat snook (*Centropomus parallelus*) aquaculture": Vinicius Ronzani-Cerqueira, Federal University of Santa Catarina, Brazil.

"Histological determination of gonadal development in teleosts with emphasis on common snook": Harry Grier, FWC Fish & Wildlife Research Institute Florida, USA). The symposium was widely advertised using listservs, newsletters, web site outlets and a TV program on sport fishing. A researcher's network was built as a result of the symposium. The proceedings were compiled and printed with a copy forwarded to the AquaFish CRSP main office. More information will be provided in the final report.

07IND02UA - Incorporation of the Native Cichlids, Tenhuayaca, Petenia splendida and Castarrica, Cichlasoma urophthalmus into Sustainable Aquaculture in Central America: Improvement of Seedstock and Substitution of Fish Meal Use in Diets

Experiment 1. Genetic improvement of Petenia splendida, Castarrica, and Cichlasoma urophthalmus Using Total Length and Condition Factor. This experiment has been delayed by two consecutive flooding events that impacted Tabasco in 2007 and 2008. Fortunately we were able to re-start the experiment establishing broodstock groups and obtaining the first spawnings during early 2009. Castarrica broodstock was collected from three sites in Southeastern Mexico (Centro, Centla and Comalcalco in Tabasco). Tenhuayaca broodstock was collected from Centro, Nacajuca and Centla (Tabasco) and Malpaso (Chiapas). Seventy adult castarricas were

collected on average from each location. A total of 36 castarricas were selected from Centla; 24 from Comalcalco and 24 from Centro. Fifty tenhuayacas on average were collected from each location and 12 were selected from Centla, 24 from Nacajuca and Malpaso and 36 from Centro. Each fish was tagged using a microchip for family identification. Biometric measures were taken from each fish and the fish were then randomly placed in reproduction units. Fish from separate locations were kept in different experimental units. After acclimation to captivity, the first generation of castarrica fry was obtained, consisting of 12 families from Centla, 8 from Comalcalco and 7 from Centro. Fry were collected and stocked in 100-L tanks. All fish were fed five times per day with *Artemia* nauplii during 15 days. After this, all fish were fed with artificial feeds (Silver Cup; micro-particulate). For genetic selection, 13 families were moved to the Agriculture Academic Division at UJAT; fish were stocked in 2 m^3 mosquito mesh-hapas at a density of 150 fish/m^3. After 90 days of grow-out, fish were moved to the Mariano Matamoros Hatchery (State-owned farm) into 2 m^3- 1cm mesh-floating cages for 135 days. Fish were separated by sex; weight and total length were measured to conduct the first selection. Currently, these fish are being grown in 2 cm mesh-floating cages at a density of 20 fish/m^3. Fish from Centla have demonstrated the best Condition Factor ($k = 2.42 \pm 0.30$) compared with those from Comalcalco ($k = 2.25 \pm 0.52$) and Centro ($k = 1.99 \pm 0.16$). However during the grow-out phase, fish did not show significant differences in weight. Average weight for males was 15.33 g and for females 9.54 g. A second selection has been scheduled for May 2010.

In the case of Tenhuayaca, 30 spawnings from different locations were obtained and kept in 150 L tanks. For genetic selection, 12 families were moved to the Agriculture Academic Division at UJAT; fish were stocked in 2 m^3 mosquito mesh-hapas at a density of 150 fish/m^3. After 90 days of grow-out, fish were moved to the Mariano Matamoros Hatchery (State-owned farm) into 2 m^3- 1 cm mesh-floating cages. These fish are too small for first selection; therefore separation will be conducted in February 2010.

Experiment 2: Effects of the substitution of fish meal with pork meal on P. splendida and C. urophthalmus juveniles. Growth of *P. splendida* and *C. urophthalmus* juveniles were evaluated using practical iso-caloric and iso-nitrogenous diets in which fish meal (FM) was partially or fully substituted with pork meal (PM) to replace the 25% FM ingredient component of the diet (T1: 100%PM-0%FM, T2: 75%PM-25%FM, T3: 50%PM-50%FM, T4: 25%PM-75%FM, T5: 0%PM-100%FM. The experiments were conducted stocking 10 fish per tank (5.0 ± 0.1 g) randomly assigned, which were fed for 90 days. Each fourteen days wet weight and total length were determined for the total population. Additionally, survival and chemical composition of complete fish were analyzed at the end of the experiment.

Our results for *C. urophthalmus* showed that the highest wet weight was obtained in the fish feed with T3 and T4, which were statistically higher ($P<0.05$) than the other treatments. For total length, no statistical differences ($P>0.05$) were detected among treatments. Meanwhile, for *P. splendida* differences were detected for wet weight and total length where fish fed with T3, T4 and T5 being statistically higher than the other treatments. Survival for both species was statistically different; fish fed with T1 and T2 had between 50 and 70% survival, while fish fed with T3 and T4 had 65 and 75% respectively, fish fed with T5 had 100% survival. We conclude that the use of pork meal (25-50% PM) as substitute of fish meal for *C. urophthalmus and P. splendida* juveniles is feasible. Whole fish samples for chemical composition are currently under analysis.

Experiment 3: Effects of the substitution of fish meal with poultry meal on P. splendida and C. urophthalmus juveniles. Growth of *P. splendida* and *C. urophthalmus* juveniles were evaluated using practical iso-caloric and iso-proteic diets in which poultry meal (PouM) partly substituted for fish meal. Treatments were: T1: 100%PouM-0%FM, T2: 75%PouM-25%FM, T3: 50%PouM-50%FM, T4: 25%PouM-75%FM, and T5: 0%PouM-100%FM. The experiments were conducted by stocking 10 fish per tank (5.0 ± 0.1 g) randomly assigned, which were fed for 90 days. Each

fourteen days, wet weight and total length were determined for the total population. Survival and chemical composition of complete fish were analyzed at the end of the experiment.

Results for wet weight and total length with poultry meal substitution were similar for *C. urophthalmus* and *P. splendida*, showing statistical differences for fish feed T2, T3, T4, and T5compared with fish fed T1, that were the smallest. Survival in both species showed no significant differences for any substitution level. We conclude that the use of poultry meal (75% PouM) as substitute of fish meal for *C. urophthalmus and P. splendida* juveniles is feasible. Whole fish samples for chemical composition are currently under analysis.

07HHI02UA - Food Safety Study of Leafy Greens Irrigated with Tilapia Farm Effluents

Aquaponics has drawn interest as a sustainable farming method merging aquaculture with hydroponics. Using the effluent from fish farming to irrígate and fertilize vegetables which filter the water so that it can be reused for fish production has many benefits but unknown risks. One potential concern would be the potential for pathogens from fish effluent splashing onto the plants and then being passed to the human consumers of the plants.

To explore this concern we developed an aquaponics system in a new dedicated greenhouse and planted a lettuce crop in perforated styrofoam boards floating in a raceway filled with effluent from a tilapia production unit in a recirculating aquaculture system. The effluent and plant leaves were tested for bacterial counts. In an additional trial, we developed a simple ultraviolet treatment system in an effort to reduce the level of bacteria in the water and on the plants.

We did not discover any pathogenic bacteria in the water or on the plants, but did record relatively small numbers of non-pathogenic bacterial colonies. The UV system did reduce these bacteria to non-dectable levels in most cases. In conclusion, we did not find any health hazard in the aquaponic system tested and we did develop a simple UV treatment system that lowered the levels of the bacteria that were observed.

07TAP03UA - AquaFish CRSP Sponsorship of the Eighth International Symposium on Tilapia in Aquaculture to be Held in Egypt

The ISTA 8 was successfully held in mid-October 2008. Almost 450 people attended the conference and tradeshow. The Proceedings, co-published by the AquaFish CRSP, included over 100 papers filling two volumes and 1500 pages. At the September 2009 World Aquaculture Meetings, student poster presentations were judged. The criteria for judging included applicability to sustainable aquaculture practices in developing countries, quality of the science, visual presentation of research on the poster, and on oral discussions with the judges.

07MNE06UA - Elimination of MT from Aquaculture Masculinization Systems: use of Catalysis with Titanium Dioxide and Bacterial Degradation

Experiment 1. Use of TiO2, UV light and air. This experiment has been conducted, samples are been processed for MT determination. The Enzyme-Linked ImmunoSorbent Assay for measuring MT in each sample is very sensitive and several trials were needed to establish a confident assay.

Experiment 2. Use of bacterial degradation. The objective of this Project was to evaluate the elimination of MT from a masculinization system through bacterial activity. Heterotrophic bacteria were isolated from biofilms formed in the biological filter placed on the masculinization systems. The culture media used were: nutritive agar and eosine agar and methylene blue. The species identification was conducted using the bacteria identification system API WEB and dichotomous key. 160 samples were isolated identifying 15 species. Each of them was evaluated for their adaptability to an enriched media culture of MT in 3 different concentrations. The species *Bacillus ceresus*, *Pseudomonas aeuriginosa*, *Bacillus subtilis, Serratia*

marcense and *Pseudomonas fluorescens* demonstrated the best adaptation to the mineral MT media as the only source of carbon and good growth at 30º C. In the mineral media with the other two concentrations there was no bacterial growth.

Experiment 2. Use of bacterial degradation. We conducted a masculinization trial and a total of 140 isolates were obtained from the filters located in the masculinization tanks (78 isolates from replicate 1 and 62 from replicate 2). From these isolates we identified 13 species of bacteria. A single isolate was selected from each species and we ran an adaptability test to MT-enriched culture media (forty mg of MT in 100 ml of mineral media). The isolates corresponding to *Bacillus cereus, Pseudomonas aeruginosa, B. pumilis, Serratia marcense* and *Pseudomonas fluorescens* demonstrated good adaptability to the MT-enriched media with MT providing the only source of carbon with a good growth rate from 3 to 20 days at 30ºC. From testing the species mentioned above at a concentration of 1 μg of MT/L of water, *P. aeruginosa* resulted as the best species with the best adaptation with the highest number of cells reached after 48 hours. *Bacilus subtillis* and *Pseudomonas fluorescens* showed significant growth at 72 h. *Bacillus cenesus* and *Serratia marcescens* were the species with the slowest growth at 96 and 198 h. The statistical analysis showed significant differences among the five species evaluated (Kruskal Wallis; $p<0.05$) confirming that *P. aeruginosa* was the best adapted bacteria strain. With the growth curves obtained in mineral-media enriched with MT, we determined the microbial developmental phases. At this stage we also obtained samples to determine MT degradation. Samples are currently being assayed for MT concentration, using the ELISA method.

Experiment 3. Use of bacterial degradation of MT in masculinizing systems. This experiment is currently been conducted. A bacterial biomass was produced using the colony that we considered "best" for degrading MT. Our data indicate that *P. aeruginosa* has a very prominent growth during the first week of culture where MT is present. However, one concern is that despite its generalist presence in all aquaculture systems, this species is opportunistic and may infect fish when their immune system is compromised under stressful conditions.

Presentations and Publications

Table VI-5. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID/Citation	Satus	Status Date
From the Pharaohs to the Future: Proceedings of the Eighth International Symposium on Tilapia in Aquaculture	Hussein Elghobashy	Journal Article	From the Pharaohs to the Future: Proceedings of the Eighth International Symposium on Tilapia in Aquaculture	ISBN: 978-1-888807-18-9	Accepted	October/3/2008
Chapter 36. Inland saline aquaculture	Geoff Allen	Book Chapter	New Technologies in Aquaculture. CRC Press and Woodhead Publishing.		Accepted	June/1/2009
Tilapia farming integrated with field crops: A new model for global farming	Kevin Fitzsimmons	Proceedings	Proceedings of the 5th International Tilapia Industry Development Forum. Hainan, China.		Accepted	December/1/2008
Application of submerged surface flow constructed wetlands in a recirculating tilapia production system.	Walter Zachritz	Journal Article	Aquacultural Engineering	39(1):16-23	Accepted	January/1/2009
Aquaculture In Guyana - Tilapia, Pacu, Shrimp Raised With Plant Crops	Jason Licamele	Other	Global Aquaculture Advocate		Accepted	September/1/2009
A good year for tilapia producers and consumers in 2007	Kevin Fitzsimmons	Other	AquaCulture Asia Pacific	4(4):24-25	Accepted	July/1/2008
Tilapia Production, Market Report - Production, Consumption Increase Despite Economic Downturn	Kevin Fitzsimmons	Other	Global Aquaculture Advocate	12(2):67-70	Accepted	September/1/2009

LEAD US INSTITUTION: UNIVERSITY OF CONNECTICUT–AVERY POINT

Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets

Project Summary

In the Lower Mekong River Basin of Cambodia and Vietnam, freshwater aquaculture production has been growing in response to the overexploitation of capture fisheries resources. One consequence of aquaculture's growth is an increased reliance on low-value, small-sized fish (SSF) as a local source of fish-based feeds for aquaculture and livestock production. Use of SSF as feed places aquaculture directly in conflict with the traditional SSF capture fisheries that supply the rural poor with a cheap source for fish and processed fish products. Food security and livelihoods are affected on either side of the conflict.

This project takes an integrated approach for assessing the complexities of the aquaculture-SSF fisheries conflict through five separate but complementary investigations: (1) analysis of supply and demand, and support policy development addressing aquaculture/capture fisheries interactions (07MER01UC); (2) assessment and management of the abundance and status of low value/trash fish fisheries (07MNE01UC) ; (3) development of alternative feeds and feeding strategies (07SFT01UC); (4) outreach and feed technology adoption (07TAP01UC); and (5) trade and value-added product development (07FSV01UC). Guiding this work is the need to balance social, economic, and environmental/natural resource needs and issues. Among the project outcomes will be management recommendations for ensuring the sustainability of the SSF capture fisheries as well as the food security and livelihoods of local stakeholders who depend on the fisheries. In the outreach component, fish farmer trainings will focus on transferring alternative feed technologies and best management practices.

USAID Focal Areas: Improving nutrition and health; Broadening market access; Increasing incomes; Improving food quality, processing, and food safety; Enhancing productivity and livelihoods in marginal areas

AquaFish CRSP Global Theme: Enhanced Trade Opportunities of Global Fishery Markets

Host Countries: Cambodia, Vietnam

Project Participants

UNIVERSITY OF CONNECTICUT-AVERY POINT
Robert S. POMEROY: US Lead PI
Sylvain DE GUISE: US Investigator
Tessa GETCHIS: US Investigator

CAN THO UNIVERSITY
Hien TRAN THI THANH: HC Co-PI
Sinh LE XUAN: HC Investigator
Do Minh CHUNG: Research Assistant
Tu TRAN LE CAM: Research Assistant

IFREDI
Nam SO: HC Lead PI
Somany PRUM: HC Investigator
Sochivi KAO: HC Investigator
Navy HAP: HC Investigator
Sokheng CHAN: Research Assistant
Chim CHAY: Research Assistant
Tong ENG: Research Assistant
Sopheavy HING: Research Assistant
Sy Vann LENG: Research Assistant
Vichet MEAS: Research Assistant

Bun NGO BENG : Research Assistant
Thavry SIM: Research Assistant
Norng SOEUN: Research Assistant
Phalla TAN: Research Assistant
Savary Chea: Research Assistant

UNIVERSITY OF RHODE ISLAND
David A. BENGTSON: US Co-PI
Chong M. LEE: US Investigator

Investigation Progress Reports

Submitted by Robert Pomeroy, US Lead PI

07MER01UC - Competition and Impacts Between Use of Low Value/Trash Fish for Aquaculture Feed Versus Use for Human Food

Additional references have been reviewed regarding use of low value fish and the inland fisheries and wetland aquatic resources in the Lower Mekong Basin in Vietnam and Cambodia.

Target groups were interviewed in nine provinces of Vietnam: An Giang, Dong Thap, Can Tho & Hau Giang. Long An and Tien Giang. In Cambodia, 4 provinces were selected for interviews: Kandal, Kampong Cham, Kampong Chhnang, and Siem Reap. Two sets of forms for data collection were prepared. A set of survey forms were developed and pre-tested before being used for formal surveys at the end of October 2008. These include the interview forms for KIP; group discussions of low-value fish and snakehead , fishers, fish traders, fish users, and snakehead fish farmers. Surveys were completed at the end of March. Additional small surveys were also conducted in July 2009 to correct or add information. In Vietnam, the following stakeholders were surveyed: 650 snakehead farmers, 445 fishing households, 190 fish traders, and 310 non-fish households. There were 22 KIP interviews conducted and 10 group discussions held. In Cambodia, the following stakeholders were surveyed: 48 snakehead farmers, 240 fishing households, 28 fish traders, and 160 non-fish households. There were 20 KIP interviews conducted and 8 group discussions held.

To conduct the surveys, the research teams obtained assistance from the provincial and local fisheries officers. Local extension officers often helped the team with the field surveys. In each province, the research teams organized the focus group discussions and the individual interviews with key informants and selected sample households. Meetings were also held with scientists for secondary data collection. All collected data and information were coded and entered by the end of July. Data analysis was started in July 2009.

Dr So Nam and Dr Prum Somany (IFReDI, Cambodia) joined Tran Thi Thanh Hien and Le Xuan Sinh (Can Tho University, Vietnam) for a field trip in the Mekong Delta from 8-10 January 2009.

Two students completed their theses; four MS students continued their studies.

07MNE01UC - Assessment of Diversity and Bioecological Characteristics of Low Value/Trash Fish Species

Interviews were conducted of the following groups to collect information of species diversity, catch composition and abundance, importance, and harvesting issues of small-sized fish (SSF) resources using three types of standard, semi-open questionnaires: (1) 350 small, medium, and large-scale fishers who use different types of fishing gear to catch SSF species in seven Cambodian provinces (Kampong Cham, Prey Veng, Kandal, Phnom Penh, Kampong Chhnang, Battambang, and Siem Reap) and (2) 60 fishers in three Vietnamese provinces (Can Tho, Dong Thap, and An Giang). In addition to the proposed activities, IFReDI fish biologists added an additional study task to complement the field interviews — conducting fish species catch composition and fish species identification in the fishing grounds where fishers use different types of fishing gear to catch SSF species. Data analyses are on-going of the field interview and ground truthing data. Using a standard, semi-open questionnaire form to collect information on

the role and impacts of SSF utilization in aquaculture development and other sectors, interviews were conducted of (1) 210 fish farmers who operate snakehead and pangasiid and clariid catfish culture in cages and ponds in seven Cambodian provinces (Kampong Cham, Prey Veng, Kandal, Phnom Penh, Kampong Chhnang, Battambang, and Siem Reap) and (2) 100 snakehead farmers in three Vietnamese provinces (Can Tho, Dong Thap, and An Giang). The data analysis is underway.

The field data collected in interviews from the 350 small, medium, and large-scale fishers and 210 snakehead and pangasiid and clariid catfish farmers, as well as the ground truthing data relating to fish species catch composition and fish species identification, have been checked for accuracy and entered in Excel®. Small-size fish species and snakehead aquaculture data collected from 60 fishers and 100 snakehead farmers have been checked for accuracy and entered in SPSS. The data analyses are expected to be completed by mid-October 2009.

A 20-page literature review report entitled "Fish and Fisheries and Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam", and outlines of two final technical reports on this investigation entitled (1) "Species Diversity and Fisheries of Small-Sized Fish in the Lower Mekong River Basin of Cambodia and Vietnam" and (2) "Impacts of the Use of Small-Sized Fish for Aquaculture in the Lower Mekong River Basin of Cambodia and Vietnam" are enclosed with this report.

There are five students (four BS and one MS) who have partial support from this Investigation. Four BS students have graduated and now are working for different NGOs working on rural development and environmental and natural resources conservation. One MS student is still working on his thesis research.

Reviewing and revising the species list of SSF with scientific names; common names in English, Cambodian, or Vietnamese; maximal sizes; and photographs are on-going. At least 2-3 posters of this SSF species list will be published.

A meeting of the USAID/Cambodia Agriculture & Environment Assessment Team was held on 10 August 2009 to better understand the Fisheries Administration's role in Cambodia's agricultural development. The team is led by Ronit Kirshner Gerard (USAID Mission in Phnom Penh) and is composed of members from USAID Headquarters in Washington DC, the US Embassy in the Philippines, development partners from the WorldFish Center in Malaysia and the private sector, CRSP researcher Dr. So Nam, and senior officiers of the Fisheries Administration. The primary purpose of this team is to provide a concise review of existing Royal Government of Cambodia (RGC) strategies, policies, and plans; development partners' plans and ongoing assistance programs and report findings; and other previously conducted assessments in the agriculture and environment sector. The review team will identify the gaps, constraints, and possible opportunities for future USAID assistance, taking into consideration the agency's demonstrated comparative advantage in sustainable natural resources and agricultural production and management development. The team's secondary purpose is to provide technical and programmatic guidance to USAID/Cambodia for supporting the RGC's efforts to improve the performance of agriculture and the environment, and towards this end, elaborate a results framework and assistance objective for USG long-term support. Dr. So Nam presented an oral presentation to the team on the "Fisheries and Aquaculture Development in Cambodia: Current Status, Major Issues and Perspectives".

07SFT01UC - Alternative Feeds for Freshwater Aquaculture Species.

1. Qualitative and quantitative assessment of the regular trash fish diet for snakehead food, The study on the use of trash fish for aquaculture was carried out during the 2008 flood season in An Giang province, Vietnam. Results indicated that 33 species of freshwater fish were used and the most common species were *Cirrhinus lobatus* (19.55%), *Cirrhinus lobatus* (12.55%), *Anabas testudineus* (10.06%), *Trichogaster trichopterus* (8.24%), *Puntioplites proctozysron* (7.27%), *Mystus*

mysticetus (5.63%), *Puntius orphoides* (5.59%), *Esomus metallicus* (4.75%), *Labiobarbus leptocheilus* (3.27%), and *Oreochromis niloticus* (2.95). The minimum length of the trash fish fluctuated from 13 to 157 mm; the smallest (13 mm) belonged to *Anabas testudineus* and the largest (157 mm) to *Puntius orphoides*. The chemical composition of the mixed mix trash fish was 73- 75% moisture, 13-15% crude protein, 3-5% crude fat, and 2.5- 3.5% ash. The results showed that most of these species are commercially important in Vietnam and at least seven species are also key species for aquaculture. The results also indicated that almost all the collected trash fish are juvenile and thus do not contribute to the spawning stock. Therefore, the inland fisheries in the Mekong Delta should be managed properly, especially in flood season.

2. Weaning methods

The replacement of trash fish by formulated feed was conducted in *Channa striata* diets for eight weeks. Free-swimming larvae were fed with *Moina* (a cladoceran) for 10 d and then changed to formulated diets at 10, 17, or 24 d with two levels of 10% and 20% trash fish as the control treatment. Formulated feed contained 50% crude protein and 4.7 kcal/g. *Channa striata* larvae were randomly distributed into 50-L tanks with stocking density of 5 larvae/L. Fish were fed three times a day. Uneaten feed and feces were siphoned out before feeding. The water was maintained at 28±2ºC. Any dead fish were recorded and removed daily. The results showed that the survival rate tended to increase with delayed introduction of formulated diets and high percentage of experimental diets. Similarly, the growth of larvae increased with the above factors. This study demonstrated that weaning for snakehead larvae can begin 17 d after hatch.

3. Replacement of fishmeal with soybean with or without phytase and taurine in diets for snakehead

3.1 Replacement of fishmeal with soybean meal as protein source with and without phytase supplementation in diets for snakehead (*Channa striata*)

Phytase supplementation is advantageous when significant portions of plant protein meals such as soybean meal are used in fish feeds. Thus, the main goal of the study is to find out the appropriate soybean meal level to replace fishmeal with and without phytase supplementation in a snakehead (C*hanna striata*) diet. The experiment included nine practical diets formulated to replace 0% (control), 20%, 30%, 40%, and 50% of fishmeal by soybean meal without phytase supplementation (FM, 20% SM, 30% SM, 40% SM, and 50% SM, respectively); and 20%, 30%, 40%, and 50% with phytase addition (20% SMP, 30% SMP, 40% SMP, and 50% SMP respectively) on a protein-equivalent basis in the diet. Treatments were set up randomly into 27 experimental tanks (500-L each) with three replicates for each of the nine treatments. Thirty fingerlings (4.57–4.81g in initial weight) were assigned to each tank and were fed to satiation. No significant differences in survival rate and protein efficiency ratio (PER) were seen among diets. Food conversion ratio (FCR) in treatment 50 SBM (1.64) was the significantly highest FCR among the treatments ($P<0.05$). Daily weight gain of fish showed a downward trend when replacement fishmeal by soybean meal to 50% SM without phytase addition. However, growth was improved with phytase supplementation; weight gain was not significantly different at 40% SMP treatments compared to control treatment. The present study demonstrated that SM with phytase supplements could replace dietary FM protein up to 40% without negative effects on growth performance, feed utilization, and survival of snakehead juveniles.

3.2 Replacement of fishmeal with soybean meal in giant snakehead *Channa micropeltes* with phytase supplementation diets

This study was designed to determine the maximum replacement levels of fishmeal (FM) by soybean meal (SM) with phytase supplementation for *Channa micropeltes*. FM in the basal diet was replaced by SM in the diets at replacement levels of 20%, 30%, 40%, and 50% with 0.02% phytase supplementation. *Channa micropeltes* fingerlings (4.3 ± 0.03 g/fish) were randomly distributed into 15 tanks (500 L each) with 25 individuals per tank. Fish were fed twice a day to satiation. After 8 weeks of feeding, there were no significant differences in survival rate among the treatments. Compared to the control treatment (FM), replacement of 20%, 30% and 40% of FM by SM did not significantly affect growth performance, FCR, or PER while the replacement

level of 50% significantly reduced these parameters, except for FCR. From an economic view, replacement of FM by SM up to 40% in *Channa micropeltes* diets reduced feed costs/kg diet and feed costs/kg weight gain by 10.8% and 4.83%, respectively.

3.3 Replacement of fishmeal with soybean meal as protein source with and without taurine supplementation in diets for snakehead (*Channa striata*)

The present study aims to investigate the effect of dietary taurine supplementation on growth of snakehead with SM replacement of fishmeal (FM). Nine practical feeds were formulated to replace 0% (control), 20%, 30%, 40% and 50% of FM with SM without taurine supplementation (FM, 20 SM, 30 SM, 40 SM, and 50 SM respectively) and 20%, 30%, 40%, and 50% with taurine supplementation (20 SMT, 30 SMT, 40 SMT, and 50 SMT respectively) on a protein-equivalent basis. In this experiment, nine diet treatments were set up randomly into 27 experimental tanks (500 L each) in three replicates. Thirty fingerlings (4.57–4.81g initial weight) were assigned to each tank and were fed to satiation. As the percentage of SM increased, the daily weight gain (DWG) of fish decreased from 0.28 to 0.14 ($g.day^{-1}$) without taurine supplementation. In contrast, daily weight gain was not significantly different between the control treatment and the treatment replacing 40% of soybean with taurine addition. Also, there was no significant difference in survival rate of fish among diets. FCR and PER of fish fed all other diets were not significantly different from each other and ranged from 1.08 to 1.43 and 1.86 to 2.15 respectively with replacement of FM by SM up to 30% without taurine and 40% with taurine supplementation. However, replacement of 50% FM by SM with or without taurine supplementation in diets illustrated a poor performance both in DWG and FCR. Thus, SM can replace up to 40% of FM in diets for juvenile snakehead when taurine is used as supplementation.

4. Replacement of fishmeal by rice bran and soybean meal with alpha-galactosidase supplementation

4.1 Utilization of rice bran in snakehead *Channa striata* feed

Compared to SM, rice bran (RB) is cheaper and more available in Vietnam. Therefore, replacement of FM and SM with a less expensive local ingredient would be beneficial in reducing the feed costs and environment impact. The objective of this study is to determine the possibility of partial replacement of rice bran in diets for *Channa striata.* The experiment was conducted in four treatments in which RB replaced 0, 10, 20, or 30% of combined fishmeal and soybean meal (phytase supplementation). Four iso-nitrogenous (44% crude protein) and iso-energetic (4.7 Kcal/g) experimental diets were formulated and fed twice a day to satiation. Healthy snakehead fingerlings (initial weight 4.6±0.07 g/fish) were selected for the trial. Fish were acclimated in tanks for a week prior to the experiment. Stocking density was 50 fish/500-L tank. After 8 weeks of feeding, there was no significant difference in survival rate, FCR or PER among treatments. Growth performance in 10% RB diet was significantly greater than the control ($P<0.05$). However, DWG of fish in treatments in which RB replaced 20 and 30% were not significantly different from treatments in which RB replaced 0% and 10% ($P>0.05$). To sum up, RB can replace up to 30% of combined FM and SM for making *Channa striata* feed.

4.2 Replacement of fishmeal by soybean meal with alpha-galactosidase in diets for snakehead, *Channa striata*

SM can replace up to 30% of FM in the diet without addition of phytase or 40% of FM with the addition of phytase (Hien, 2009). In this experiment, we tested a control diet of FM against diets in which SM replaced FM at several levels (50, 60, or 70% replacement), with appropriate essential amino acid (EAA) additions so that all diets matched the EAA profiles of FM. The replacement diets were supplemented with phytase and alpha-galactosidase. All treatments were done in triplicate. The experiment began with snakehead juveniles that averaged 3.8 g in size and lasted for 8 weeks. Growth of the fish on diets with 50% or 60% replacement of FM with SM with phytase and alpha-galactosidase.was statistically indistinguishable from those fed the control diet, but diets with 70% FM replacement yielded statistically poorer growth. Thus,

SM can replace up to 60% of FM in the diet with the addition of phytase and alpha-galactosidase.

5. Replacement of trashfish by pellets for snakeheads,

5.1 Replacing trash fish by formulated feed for snakehead *Channa striata* diets

The objective of this experiment is to determine the maximum replacement levels of trash fish by formulated feed in *Channa striata* diets. Trash fish in the basal diet was replaced by formulated feed in the diets at replacement levels of 0 (control), 25, 50, 75 and 100%. Formulated feed contained 44% crude protein and 4.7 Kcal/g. The experiment was conducted randomly in 15 hapas (1 m^3/hapa) and stocking density was 50 fish per hapa with 4.7±0.02 g/fish in initial weight. Fingerlings were fed twice a day to apparent satiety. At the end of experiment, survival was similar among the 0-75% replacement treatments (85.3-92.7%), but lower when formulated feed replaced 100% (73.3%). Growth was not significantly affected when trash fish was replaced by formulated feed up to 50%. FCR and PER were dramatically different among treatments. Chemical composition of fish carcass was very similar when formulated feed replaced 0%, 25% and 50% of trash fish and better than that of fish carcass in the 100% formulated feed treatment. In general, replacement of trash fish by formulated feed up to 50% in *C. striata* diets is possible.

5.2 Replacing trash fish by formulated feed for giant snakehead *Channa micropeltes* diet

The objective of this experiment is to determine the maximum replacement levels of trash fish by formulated feed in *Channa micropeltes* diets. Trash fish in the basal diet was replaced by formulated feed in the diets at replacement levels of 0 (control), 25, 50, 75 and 100%. *Channa micropeltes* fingerlings (5.4 ± 0.03 g/fish) were randomly distributed into 15 hapas (1m^3/hapa) with 50 individuals per hapa. Fish in control treatment had significantly higher survival than the other treatments,, which did not differ significantly among themselves (74.7- 83.3%). Specific growth rate (SGR) in control treatment was not significantly different from the 25% and 50% replacement treatments ($P<0.05$), but was significantly greater than that of the 75% and 100% replacement treatments. FCR in the control was significantly highest and the lowest was in treatment with 100% trash fish. In fact, FCR decreased as the portion of trash fish replaced increased. PER in thecontrol treatment was significantly higher than in other treatments. Chemical composition of fish carcass was not significantly different from that of fish in the 50% replacement treatment. In summary, replacement of trash fish by formulated feed at levels up to up to 50% in *C. micropeltes* diets is possible.

Conclusions

- Thirty-three species of freshwater fish were identified as being used to raise snakehead in Vietnam; almost all of them are important commercial fishery species in Vietnam and at least seven species are key species for aquaculture.

- Weaning for snakehead larvae can begin at 17 d after hatch.

- Soybean meal can replace up to 30% of fishmeal in the diet and up to 40% of fishmeal with the addition of phytase or taurine.

- Rice bran can replace up to 30% of combined fishmeal and soybean meal for making snakehead feed.

- Soybean meal can replace up to 60% of fishmeal in the diet with the addition of phytase and alpha-galactosidase.

- Formulated feed can replace up to 50% of trash fish in diets for both snakehead species, *Channa striata* and *C. micropeltes*.

07TAP01UC - Feed Technology Adoption and Policy Development for Fisheries Management.
This investigation focuses on workshops, outreach, and training activities for farmers. Its overall objective is to transfer appropriate technology developed in Investigation 3 (07SFT01UC) to end-users of aquaculture and aquatic resources to change their negative attitudes and behaviors.

We have reviewed all relevant literature regarding fish process technologies and existing practical aquaculture technologies, which have been successfully implemented by AIT Aquaculture Outreach Program and JICA Aquaculture Development Program in Cambodia. Orientation of the investigation team members was conducted to acquaint them with the project and its required accomplishments. A consultation meeting with team members for three investigations involving IFReDI was held to review the project's process and procedure as well as its goals and objectives, particularly for the three investigations. The consultation was also intended to establish a link of each investigation in terms of its activities, planning, and implementation.

The inception workshop was conducted on June 13, 2008 at IFReDI to introduce the project to the stakeholders whose work is related to aquaculture development and also to seek their suggestions and recommendation. Thirty participants were invited to participate in this workshop. Fourteen participants were from seven provinces, seven from NGOs, two from universities, and seven from Fisheries Administration staff.

Three different field trips, lasting 10 days, were organized for a preliminary assessment and selection of investigation sites for targeted technology adoption and intervention for four provinces: Siem Reap, Battambang, Pursat, and Kompong Chhnang Province. The trips were arranged to make a preliminary assessment of existing aquaculture feeding practices and aquatic resources issues and problems at the sites. One trip was made to assess and understand the fish processing process of a private Fish Paste Company and the household fish paste producers in Battambang province.

A consultation meeting was conducted for the AquaFish CRSP IFReDI team members to finalize the research questionnaires. Two trainings were conducted for the research assistants prior to data collection. The Participatory Communication Appraisal (PRCA) survey was conducted to determine an effective means for transferring information to end-users. The data collected from the seven provinces in Cambodia and Vietnam were entered in SPSS and analyzed. However, communication materials for transferring technology to farmers have not been developed since the new feeding technology has not yet been tested with farmers. This work will be carried out during the no-cost extension (NCE) phase of the project. This Investigation will conduct a feed adoption pilot project with lead fish farmers. Results of their adoption levels will be published and transferred through communication materials during the NCE phase.

Three international trips were made in this year to (1) Can Tho University in Vietnam in February to finalize the research questionnaires and discuss project activities with other investigations, (2) to attend the AquaFish CRSP annual meeting and Aquaculture America Meeting in Seattle, Washington in February, and (3) to Can Tho University in Vietnam in May, 2009 to follow up on activities.

07FSV01UC - Maximizing the Utilization of Low Value or Small Size Fish for Human Consumption Through Appropriate Value Added Product Development.
The literature has been extensively reviewed, and a 12-page literature review entitled "Fish Processing Products and Market Chain and Trade in Cambodia" is enclosed with this annual progress report. Using two standard semi-open questionnaires to document traditional and modern fermenting practices/techniques and to determine BMPs for small-sized fish fermenting technologies, we have interviewed 150 micro-, small-, medium- and large-scale, small-sized fish fermenting operators in five Cambodian provinces (Kandal, Kampong

Chhnang, Battambang, Siem Reap, and Phnom Penh). Additionally, 200 small-sized fish fermented paste retailers, traders, wholesalers, exporters, operators/processors, and consumers in five Cambodian provinces (Kandal, Kampong Chhnang, Battambang, Siem Reap, and Phnom Penh) have been interviewed using five standard forms of the semi-open questionnaires to collect information on marketing channels and trade and economic aspects.

The field data collected from the 150 processing operators has been analyzed with SPSS. A final technical report is under preparation. An abstract of the paper entitled "Small-sized fish paste production technology in Cambodia's Mekong River Basin" has been submitted to WAS 2010 for oral presentation. The abstract is also enclosed with this annual report. The field data collected from the 200 fish retailers, traders, wholesalers, exporters, processing operators, and consumers have been analyzed with SPSS. The Final Technical Report is under preparation. An abstract of the paper entitled "Market channel and trade of fish paste from small-sized fish in Cambodia" has been submitted to WAS 2010 for oral presentation.

Two MS students on partial support in this investigation are now writing their theses. Defense of their theses is expected to be in November 2009.

Presentations and Publications

Table VI-6. Presentations

Title	Authors	Type	Event	Date	Location
Research Methodology	Prum Somany	Oral	Lecture		University of Pagnasastra; RUA
Communication Strategy for Technology Transfer	Prum Somany	Oral	Lecture		University of Pagnasatra; Build Bright University
Use of Freshwater Low Value Fish for Aquaculture Development in the Cambodia Mekong River Basin	So Nam, Eng Tong, Seung Norng, Hortle Kent	Paper	American Aquaculture 2009		Seattle, WA, USA
Overview of low value fish resources: trends in catch and abundance, utilization, and management	So Nam	Oral	Lecture		RUA
Fisheries Resources in Cambodia	So Nam	Oral	Lecture		IFReDI
Socio-technological assessment of the utilization and importance of low value fish in Cambodia and other Mekong riparian countries	So Nam	Oral	Lecture		RUA
Catch and market chain of low value fish along the Tonle Sap River, Cambodia	So Nam	Oral	Lecture		RUA
Aquaculture Production System	So Nam	Oral	Lecture		RUA

LEAD US INSTITUTION: UNIVERSITY OF HAWAI'I AT HILO

Human Health and Aquaculture: Health Benefits Through Improving Aquaculture Sanitation and Best Management Practices

Project Summary

Development of a sustainable shellfish fishery and subsistence aquaculture in rural coastal communities in the Pacific Central American Region depends on effective information transfer and training. The challenge lies in the diverse issues that must be addressed for establishing a viable livelihood for shellfish producers and vendors—production and environmental management, sanitation, product quality, and food safety. The goal is to improve food security by building community capacity for making a livelihood with shellfish culture and market opportunities. Success depends on community involvement, integration of women, and strengthening research and extension capacity.

This bivalve project builds on current coastal zone and aquaculture management efforts to develop a thriving bivalve fishery and aquaculture industry in five estuaries in Mexico and Nicaragua. Eight investigations integrate research, training, and outreach to (1) develop bivalve aquaculture and assess market opportunities for indigenous oyster and cockle species (07HHI05UH, 07IND03UH, 07IND04UH); (2) determine carrying capacity for oyster culture in a nationally important Mexican estuary (07WIZ02UH); (3) train shellfish farmers in BMPs to improve production and sanitation; (4) build capacity in shellfish sanitation and culture for stakeholders at all levels through workshops and trainings (07BMA05UH; 07HHI03UH, 07HHI04UH). This work focuses on capacity building within coastal communities, with special emphasis on women, through meetings, trainings, outreach, and involvement in research. Indigenous species culture is stressed because these shellfish are low on the food chain, have low technology requirements, and have high market value. Training also stresses building links among professional colleagues in Mexico and Nicaragua.

USAID Focal Areas: Improving nutrition and health; Broadening market access; Increasing incomes; Improving food quality, processing, and food safety; Enhancing productivity and livelihoods in marginal areas

AquaFish CRSP Global Theme: Improved Health and Nutrition, Food Quality, and Food Safety

Host Countries: Mexico, Nicaragua

Project Participants

UNIVERSITY OF HAWAII AT HILO
Maria HAWS: US Lead PI
William STEINER: US Co-PI
Sharon ZIEGLER-CHONG: Collaborator

CIAD
Omar CALVARIO MARTINEZ: HC Co-PI

CIDEA-UCA
Carlos RIVAS LE CLAIR: HC Co-PI
Nelvia HERNANDEZ DEL SOCORRO: HC Investigator
Erik José SANDOVAL PALACIOS: HC Investigator
Rodolfo LARZARICK: Research Assistant

LOUISIANA STATE UNIVERSITY
John SUPAN: US Co-PI

UNIVERSIDAD AUTONOMA DE SINALOA-CULIACAN
Eladio GAXIOLA CAMACHO: HC Lead PI
Ambrocio MOJARDIN HERALDEZ: Investigator

UNIVERSIDAD AUTONOMA DE SINALOA-MAZATLAN
Guillermo RODRIGUEZ DOMÍNGUEZ: HC Co-PI
Gustavo RODRIGUEZ: HC Investigator
Olga ZAMUDIO ARMENTA: HC Investigator

Investigation Progress Reports

Submitted by Maria Haws, US Lead PI

07IND03UH - Spat Collection, Growth Rates and Survival of the Native Oyster Species, Crassostrea corteziensis at Santa Maria Bay, Mexico.

This work has been completed and the final technical report is being drafted. The objective of this investigation was to trial spat collection at Bahia Santa Maria. Availability of spat or eyed larvae has been an obstacle to expanding and scaling up oyster culture in this large coastal lagoon area. Both *Crassostrea gigas* and *C. corteziensis* spat were collected and grown out by the women oyster producers of Bahia Santa Maria. Growth was slower than expected. In part this may be attributable to elevated water temperatures and decreased levels of particulate organic matter. The former is consistent with this being an El Nino year, but normally decreased levels of POM are not observed during El Nino years. The local shrimp fishery also produced lower harvest this year as well. Oyster survival rate was on the average 53%, lower than expected. The women were able to sell the oysters, which resulted after seven months of growout, however. Monitoring of the temperature and POM levels will continue, as there is concern about this situation. This work also suggests that spat collection may still be feasible to some degree, pending further testing under what may be more standard climatic conditions. Also, the need for a hatchery to produce eye larvae and spat is indicated.

07IND04UH - Oyster-relaying and Depuration in Open-water Locations

This work was delayed through much of the life of the project due to rains, flooding, and the swine flu outbreak, followed by detection of *Perkinsus marinus* "Dermo" on the Pacific Coast of Mexico. *Perkinsus marinus* is a devastating disease affecting oysters on the East Coast of the USA and Mexico (*Crassostrea virginica*), but not *C. gigas*, which is the predominant species on the Pacific Coast. *Crassostrea corteziensis*, the native oyster found in Nayarit and Sinaloa States is the subject of the CRSP efforts. Unfortunately *P. marinus* also affects this species. Based on genetic analysis, it is believed that this disease reached the Pacific Coast of Mexico through transfer of *C. virginica* from the East Coast. Since discovery of the presence of *P. marinus* on the Pacific Coast, the team of researchers working on the relay and depuration efforts has confronted multiple obstacles to completing this research. First, it was necessary to evaluate whether movement of oysters was even a good idea, given that transfer of oysters might spread the disease. This risk was assessed and it was determined that transfers within this particular area would not pose a risk. A more serious issue, however, was the fear of local residents that movement of oysters for depuration might cause problems. It was necessary for the team to reach a consensus with the community surrounding the estuary area that was targeted as a depuration site in order for them to allow the transfer. In September 2009, two relay and depuration trials were conducted. The first trial was conducted at Pozo Chino and the second at La Palicienta. The waters at Pozo Chino were intensively monitored during the prior CRSP project and bacterial levels (total and fecal coliforms, *E. coli*) fall well below the established legal standards for shellfish growing grounds. In the case of La Palicienta, waters were tested just before the trials began and bacterial levels were slightly higher than the legal allowable limits. Oysters were transferred and monitored for 10 days. Tissues and intervalvular liquid were sampled every three days. It was found that at both sites, bacterial levels in both tissue and

intervalvular liquid fell to below the allowable standards during neap tides, but rose dramatically during the spring tide. The trials will be repeated in October and November. The final report will be submitted in December.

07WIZ02UH - Determination of Carrying Capacity of the Boca Camichin Estuary in Reference to Oyster Culture

The first community meeting was held on November 30, 2007 with the oyster producers of Boca de Camichin, Nayarit State, to present the project and community collaboration with the project. Since that time, sampling has been conducted four times, with water samples totaling 216. Parameters being measured are inorganic and organic materials, temperature, salinity, and dissolved oxygen. At each sampling period, biometric measurements of oysters are being taken at three sites longitudinally distributed along the length of the estuary. Data on mortality is also being taken. Preliminary results were presented at the Korea WAS meeting (2008) and final results at the Seattle Aquaculture America meeting (2009). Results indicate that the current standing stock of oysters cultured at Boca de Camichin (~736 MT) is below the maximum sustainable limit projected by the study (~1100 MT).

Two students are participating in this work, Laura Edith Corona Osuna and Jorge Alberto Domínguez Sandoval, both of whom are in the fifth year of their studies related to Fisheries and Marine Sciences at UAS. Ms. Coruna Osuna successfully defended her thesis in December 2008 and Mr. Dominguez Sandoval successfully defended in June 2009. A forty-one-page manuscript has been drafted in Spanish; the rest of the project team is now reviewing this. Once finalized and translated to English, it will be submitted for publication in a peer-reviewed journal. The final technical report will be submitted in November 2009.

07HHI03UH - International Workshop for Aquaculture Sanitation

This work has been completed. The workshop was held in two parts. The first component was held at UAS in Culiacán, Mexico on September 22-24, 2008 and included two days of conferences with 19 presentations, and a one-day field visit to a pilot site where shellfish polyculture (oyster, pen shell, shrimp) is being demonstrated in conjunction with a Santa Maria Bay community. Thirty-six persons participated in this part of the workshop. This area of the Bay (Altata) is now targeted for shellfish growing water classification by the State of Sinaloa and the Mexican Federal Government. The second component was conducted in Nayarit State in Santiago Ixcuintla. Eleven presentations were held the first day. Thirty-nine persons participated in this part of the workshop. Two field visits were made; the first on September 26 to a major oyster growing area, Pozo Chino. This area is one that is now projected for shellfish growing water classification by the State of Nayarit and the Mexican Federal Government. The second field visit on September 27 was to another major oyster growing area, Boca de Camichin.

Workshop organizers included: UAS, Sinaloa Institute of Aquaculture, Sinaloa State Aquaculture Sanitation Committee, CIAD, National Polytechnic Institute (CIIDIR-IPN), Autonomous University of Nayarit and University of the Coast. Dr. John Supan from LSU also participated. An industry volunteer from the U.S., Mr. David Nisbet, owner of Goosepoint Oyster Company, also attended and provided technical input. Erick Sandoval, CRSP Collaborator and Microbiologist at UCA-Nicaragua, attended the workshop and made several presentations. He also visited several microbiology and public health laboratories in Culiacán and Nayarit. The US PI, Maria Haws, also participated in organizing the workshop and made several presentations. The final report will be submitted in November 2009.

07HHI04UH - Regional Workshop on Shellfish Culture and Sanitation

The Regional Workshop on Shellfish Culture and Sanitation was held September 28-30, 2009 at UAS in Culiacan, Mexico. Forty-three attendees were present, representing educational, private sector and governmental institutions. In particular, representatives from the Aquatic Sanitation Committees from five of the Mexican States on the Pacific Coast were represented. This is significant since the ASCs provide extension services to aquaculture producers, and since 2008,

have expanded from working only with shrimp to inclusion of bivalve production in recognition of the rapid growth of the bivalve production industry. In addition to training and sharing lessons learned, the group also issued the "Declaration of Culiacán", a public manifesto expressing the needs of the sector and requesting specific actions from industry and responsible government agencies. This work is now completed except for the final technical report. The participant list is being submitted as part of this report.

07BMA04UH - Training in Best Management Practices for the Production of Molluscs in the States of Nayarit and Sinaloa

This work has been delayed multiple times due to various factors, including the initial swine flu outbreak followed by precautionary closings of the university since that time. All planning and materials have been prepared. The events will be held in October through December and barring further issues, will be completed on time.

07HHI05UH - Microbiological Quality of Shellfish Growing Waters and Tissues

This investigation consisted of three subcomponents.

1. Sampling of water and bivalve tissues to monitor the presence of *Salmonella*, *E. coli*, and *Vibrio parahaemolyticus* has been conducted for one year (August 2008 to August 2009) and has been completed. Data are now being analyzed and the report written.

2. A depuration site has been established in the Asseradores Estuary and controlled trials have been conducted in the laboratory to determine the depuration rate for cockles (*Anadara* spp.). The laboratory trials have been completed. All preparations required to begin the field testing have been completed and the field depuration will take place in October, 2009.

3. A market trial and cost-benefit analysis for depurated cockles was conducted. This work is complete and the final report is being drafted.

07BMA05UH - Intensive Training and Internship in Bivalve Culture and Shellfish Sanitation

This training event was completed in FY08. The first two days of the workshop were spent attending the annual meetings of the Shellfish Sanitation Conference for the Southeastern States. This included visits to Motivatit Seafoods, a company which uses hydrostatic pressure as a post-harvest treatment for oysters, and a second company which uses a pasteurization post-harvest treatment. The remainder of the workshop was spent in training and hatchery work at the LSU oyster hatchery located at Grand Isle, Louisiana. This training included topics in microalgae culture, larviculture, grow-out methods, oyster restoration, and emergency preparedness. Ironically, shortly thereafter, the hatchery was destroyed for the second time by Hurricane Gustav but due to the LSU emergency plan, much of the equipment and materials were saved. This plan and strategies are now being used to inform other hatcheries around the world that are vulnerable to natural disasters. Follow-up after the workshop to evaluate the effectiveness of the training demonstrates that the participants have been able to utilize the knowledge and skills gained. For example, Olga Zamudio Armenta has since taken on work related to two of the CRSP investigations in Mexico; Nelvia Hernandez is involved in the planning process for a hatchery to be built in Nicaragua; and Maria Haws and her graduate student Daren Gariques have replicated the LSU microalgae bag culture system at UHH. Additionally, both UAS and UCA are in the process of establishing small bivalve hatcheries for research and small scale production. The UAS work will be partially supported by continuation funding from CRSP if that proposal is approved. UCA is funding their hatchery under funds from the EU, but John Supan and Maria Haws continue to advise on the design and operation of both hatcheries.

Presentations and Publications

Table VI-7. Presentations

Title	Authors	Type	Event	Location	Date
Concentration of organic matter in oyster (*Crassostrea corteziensis*) growing waters at Boca de Camichin, Nayarit, Mexico	Haws, M.C., G. Rodriguez-Dominguez, O. Calvario-Martinez, L. E. Corona-Osuna and E. Gaxiola-Camacho	Oral	Aquaculture America 2009	Seattle, Washington	02/2009
Human health and aquaculture: bivalve farming and sanitation in Sinaloa and Nayarit, Mexico	Haws, M.C., E. Gaxiola-Camacho, G. Rodriguez-Dominguez, O. Calvario-Martinez, and G. Rodriguez-Dominguez	Oral	Aquaculture America 2009	Seattle, Washington	02/2009
Development of the Pacific Fat Sleeper (*Dormitator latifrons*) for diversification of aquaculture in Latin America	Rodriguez M. de Oca, G., M.C. Haws, G. Rodriguez-Dominguez, E. Gaxiola-Camacho, A. Medina-J., R. Elao, G. Guevara, F. Cotera.	Oral	World Aquaculture 2009	Veracruz, Mexico	09/2009
Accomplishments of the SUCCESS and CRSP program in Nicaragua	Haws, M.C., N. Hernandez, C. Rivas, J.R. Bravo, B. Crawford.	Oral	SUCCESS program closing event	Chinandega, Nicaragua	04/2009
Accomplishments of the CRSP program	Nelvia Hernandez	Oral	Celebration of Earth Day	Asseradores, Nicaragua	04/2009
Accomplishments of the CRSP program	Nelvia Hernandez	Oral	Small Entrepreneurs Conference	Managua, Nicaragua	2009

Table VI-8. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Marketing, extension and outreach in Sinaloa, Mexico: a preliminary analysis of preferences for oysters.	Quentin Fong	Journal Article	Marine Resource Economics		Accepted	01/2009
Aquaculture research and development	Maria Haws	Journal Article	Coastal Management		Accepted	08/2009

Table VI-8. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
as an entry point and contributor to natural resources and coastal management.			Journal			
Small scale fisheries management: lessons from cockle harvesters in Nicaragua and Tanzania	Brian Crawford	Journal Article	Coastal Management Journal		Accepted	08/2009
Chame Seed Project In Ecuador	Gustavo Rodriguez-Montes de Oca	Newsletter	AquaNews	Vol 24, pp 1, 5	Published	02/2009
Safe and Healthy Seafood from Sinaloa Mexico	Maria Haws	Newsletter	Aquanews			submitted 04/2009

LEAD US INSTITUTION: UNIVERSITY OF MICHIGAN

Improving Sustainability and Reducing Environmental Impacts of Aquaculture Systems in China, and South and Southeast Asia

Project Summary

This project is designed to provide a platform for collaborative research that will develop host-country capacity for better problem solving. The project vision is for current and future work to focus both on solving important aquaculture problems in the region and developing the capacity for host-country investigators and their students to contribute to future research.

Six diverse investigations, designed for successful research outcomes that will lead to future work, include the following: (1) evaluation of the effects of past introductions of exotic fish species (icefish in China; tilapia in Vietnam) on the local small-scale fisheries in three reservoirs that provide economic benefits mainly to the regional rural poor (07MNE03UM); (2) evaluation of the effects of effluent releases and pond water quality from intensive small-scale freshwater and marine pond aquaculture on local water quality (07MNE04UM); (3) application of quantitative methods that combine life cycle assessment (LCA), life cycle cost analysis (LCCA), and mass balance modeling to quantify impacts and make fair comparisons between aquaculture and other food production systems (07MNE05UM); (4) adressing the health-related issue of algal blooms through research on detection and elimination of cyanotoxins in the low trophic-level species culture of tilapia (07HHI01UM); (5) initiation of a polyculture system with mixed-sex tilapia and sahar, an important Nepalese game fish under threat (07BM02UM); (6) concluding workshop to share research results with a wider research audience and discuss plans (07MNE07UM). The impact assessment components of this research will help address environmental effects that directly affect the lives of the rural poor as well as those that can extend to the global level. Results from the experimental microcystin studies will help small-scale farmers in their sale of fish that is safe for human consumption. The tilapia-sahar work may lead to a new aquaculture industry in Nepal with the added benefit of protecting reducing demand for sahar from wild populations.

USAID Focal Areas: Improving nutrition and health; Maximizing water and soil quality and productivity; Improving food quality, processing, and food safety; Enhancing productivity and livelihoods in marginal areas

AquaFish CRSP Global Theme: Environmental Management for Sustainable Aquatic Resources Use

Host Countries: China, Nepal, Vietnam

Project Participants

UNIVERSITY OF MICHIGAN
James S. DIANA: US Lead PI
Barbara DIANA: Research Assistant

HAINAN UNIVERSITY
Qiuming LAI: HC Co-PI

HUAZHONG AGRICULTURAL UNIVERSITY
Weimin WANG: HC Co-PI

INSTITUTE OF AGRICULTURE & ANIMAL SCIENCE
Madhav K. SHRESTHA: HC Co-PI
Sunila RAI : Research Assistant

SHANGHAI OCEAN UNIVERSITY
Liping LIU: HC Lead PI (from August 2009)
Yi YANG: HC Lead PI (through July 2009)
Min JIANG: HC Investigator

UNIVERSITY OF AGRICULTURE & FORESTRY
Hung LE THANH: HC Co-PI
Hoa NGUYEN PHU: Research Assistant
Luong VU CAM: Research Assistant

UNIVERSITY OF MICHIGAN
James S. DIANA: US Lead PI
Barbara DIANA: Research Assistant

WORLD WILDLIFE FUND IN ASIA
Flavio CORSIN: US Co-PI
Tuong Phi LAI: Research Assistant

WUHAN UNIVERSITY
Biyu SONG: HC Co-PI

Investigation Final Report Summaries

Submitted by James Diana, US Lead PI

07BMA02UM - Polyculture of Sahar (*Tor putitora*) with Mixed-sex Nile Tilapia (*Oreochromis niloticus*) *(Final Report Summary)*

Abstract: Sahar (*Tor putitora*) were cultured with Nile tilapia (*Oreochromis niloticus*) to control the level of tilapia recruitment in aquaculture ponds. Two experiments were conducted to assess the effects of the sahar to tilapia stocking ratio on the recruitment and growth of mixed-sex Nile tilapia. The first experiment was conducted on station to determine these effects, and the second experiment was conducted on farm to verify the results in working ponds. The on-station experiment was conducted in 100 m^2 earthen ponds at the Institute of Agriculture & Animal Science, Chitwan, Nepal, and the on-farm experiment was conducted in farmers' ponds at Kathar, Chitwan, Nepal. The on-station experiment had four treatments with three replicates each: tilapia monoculture (T1), 1:16 sahar to tilapia ratio (T2), 1:8 sahar to tilapia ratio (T3), and 1:4 sahar to tilapia ratio (T4). Two-month-old tilapia were stocked at 2 fish m^{-2} (Tables 1 and 2). The ponds were fertilized weekly using diammonium phosphate (DAP) and urea at the rate of 0.4 g N m^{-2} day^{-1} and 0.1 g P m^{-2} day^{-1}, respectively. Tilapia were fed with a locally made pellets (27 % crude protein) at the rate of 2% of body weight every other day after they attained a size of 100 g. The on-farm experiment was composed of three treatments with three replicates each: tilapia monoculture (T1), 1:33 sahar to tilapia ratio (T2), and 1:16 sahar to tilapia ratio. Ponds were fertilized every two weeks with DAP and urea at a rate similar to the on station experiment.

Results of the on-station experiment showed a significantly increased size of tilapia at harvest ($p<0.05$) in treatment 2, when sahar were stocked with tilapia, compared to a tilapia monoculture (Table 1). The number of recruits significantly decreased ($p<0.05$) in ponds where sahar were stocked, and recruits decreased with increasing sahar stocking density (Table 1). Thus, the results demonstrated that stocking sahar controlled tilapia recruitment in a mixed-sex Nile tilapia pond culture system, and the lower density of tilapia allowed better food access for growth and production. Stocking at 1:16 sahar to tilapia ratio showed the overall best performance on station (Table 1). On-farm results showed significantly higher growth of tilapia with a 1:33 stocking ratio of sahar to tilapia compared to tilapia monoculture (Table 2). A complete analysis of the on-farm experiment is ongoing and will provide greater understanding of these results.

Table 1. Stocking and harvest size (Mean ± SE) and number of tilapia recruits in the on-station experiment.

	Treatment			
	T1	T2	T3	T4
Stocking size (g)	11.6 ± 0.2	11.3 ± 0.1	11.5 ± 0.4	11.1 ± 0.4
Harvest size (g)	92.4 ± 2.6 [b]	112.0 ± 6.0 [a]	106.6 ± 7.4 [ab]	103.1 ± 1.6 [ab]
Recruitment (ind. /pond)	324 ± 40 [a]	169 ± 74 [b]	89 ± 15 [b]	69 ± 32 [b]

Means with different superscript letters among treatments were significantly different using an ANOVA ($p<0.05$).

Table 2. Stocking and harvest size (Mean ± SE) of tilapia in the on-farm experiment.

	Treatment		
	T1	T2	T3
Stocking size (g)	10.5 ± 0.0	9.6 ± 0.0	8.9 ± 0.9
Harvest size (g)	138.0 ± 10.7 [a]	190.0 ± 2.0 [b]	169.3 ± 9.3 [ab]

Means with different superscript letters among treatments were significantly different using an ANOVA ($p<0.05$).

***07HHI01UM - Monitoring and Reducing Microcystins in Tilapias and Channel Catfish Cultured in a Variety of Aquaculture Systems*.**

MONITORING AND REDUCING MICROCYSTINS IN NILE TILAPIA *Oreochromis niloticus* CULTURED IN A VARIETY OF AQUACULTURE SYSTEMS *(Final Report Summary)*

Abstract: This study surveyed microcystin concentrations in pond water and Nile tilapia muscles from a typical eutrophic aquaculture pond in China and developed possible techniques for removing the microcystin-producing alga *Microcystis aeruginosa*. Both Nile tilapia flesh (0.10-2.21 ng/g) and pond water (0.052 - 0.134µg/L) contained considerable levels of microsystins. The pond was dominated by blue–green and green algae; Cyanophyta were 27-36 % of total algal counts, and Chlorophyta were 52-58 %.

In order to eliminate microcystins from the water, two possible coagulant treatments for removing *M. aeruginosa* were tested, using chitosan-modified clay or polymeric aluminum chloride (PAC)-modified clay (Kaolin). Results showed that both chitosan- and PAC-modified clays can remove cultured *M. aeruginosa* (strain HAB 657) effectively. After treated with clays, algae sedimented to the bottom and their vitality decreased noticeably. The sedimented *Microcystis* cells died within a month of flocculation with chitosan-modified clay. Maximum electron transport rates (ETR_{max}), a measure of photosynthetic activity, decreased from 99.6 µmol photons cm^{-2} s^{-1} to 23.9 µmol photons cm^{-2} s^{-1} after 30 days. For those treated with PAC-modified clay, algal cells became yellowish, decayed in a week, and ETR_{max} decreased from 97.2 µmol photons cm^{-2} s^{-1} to 20.6 µmol photons cm^{-2} s^{-1} after seven days. Of the two treatments, PAC-modified clay had a quicker and slightly stronger effect. Optimal conditions and dosages of the coagulant treatments were determined through a series of experiments. For chitosan-

modified clays, the optimal pH range was from 5 to 8. Optimal dosages (y_1, ml) were determined by a relationship with OD_{680} (x_1, OD_{680}), where $y_1 = 0.0349x_1 - 0.0019$ ($R^2 = 0.9972$), and by a relationship with chlorophyll-a (x_2, mg/L), where $y_2 = 0.0524x_2 - 0.009$ ($R^2 = 0.9864$). For PAC-modified clays, the optimal pH was from 5 to 9. Optimal dosages (y_1, ml) were determined by a relationship with OD_{680} (x_1, OD_{680}), where $y_1 = 0.0351x_1 + 0.0065$ ($R^2 = 0.9986$), and by a relationship with chlorophyll-a (x_2, mg/L), where $y_2 = 0.0676x_2 - 0.0059$ ($R^2 = 0.9854$). Chitosan-modified clay was more environmentally benign and was also shown to effectively remove field-reared *M. aeruginosa*. After clay treatment, chlorophyll-a decreased from 1.172 ± 0.210mg/l to 0.017 ± 0.007mg/l, a removal rate of 98.60%. This study indicated that chitosan-modified clay can be used in the field.

EFFECTS OF *MICROCYSTIS AERUGINOSA* ON THE WATER FLEA (*DAPHNIA MAGNA)* AND THE RED SWAMP CRAYFISH (*PROCAMBARUS CLARKII*) *(Final Report Summary)*

Abstract: The occurrence of dense cyanobacterial blooms in eutrophic freshwater has been a worldwide problem. These lead to possible adverse effects on many aquatic organisms due to the toxic microcystins that are produced and released by the cyanobacteria as well as deteriorated water quality. In this study, experiments were designed to investigate the harmful effects of *Microcystis aeruginosa* on water fleas (*Daphnia magna*) and red swamp crayfish (*Procambarus clarkii*). The results showed that water fleas could feed on *M. aeruginosa*, but that *M. aeruginosa* had adverse impacts on survival of water fleas. When exposed to 1.5×10^6, 3×10^6, 7.5×10^6, and 1.5×10^7 cells ml^{-1} of *M. aeruginosa* for 96h, survival rates of water fleas for all treatments were less than 40%, which was significantly lower than the 98% survival rate in the control group. Density-dependent effects of *M. aeruginosa* included decreased body length, shorter time to the first brood, as well as lower brood numbers, gross fecundity, lifespan, and population growth in *D. magna*. *M. aeruginosa* also had adverse impacts on the survival of red swamp crayfish. When exposed to 1×10^7 cells ml^{-1} and 2×10^7 cells ml^{-1} of *M. aeruginosa* for 7 days, survival rates of red swamp crayfish were 7.69 and 11.53%, respectively, which were significantly lower than in the control group. Observations using a transmission electron microscope detected *M. aeruginosa* destroying the hepatopancreas cellular ultrastructure of red swamp crayfish, resulting in a swollen or broken cellular membrane. These results suggest that the occurrence of *M. aeruginosa* blooms could strongly inhibit population growth of water fleas by depressing their survival rate, individual growth, and gross fecundity, which could disrupt the ecological balance and reduce the primary productivity of aquaculture systems. Preliminary results on the lethal impacts of *M. aeruginosa* on red swamp crayfish are a new contribution to the knowledge of the toxic mechanisms of cyanobacterial blooms on aquatic organisms.

07MNE03UM - Impact of Introduction of Alien Species on the Fisheries and Biodiversity of Indigenous Species in Zhanghe Reservoir of China and Tri An Reservoir of Vietnam.

IMPACT OF THE INTRODUCTION OF ALIEN SPECIES ON THE FISHERIES AND BIODIVERSITY OF INDIGENOUS SPECIES IN THE ZHANGHE RESERVOIR OF CHINA *(Final Report Summary)*

Abstract: China has a long history of introducing alien species (e.g., tilapia, rainbow trout) to develop aquaculture. These alien species have indeed brought numerous benefits for economic development, but there has been little study of the ecological and economic impacts that these species have had. There is a growing concern that introduced alien fishes may change local ecosystems by modifying species composition, population structure, and food chains, causing not only the loss of biodiversity but reducing the potential for development of sustainable local fisheries. The objective of this research was to estimate the environmental impacts of the 1992 introduction of Taihu icefish (*Neosalanx taihuensis*) in Zhanghe Reservoir. Historical data on fish catches and fish species composition were collected from relevant reservoir management agencies and the Zhanghe Reservoir Fisheries Management Company. The primary data on fish catches were collected through seining surveys of fish at thirteen locations in the reservoir, surveying the species structure at fish landing points, and analyzing questionnaires completed

by fishermen. Meanwhile dissolved oxygen, water temperature, pH, and Secchi disc visibility were measured weekly. Total alkalinity, nitrate-nitrogen, nitrite-nitrogen, total ammonia-nitrogen, phosphate and chlorophyll-*a* concentrations of pond water were measured monthly. Before 2005, the mean icefish yield was approximately 150 t yr^{-1}. The yield of icefish in Zhanghe Reservoir unexpectedly decreased significantly in 2006, and they were nearly extirpated in 2007. Icefish and bighead carp *(Aristichthys nobilis)* have similar feeding habits. Because of the reduction in competition for food, the yield of bighead carp increased gradually from 200322003 through 2008. The decreasing yield of icefish was attributed to the rapid increase in yield of culters (*Culter alburnus* and *Culter mongolicus*). Culters eat icefish as their main food, and the culter yield was steady at ~50 t per year before 2004, but increased to 120 t in 2008. The reason for this increase was the disappearance of the top predator yellowcheek (*Elopichthys bambusa*) in this reservoir. Before 2008, people recognized yellowcheek as the inhibitor to increased icefish yield and have tried to eliminate this species from Zhanghe Reservoir since 2004; thus, the yield of yellowcheek decreased very rapidly from 2004 and almost disappeared in 2006. The disappearance of the top predator yellowcheek indirectly led to the extirpation of icefish and increased yield of bighead carp in Zhanghe Reservoir. This provides us with strong evidence that not only can alien species influence indigenous species, but also vice versa.

IMPACTS OF THE INTRODUCTION OF ALIEN TILAPIAS (*Oreochromis* spp.) ON THE FISHERIES AND BIODIVERSITY OF INDIGENOUS SPECIES IN TRI AN RESERVOIR, VIETNAM *(Final Report Summary)*

Abstract: This study was conducted to determine the impact of alien tilapias (*Oreochromis* spp.) on the fisheries and biodiversity of indigenous species in Tri An Reservoir, Vietnam, from November 2007 to June 2009. Historical data on fish catches and species composition were collected from Dong Nai Fisheries Company and Dong Nai Aquatic Resources Conservation Bureau. To compile species composition data, we interviewed fishermen and middlemen at fish landing points for details about their fishing gears and harvests. To understand the fluctuations of populations across fishing seasons and locations, gill nets (mesh size 40-60 mm) were used to seine fish at four, five, and four locations upstream in the reservoir and downstream from the reservoir four times per year. There are 139 species of fish in Tri An Reservoir, of which 102 species, including Mozambique tilapia (*Oreochromis mossambicus*), were present before the reservoir's establishment. Immediately after the reservoir was created, 109 species were present, including Nile tilapia (*Oreochromis niloticus*), *Tilapia* sp., peacock cichlid (*Cichla ocellaris*), and *Hypostomus* sp. However, creel surveys in this study observed only 40 fish species recorded at landing points. The total fish production in 1995, 2000, 2005, and 2008 was 1126, 2301, 2589, and 3823 tons, respectively. But the total production from 4 landing points was only approximated 1661 tons. This study was unable to use historical catch data from the Dong Nai Fisheries Company and the Aquatic Resources Conservation Bureau because the lack of species composition and descriptions of the fishing gears used in their data limited its interpretation. There are currently 19 different types of fishing gears in use at the reservoir, of which 14 caught tilapias. Of the five fishing gears with the highest total catches, only two caught tilapias, resulting in only an estimated 4.62% of tilapias fishermen harvested and 5.09% of landing point records, repectively. However, tilapias were the 6th most common of the 40 fish species caught from fishermen's survey data, indicating the rather low productivity of most other fish species in the reservoir. Among the six species with highest biomass, the only economically valuable species recorded were the silver barb (*Barbonymus gonionotus*) and tilapias. The species with little or no economic value that are abundant in the reservoir (glass fish *Parambassis siamensis*, river sprat *Corica soborna*, repassan *Cyclocheilichthys repasson,* and wrestling halfbeak *Dermogenys pusillus)*, accounted for 64% of estimated total fish harvest (3823 tons) in the reservoir in 2008. Their abundance is also shown by their production records at landing points in 2008, with glass fish (355.91 t) and river sprat (243.68 t) accounting for a large portion of the total production (1661 t). These indicated that the abundance of fishes with low economic value may affect fisheries and fish biodiversity much more than the alien species.

When using gill nets instead of seining, fish species composition was composed of more species with high economic value. Estimated tilapia catches and landing records also show that tilapia species are abundant (84.62 tons of total 1661 tons at landing points), second only to silver barb (147.59 tons/1661 tons). These high catches, despite the fact that they haven't been stocked regularly as silver barb and other cultured fish species, indicates favorable development of such species in the reservoir. During the peak catches of tilapias in August 2008, the other top five most commonly caught fishes were not at their peak catches, indicating the likely impact of tilapia on other main economically important fish species such as silver barb, common carp (*Cyprinus carpio*), repassan, and *Labiobarbus spilopleura*.

07MNE04UM - Assessing Effectiveness of Current Waste Management Practices for Intensive Freshwater and Marine Pond Aquaculture in China. *(Final Report Summary)*

Abstract: This study evaluated the different waste management strategies used by small-scale farmers in Hubei and Hainan for intensive carp, tilapia, and shrimp pond culture to reduce effluent and solid waste pollution.

Through interviews and questionnaires, we found that the farmers always check water quality and use chemicals to adjust water quality during culture. Carp and tilapia farmers did not discharge effluents from ponds directly into receiving waters, but treated and reused the effluents. Most of the farmers in China have realized the importance of water quality and have become more environmentally aware, which would benefit the sustainable development of the aquaculture industry in China.

For intensive carp polyculture in Hubei, water quality, sediment quality, and nutrient budgets were measured in four farms with different management strategies. Farm A had the lowest stocking density and greatest aerator usage and also had the best water and sediment quality among the four farms. With increasing stocking density and decreasing aerator usage, water and sediment quality worsened. Fertilizer was the major source of nutrient inputs in the carp pond, and the second was feed. Percentages of nitrogen (N) and phosphorus (P) inputs in the form of feed were significantly higher in farm D, with highest stocking density. Based on our results, proper stocking density for carp polyculture should be 1 to 2 fish per 10 m^2 of pond surface area (0.12 - 0.18 kg/m^2) with aerator usage at 4-8 hr day^{-1}.

For intensive tilapia culture in Hainan, variations in seasonal stocking schedules and equipment usage were tested using trial ponds. Tilapia growth performance in trial C was significantly better than the other three trials ($P < 0.05$). Trial C may have benefited from water refilling and culturing tilapia in the summer. Trial B had the worst water quality. This was a result of the lack of water exchange and the fact that tilapia were cultured in fall and winter. Among parameters measured, dissolved oxygen (DO) and chemical oxygen demand (COD) were significantly different between filling and draining ($P < 0.05$), which showed that tilapia culture would result in accumulation of organic matter in the water column. Among these four trials, trial C had the highest DO value and stratification was not evident, which was attributed to the use of an axial-flow water circulator and extended usage of aerators. Among the four trials, the sediment quality parameters of organic matter, total nitrogen (TN), and total phosphorus (TP) all increased significantly when measured after draining ($P < 0.05$). The N and P input budgets in the four trials also indicated that N and P were mostly lost into sediments. At the same time, commercial feed was the major source of nutrient inputs, followed by fertilizer. Fish harvest removed 35.43 ± 4.97% N and 32.06 ± 3.81% P from the total inputs. The N and P inputs in trial B were the highest, as were the losses to the sediments. Based on our results, proper stocking density for tilapia culture should be 2-3 fish per m^2 with aerator usage at 4-8 hr day^{-1}.

For intensive shrimp pond culture in Hainan, parameters related to water quality, sediment quality and nutrient budgets were evaluated in four farms with different management strategies. Shrimp in trial A had the highest growth rate and the highest water temperature among the four trials. SPF shrimp in trial B had better growth performance than a local shrimp strain. During the culture period, many parameters of water and sediment quality worsened gradually. Commercial feed was the major source of N (80.73 - 93.16%) and P (94.41 - 96.63%) in the four trials. N was mostly used by shrimp and P was mostly lost to sediment. Nutrients retained by shrimp were not significantly different among the trials A, B, and D, which implied that utilization efficiencies of N and P were not affected by different stocking densities. Trial C, with fingerlings cultured in a nursing period, had the best culture efficiency with highest survival rate and N and P utilization efficiency. Nursing fingerlings before formal culture is beneficial for intensive shrimp pond culture. The stocking density for shrimp should be not more than 120 per m^2 with aerator usage of an 8-12 hr day^{-1}.

07MNE05UM - Determining the Ecological Footprint of Shrimp Aquaculture Through Life Cycle Analysis of Outdoor Pond Systems *(Final Report Summary)*

Abstract: A life cycle assessment (LCA) was applied to evaluate environmental impacts and identify sustainability issues of three different farming systems (scenarios) based upon case studies on Hainan Island, China. These scenarios included intensive farming for an overseas export market using larvae produced by imported specific pathogen free (SPF) broodstock; semi-intensive farming for export to the mainland using larvae produced by imported SPF broodstock; and semi-intensive farming for local consumption using larvae produced by local broodstock. Environmental impact categories used in this study were based on the Eco-indicator 95 method from SimaPro (V. 7.1.8) and included global warming potential, ozone layer depletion, acidification, eutrophication, heavy metals, carcinogens, pesticides, summer smog, winter smog, energy use, and solid waste. The life cycle model included hatchery, outdoor farming, post-farming, consumption, and transportation stages. Data were collected at farms on Hainan Island during the summer of 2008 and analysis is ongoing.

Results showed that the main differences among the three scenarios were related to energy use, global warming, and eutrophication potential. Intensive farming showed the highest environmental impacts in each category compared to the other two scenarios. Shrimp farming was the key life cycle stage contributing the most significant impacts, and it accounted for about 70% of total impacts. These impacts were mainly caused by feed use, electricity use, and wastewater discharge. The export of shrimp from China to the U.S. also caused large impacts; to produce 1 kg of farmed shrimp for export, 90-100 MJ of energy were needed, generating 6.9-7.8 kg CO_2 and 0.1-0.2 kg PO_4. These results indicated shrimp should be consumed locally to reduce environmental impacts.

A comparison between shrimp exported from China using intensive outdoor systems with flow-through technology and indoor recirculating systems in the U.S. was also conducted. U.S. indoor systems consumed 1.4 times more energy but 70% less water and produced 15%-80% less global warming emissions, acidification potential, and eutrophication potential compared to Chinese outdoor systems. This result indicated that the U.S. should produce shrimp for themselves instead of relying largely on imports from Asian countries.

07MNE07UM - Workshop on Aquaculture, Human Health and Environment
(Final Report Summary)

Abstract: The AquaFish CRSP Workshop on Aquaculture, Human Health, and Environment was held in Shanghai, China from 7-10 July 2009. The workshop was attended by at least 28 people, including faculty, students, and staff from all Asian Host Country universities, as well as staff from the World Wildlife Fund. Professors Liu Liping and Min Jiang made the arrangements for hosting by Shanghai Ocean University. The workshop served as a wonderful venue for

members of the AquaFish CRSP team to review their progress, discuss future plans, and consider the relationship between their research program and needs within their countries.

The first day of the workshop presented an opportunity for each project to summarize their results to date. Altogether, 11 presentations were made on the results of research conducted by CRSP institutions. There was a lot of discussion among CRSP participants about the kind of research being done in some countries and the kind that should move forward in other countries, as a result of the exchange of information and studies being conducted across the region.

The second day of the workshop focused on interaction among participants regarding the major issues related to aquaculture that should be a focus for our research programs in the CRSP. The first step of this process was for each individual to list three issues they felt were important. Upon review of this list, we summarized the issues by various areas of work and combined similar areas into the overall list of research priorities. The priorities fell into four categories: aquaculture practices, fisheries, mitigating environmental impacts, and socio-economics. After compression of the topics, a total of 26 different areas of research were listed under these four categories. Each person was then given the opportunity to vote on two research priorities. Highest priority was given to studies on water quality and effluents, followed by microcystins, and a three-way tie for third place—sediment management, species introductions and impacts on indigenous species, and the quality of seed in hatchery management. These research priorities will be used to consider cross-region proposals in the next round of RFPs for AquaFish CRSP research.

Presentations and Publications

Table VI-9. Presentations

Title	Authors	Type	Event	Location
Outreach, acceptance, and success of pond aquaculture in promoting rural economy and social stability	J.S. Diana, Y. Yi, et al.	Oral	Aquaculture America	Seattle, Washington
Aquaculture Production & Biodiversity Conservation	J.S. Diana	Oral	Michigan Aquaculture Association	Ann Arbor, MI, USA
Aquaculture waste water treatment by using a biological sequencing batch biofilm reactor	S. Biyu, Y. Yi, J.S. Diana	Oral	4th International workshop on Sustainable Asia	Wuhan, China
Changing and development trend of shrimp culture in China	Lai Qiuming	Oral	Shrimp Industry Development Forum of China	Zhanjiang, China
Determining the Ecological Footprint of Shrimp Aquaculture through Life Cycle Analysis (LCA)	C. Ling, J.S. Diana	Oral	Aquaculture America	Seattle, Washington

Table VI-10. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Aquaculture Production and Biodiversity Conservation	James Diana	Journal Article	BioScience	Accession #1348	Accepted	12/2008
Social, economic, and production characteristics of giant river prawn Macrobrachiumrosenbergii culture	Vicki Schwantes	Journal Article	Aquaculture	Accession #1346	Accepted	12/2008
Comparisons of growth and economic performance among monosex and mixed-sex culture of red mud crab (Scylla olivacea Herbst, 1796) in bamboo pens in the tidal flats of mangrove forests, Bangladesh	Muslima Khatun	Journal Article	Aquaculture	Accession #1351	Accepted	01/2009

Table VI-10. Publications in Print or in Process

Title	Lead Author	Publication Type	Publication Name	ID or Citation	Status	Status Date
Anatomical and histological characteristics of the intestine in the topmouth culter (Culter alburnus)	Xiaojuan Cao	Journal Article	Anatomia, Histologia, Embryologia	AHE-06-09-OA-094	Accepted	06/2009
Haematological and biochemical characteristics of two aquacultured carnivorous cyprinids, topmouth culter (*Culter alburnus*) and yellowcheek carp (*Elopichthys bambusa*)	Xiaojuan Cao	Journal Article	Aquaculture Research		Submitted	01/2006
Impacts of Microcystins in Aquaculture	Juan Tian	Journal Article	Freshwater Ecology Magazine		Accepted	05/2009
The Dangers of Microcystins in Aquatic Systems, and Progress of Research into their Detection and Elimination	Liping Liu	Journal Article	Global aquaculture advocate	Accession #1366	Submitted	01/2006
Haematological and biochemical charact eristics of two aquacultured carnivorous cyprinids, topmouth culter Culter albur nus (Basilewsky) and yellowcheek carp El	Xiaojuan Cao	Journal Article	Aquaculture Research	IDARE-OA-09-Mar-162.R2	Accepted	09/2009
Effects of GnRHa (D-Ala6, Pro9-NEt) combined with domperidone on ovulation induction in wild loach Misgurnus anguillicaudatus	Youji Wang	Journal Article	Aquaculture	AQUA-D-08-00413		02/2009
Comparison of haematology and serum biochemistry of cultured and wild Dojo loach Misgurnus anguillicaudatus	Xiaojuan Zhou	Journal Article	Fish Physiology and Biochemistry	10695		09/2008

VII. MALI ASSOCIATE AWARD PROJECT

AQUATIC RESOURCE USE AND CONSERVATION FOR SUSTAINABLE FRESHWATER AQUACULTURE AND FISHERIES IN MALI

Annual Report: 1 October 2008 – 30 September 2009

Cooperative Agreement No. 688-A-00-07-00044-00
CA/LWA No. EPP-A-00-06-00012-00

Printed as Submitted by James R. Bowman, Project Coordinator

Introduction

The *Mali Project*, "Aquatic Resource Use and Conservation for Sustainable Freshwater Aquaculture and Fisheries in Mali," operates through an award received from USAID/Mali under the "Leader with Associates" (LWA) award that established the AquaFish CRSP in 2006. The project, which has a planned span of three years (1 October 2007 through 30 September 2010), has the overall goal of "improving the productivity and income of producers in targeted areas of Mali through facilitation of access to technologies and building the capacity of stakeholders involved in freshwater fish farming and capture fisheries management." It is working in three thematic areas to:

- Facilitate access and adoption of improved aquaculture production technologies in targeted areas to increase and diversify the incomes of farmers,
- Build the capacity of the Government of Mali to develop and disseminate relevant technologies,
- Identify appropriate strategies for the implementation of integrated rice and fish farming in target areas,
- Help develop an appropriate fisheries management plan to ensure long-term viability and sustainability of capture fisheries in the target area, and
- Help establish linkages useful for further development of aquaculture and fisheries in Mali.

The Mali Project's Three Thematic Areas: The Project's three-pronged approach towards facilitating the development of sustainable aquaculture and good fisheries management in Mali is being applied through work in these thematic areas:

- Theme I: *Pond Culture—Advancing Sustainable Freshwater Aquaculture Practices and Technologies* (Theme Leaders Dr. Héry Coulibaly and Dr. Charles Ngugi)
- Theme II: *Rice-Fish—Promoting Sustainable Rice-Fish Aquaculture in Irrigated Systems* (Theme Leaders Dr. Héry Coulibaly and Drs. Yang Yi and Liu Liping)
- Theme III: *Fisheries Planning—Building Community and Consensus towards a Fisheries Management Plan* (Theme Leaders Mr. Soumaila Diarra and Mrs. Nancy Gitonga)

Theme I is working to identify, develop, and promote appropriate pond culture systems for implementation in Mali. Theme II is working to introduce appropriate adaptations of proven rice-fish systems, based on experience in China, into irrigated systems of the Niger River delta

in Mali, and Theme III is seeking to encourage local involvement (ownership) in the development of sound fisheries management plans, working initially in the Lake Sélingué area.

South-South Approach: The *Mali Project* takes a South-South approach to development, in which scientific expertise and practical applications are drawn from the experiences of the Aquaculture and AquaFish CRSPs and the global aquaculture community and brought to bear on our three theme areas.

Collaborating Institutions and Personnel:

AquaFish CRSP, Oregon State University, Corvallis, Oregon, USA (Lead US Institution)
Hillary Egna, Principal Investigator, CRSP Director
James Bowman, Project Coordinator
Dwight Brimley, Business Manager
Lisa Reifke, Graduate Student Research Assistant
Stephanie Misola, Undergraduate Student Assistant

Direction Nationale de la Pêche, Ministère de l'Élevage et de la Pêche, Bamako, Mali (Lead Mali Institution)
Héry Coulibaly, Principal Investigator and Mali Theme Leader for Themes I & II (Pond Culture and Rice-Fish)
Soumaila Diarra, Mali Theme Leader for Theme III (Fisheries Management)
Madi M. Kheita, Collaborator for Theme II
Alhassane Abdou Sidy Toure, Collaborator for Theme II
Boureima Traore, Collaborator, Theme III

Moi University, Eldoret, Kenya (Theme I Lead Institution)
Charles Ngugi, PhD, Theme Leader, Theme I
Mr. Manyala, Collaborator for Theme III

Shanghai Ocean University, Shanghai, China (Theme II Lead Institution)
Yang Yi, Theme Leader, Theme II (through July 2009)
Liping Liu, Assistant Theme Leader, Theme II (since July 2009)

Network of Aquaculture Centres in Asia-Pacific (NACA)
Derun Yuan, Assistant Theme Leader, Theme II

FishAfrica, Nairobi, Kenya (Theme III Lead Institution)
Nancy Gitonga, Theme Leader, Theme III

Fisheries Department, Government of Kenya, Nairobi, Kenya
Peter Nzungi, Frame Survey Collaborator, Theme III

Sichuan Aquacultural Engineering & Technology Research Center, Tongwei Group, China
Wu Zongwen, Collaborator, Theme II

Progress Made and Results Achieved

Short-Term Training

The *Mali Project* is largely a technology transfer project, utilizing short-term training, on-farm trials, and in-field demonstrations to adapt and modify existing technologies to better reach its targeted audiences in the three theme areas. Overall, short-term training events have occurred mainly in Mali, but some training has also been done in China and Kenya. During FY09, seven

short-term training activities were conducted in Mali and one course was conducted in Kenya, as follows:

- *Pond construction and management training* (Theme I), 2-6 February; Sotuba Centre de Formation Pratique en Élevage, Bamako; 24 trainees
- *Frame Survey training* for supervisors (Theme III), 9-10 February; ODRS (Office de Developpement Rural de Sélingué), Lake Sélingué, 11 trainees
- *Frame Survey training* for enumerators (Theme III), 11-12 February; ODRS, Lake Sélingué; 20 trainees
- *Catfish propagation and hatchery management training* (Theme I), 6-17 April; Sagana Aquaculture Centre, Kenya; 4 trainees
- *Catfish propagation and hatchery management training* (Theme I), 21 June-3 July; Sotuba Centre de Formation Pratique en Élevage, Bamako; 22 trainees
- *Pre-On-Farm Trials workshop for supervisors* (Theme I), 29 June; Sotuba Centre de Formation Pratique en Élevage, Bamako; 5 trainees
- *Pre-On-Farm Trials workshop for supervisors and farmers* (Theme I), 30 June; Sotuba Centre de Formation Pratique en Élevage, Bamako; 15 trainees
- *Workshop on Up-to-Date Techniques for Rice-Fish Culture* (Theme II), 26 June; OPIB (Office du Perimetre Irrigue de Baguineda), Baguineda; 21 trainees

The total number of trainees involved in these 2009 short-term events was 122.

Long-Term Training

Although long-term training is not a major component of our current project, three students from the Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) (Rural Polytechnic Institute for Training & Applied research), in Katibougou, received partial support for participation in project activities this year. These include Ahmadou Nouh Sow, who is associated with Theme I (Pond Culture) activities, and Fadima Kéita and Bocary Diarra, who are both associated with Theme II (Rice-Fish) activities. Ahmadou Nouh Sow has been involved in pond management and fingerling production activities at the Centre Piscicole Molodo near Niono, has assisted with the transportation of fingerlings from Molodo to sites of the Theme I On-Farm Trials, and has helped with pond monitoring at those sites. Fadima Kéita and Bocary Diarra have participated in similar ways in the activities of Theme II (Rice-Fish).

On-Farm Trials

Two sets of On-Farm Trials are planned as part of Theme I (Pond Culture) during the course of the project. The first set of trials was begun in mid-July 2009, and will run until mid-January 2010. In June, ten farmers were selected to participate in these trials. The trials themselves were preceded by two workshops, held on June 29 and 30 (see short-term training, above), to prepare both the farmers and those who would be supervising their efforts for the trials, and in particular to discuss and agree on the fish stocking (species and stocking densities), management options (fertilization, feeding), and monitoring protocols (sampling for fish growth) that would be used. The ten ponds selected were stocked with fish in mid July; however; due to water shortages and/or pond soils that would not retain sufficient water to maintain the crop through a complete culture cycle, four ponds were dropped from the trials, leaving six participating farmers. The trials are being conducted under supervision of regional directors of the Direction Nationale de la Pêche as well as by one of the students who is

partially supported by the project. This supervision includes regular (monthly) visits to the ponds to assess their status and detailed record-keeping, by date, of fish stocked, weights of fish in samples taken at monthly intervals, and amounts and costs of inputs. These ponds are expected to be harvested in January, at which time final data on fish survival, growth, yield, and gross and net income will be recorded. When all ponds have been harvested a wrap-up workshop will be held to compare and discuss the results from each pond.

Rice-Fish Demonstrations

Four farmers were selected to participate in demonstrations of rice-fish culture in their fields in the Baguineda irrigation area. Participating farmers were selected in late June and field preparations were begun immediately thereafter. Preparations involved excavation of a fish sump in one corner of each rice field being used, excavation of water channels leading through the rice field to the fish sump, and using the excavated soil to raise the surrounding embankments to ensure that fish would not escape. As with the Theme I On-Farm Trials, the fish culture part of these demonstrations began with the stocking of fish in mid-July. These demonstration fields are also being regularly monitored by the regional directors of the DNP, with monthly sampling and complete record keeping. The demonstration plots will be harvested in mid-November, when the Baguineda irrigation system is expected to be shut down for repairs to the main channel. Data collected throughout the demonstration period and at harvest, including fish and rice yields, total costs, and gross and net returns, will be analyzed. The results will be reported after harvest and analysis.

Frame Survey, Lake Sélingué

The Frame Survey of Lake Sélingué was conducted from 16–19 February 2009, immediately following the training of supervisors and enumerators (see "Short-Term Training," above). The survey team started the survey exercise at the Carrière landing site on the eastern side of the lake on 16 February 2009. Completed questionnaires from the eastern side were collected and verified on the 17 February 2009. The exercise was moved to the Faraba landing site on the western side of the lake on 18 February 2009, and completed questionnaires from the western side were collected and verified on 19 February 2009.

A database system was developed for storing and managing the survey data in early April 2009. After completion of data entry, the database was then queried for the required information and the results were exported to an MS Excel spreadsheet for further processing and analysis.

The survey results were submitted on 4 May 2009 in the document *Report on Lake Sélingué Frame Survey of February 2009*, by frame survey expert Peter Nzungi, who is collaborating with Theme Leader Nancy Gitonga. A summary table containing results for the survey organized by Administrative Communes was produced. Bar graphs and pie charts were also prepared from the summary table to facilitate comparisons between Communes. From the results, recommendations were made to guide planning for management of the Lake Sélingué fishery. An electronic version of the report, the survey database, and photos taken during the survey participants training workshops and during the survey exercise itself were submitted along with the written report. The office of the Director, Direction Nationale de la Pêche, translated the report into French and the French version became available in early September, 2009.

The 2009 Lake Sélingué Frame Survey and report were the first of this kind ever conducted on this lake. Lake Sélingué, whose average fish production is 4,000 tons, contributes significantly to the national economy through food security support, income generation, and job creation. The results of this survey are therefore expected to assist in improving management of the lake fisheries for sustainability. Assessing the fishing capacity through frame survey is the first step.

Recommendations based on the Frame Survey included:

- A frame survey of Lake Sélingué should be carried out every two years to assess the impact of management measures taken to ensure sustainable fisheries.
- The DPN should also use the survey capacity built to carry out surveys in other fisheries lakes and reservoirs in Mali.
- The use of the data software in future will require that the data experts build Malian capacity, through training on the use, data entry, and analysis.
- There is need for DPN to carry out stock assessment of Lake Sélingué so that the entire lake status (fish stocks and fishing capacity) can be known for the development of an effective fisheries management plan.

Mali Project Meeting during "Aquaculture America 2009," Washington, February 19-23
Project team members in attendance at the Annual Meeting of the AquaFish CRSP and the *"Aquaculture America 2009"* conference (World Aquaculture Society) in Seattle, Washington, from 15-18 February 2009, took the opportunity to meet to discuss project issues. Malians Héry Coulibaly (Direction Nationale de la Pêche) and Gaoussou Traore (USAID/AEG/Mali) were joined by Theme Leaders Charles Ngugi and Yang Yi and Oregon State University's Hillary Egna and Jim Bowman for these meetings. This meeting provided a chance to review problems encountered to date and approaches taken to solve them, to discuss the format and content of annual reports, and to review and adjust the schedules of activities for the work in the three theme areas.

For our Malian partners this also provided another opportunity to interact with participants in the wider AquaFish CRSP, both from the US and from participating Host Countries. Participation in the *Aquaculture America* conference brought them once again into contact with the global aquaculture community, providing examples and models of what aquaculture can and does do in other countries and regions.

Progress toward Benchmarks, Intermediate Results, and Indicators

Significant progress was made this year with respect to project impact indicators and targets, as shown in Table 1 (next page). The table consists of two sections, one for the five indicators required in the Work Plan and another for additional indicators that are being tracked to the extent possible. We have already met or exceeded our targets for some indicators, even though some related activities are scheduled for completion in FY '10.

Table 1. Impact indicators being tracked under the AquaFish CRSP Mali Project.

Required Indicators (Work Plan, p. 31):

Indicator	*Project Target*	*Previous Total*	*New This Year*	*New Total*
New technologies under field testing	*12*	*0*	*2*[11]	*2*[1]
New technologies made available	*4*	*0*	*6*	*6*
Individuals receiving short-term training[12]	*155 (79/76)*	*2 (2/0)*	*122 (114/8)*	*124 (116/8)*
Farmers who adopted new practices[2]	*16 (8/8)*	*0*	*17 (17/0)*	*17 (17/0)*
Fish processors who adopted new practices[2, 13]	*4 (2/2)*	*0*	*0*	*0*

Additional Indicators (Work Plan, pp. 32-33 and/or Tables 1-3):

Indicator	*Project Target*	*Previous Total*	*New This Year*	*New Total*
Number of Malians who attend international aquaculture meetings[2]	*3*	*2 (2/0)*	*2 (2/0)*	*4 (4/0)*
Number of students trained or mentored in Mali[2]	*3*	*0*	*3 (2/1)*	*3 (2/1)*
Number of participants trained outside of Mali[2]	*8*	*2 (2/0)*	*4 (3/1)*	*6 (5/1)*[2]
Additional aquaculture production area resulting from project efforts (either number of additional ponds or rice paddies or additional area in hectares)	*1.4 ha*	*Not yet determined*	*Not yet determined*	*Not yet determined*
Estimated increase in fish productivity in ponds or rice-fish systems in targeted areas (kg/ha/yr or percent)	*1500 kg/ha/yr*	*Not yet determined*	*Not yet determined*	*Not yet determined*
Estimated increase in income for fish farmers in targeted areas (CFA/ha/yr or percent)	*Not yet determined*	*Not yet determined*	*Not yet determined*	*Not yet determined*
Number of extension publications developed	*10*	*0*	*12*	*12*
Number of frame surveys conducted for lake fisheries	*1*	*0*	*1*	*1*
Estimated increase in income for fishermen in targeted areas (CFA/ha/yr or percent)	*Not yet determined*	*Not yet determined*	*Not yet determined*	*Not yet determined*

[11] Previously reported as 4 technologies; now re-defined as 2: Pond Culture and Rice-Fish Culture.
[12] The total number of individuals is followed in parentheses by the number of men/number of women. For example, an entry of 9 (5/4) would indicate a total of nine individuals, of which 5 were men and 4 were women.
[13] Impacts related to processors are not expected to begin until FY10.

Success Stories

Fish Farmer Seydou Toé

Mr Toé is an agricultural producer who has been practicing fish culture since 2006. His farm, operated in partnership with his brother Richard Toé, is at the edge of an arm of the Niger River in Banco, approximately 30 km from Bamako. With respect to fish farming, he has had problems related to the construction of his ponds, good feeds for the fish, management of the farm, access to fingerlings, and also with high soil permeability, which results in leaky ponds. Seydou speaks neither French nor English, but speaks Bambara and writes N'Ko. He is a founding member of the Association des Pisciculteurs et Aquaculteurs du Mali (APAM).

With respect to the activities of the USAID/AquaFish CRSP *Mali Project*, Seydou was selected by APAM to participate in the Theme I (Pond Culture) training workshops in Bamako and Sagana, Kenya, in February and April 2009, respectively. The February workshop in Bamako focused on pond construction and management, whereas the course held in Kenya specialized on the propagation of *Clarias* (African catfish) and the rearing of *Clarias* fry in the hatchery.

On his return from the Kenya training course, Seydou prepared a list of materials to purchase for the construction of a hatchery for the artificial propagation of *Clarias*. The project financed the purchase of materials and Seydou, with the support of his other colleagues, built and tested a hatchery at the Centre de Formation Pratique en Élevage in Bamako. Participants in the subsequent Theme I training course held at the center (June 2009—see "Short-Term Training" above) used this hatchery to hatch catfish eggs that they produced during the course, which focused on *Clarias* breeding and hatchery management. Seydou provided valuable assistance during this training by explaining the construction and use of the hatchery and demonstrating the catfish culture skills he had learned while in Kenya. The hatchery continues to be operated by APAM to produce *Clarias* fry.

Using local materials Seydou has also built another hatchery at his own farm. By year's end, thanks to training and assistance from this project and for the first time in Mali, Seydou has produced more than 8,000 fingerlings and marketed at least 4,000 of them locally to other farmers. His fingerling sales serve as an important source of income, enabling him to face the various expenses of fish pond operation. Moreover, Seydou has found a method of protecting small fish against predation by larger fish by putting old vehicle tires in the pond to provide refuge for the smaller fish.

The activities of the AquaFish CRSP Mali Project, financed by USAID/Mali, have brought out Seydou's resourcefulness and ingenuity and allowed him to develop them to the benefit of his own farm as well as the efforts of other Malian fish farmers. The training he has received has enabled him to produce fingerlings for sale to other fish farmers, and Seydou now also contributes to the dissemination of the information he has received and technologies he has learned by leading and advising other producers. As an example, the APAM has chosen him to go to Bougouni, approximately 200 km from Bamako, to train ten young people in fish culture in November.

Rice Farmer Mamadou Samake

Mr SAMAKE is a rice producer in the Baguineda irrigation area, approximately 40 km from Bamako. He took part in the informational meetings on rice-fish culture presented by Liu Liping, Wu Zongwen, Alassane Toure ("Sandy"), and Tiéma Traoré in June and July 2009, and volunteered to participate in the project's demonstration of rice-fish culture techniques by integrating fish into his rice production activities.

The design was laid out in Mr. Samake's rice field and he personally did all the alteration work needed to excavate the trenches and the sump to provide a place of refuge for the fish.
Fish stocking took place in August and the fish harvest was planned for November 2009.

Mr Samake maintained his field and cared for his fish well, even bringing termites for their food. He received project support for preparing fish feed.

Mr. Samake was visited by members of the Direction Nationale de la Pêche and USAID personnel in September 2009, by the participants of the Theme II training workshop in November, and by Minister Mrs. Diallo Madeleine BA, of the Ministère de l'Élevage et de la Pêche, on November 19, 2009.

The harvest of fish from Mr. Samake's rice field also took place on November 19, and more than 106 kg of fish were harvested. The harvest data are currently being analyzed. This result is very appealing to Mr. Samake because of the income that was generated. His results have generated a great deal of interest among other rice producers in the Baguineda area and a large number of them are planning to go into rice-fish culture as soon as the water supply is restored.

Frame Survey of Lake Sélingué

Lake Sélingué is the largest capture fisheries water body in Mali, which is why it was chosen for fishery status evaluation through a Frame Survey. The importance of management of a common fisheries resource cannot be overstated, but in order to put into place proper and effective fisheries management plans that involve the users and key players, it is important to have necessary information about the fishery. Fisheries status is not easy to measure since physical census of fish may not be possible. Other parameters are therefore used to evaluate the status of a fishery. The exercise that was carried out in Lake Sélingué in February 2009 provided the baseline information from which the impact of management measures can be evaluated and improved management plans can be formulated.

The overall objective of conducting the Frame Survey was to determine the existing fisheries situation with respect to the facilities and service providers at the landing sites in Lake Sélingué as well as the composition, magnitude, and distribution of fishing effort. The Frame Survey provided information on the number of fish landing sites; the facilities available at the fish landing sites to service the sector, including accessibility to the landing sites; the service providers especially fishermen cooperatives/associations; the number of fishers; the number and types of fishing canoes and their modes of propulsion; the types and sizes of fishing gear used on the lake and the mode of operation for gillnets. This information will guide the development and management of the Lake Sélingué fishery.

The Frame Survey allowed the Theme III team to develop recommendations on best approaches for managing the lake based on the information gathered. The major observation was that the way the fish stocks are exploited needs to be controlled, especially with regard to currently used destructive types of gear and fishing methods such as the use of barriers and fences. There is also a need to establish and protect breeding grounds during breeding times to ensure that healthy fish populations are sustained through recruitment. It was also recommended that the lake should be surveyed again in two years to evaluate the effects of management measures taken following this initial survey.

Through the successful training provided through this project and the completion of Lake Sélingué's first frame survey, Mali now has essential data on the lake fisheries as well as a cadre of capable frame survey supervisors and enumerators. It is now in a position to conduct regular frame surveys at Lake Sélingué as well as on other important water bodies in Mali.

Training in China and Kenya

Some of our best successes to date had their beginnings in training conducted outside of Mali. Examples of this are the successes our trainees have been involved in since their return from rice-fish training in China and catfish propagation/hatchery management training in Kenya.

Participants Alassane Toure ("Sandy") and Tieman Traoré went to Shanghai Ocean University, China, in September of 2008 and returned to share what they had learned there with farmers and OPIB officials in the Baguineda irrigation area. This led directly to the setting up this year of four rice-fish demonstration sites in Baguineda and generation of a lot of interest among other Baguineda area rice farmers, many of whom say they will modify their fields and stock fish during their next crop.

Likewise, participants who went to Sagana Aquaculture Centre, Kenya, in April of this year returned to construct hatchery facilities at public and private locations, train others in how to build and operate these facilities, and begin producing catfish (*Clarias*) fry and fingerlings on their own. One of these trainees, fish farmer Seydou Toé, has since produced over 8000 fingerlings on his farm, is selling fingerlings to other farmers, and has been independently involved in training of other farmers.

The successes of these external training activities have occurred in spite of the language differences that exist, demonstrating again the value of the active, hands-on approach to training we have used and the extent to which language barriers can be overcome when trainees and trainers alike are excited about the subject matter and believe that they can overcome language differences to communicate effectively and achieve good results.

Problems Encountered

We were saddened to learn, towards the end of May, of the serious illness of our longtime friend and colleague Dr. Yang Yi of Shanghai Ocean University, and of his passing away at the end of July. Dr. Yang Yi was for many years a respected member of the Aquaculture and AquaFish CRSP families and of the global aquaculture community. He will be remembered for his many contributions to aquaculture research and education, but also for his warm spirit, kindness, and friendship. He was instrumental in planning activities for the Rice-Fish component of this project and his team was poised to begin the first set of rice-fish demonstrations when he became ill in May. We will miss his presence and his contributions to the project.

The political unrest of early 2008 in Kenya continued to have repercussions for Dr. Charles Ngugi, leader of our Pond Culture theme. During that unrest the Ngugi family lost their home and possessions in western Kenya and fled to the Nairobi area for safety. Dr. Ngugi's work since then has been complicated by an uncertain situation in Eldoret, where Moi University is located.

While language differences have not presented a major obstacle to communication among members of the project implementation team (members from the DNP, Moi University, Shanghai Ocean University, Fish Africa, and Oregon State University), the physical distances between us do cause difficulties for our work effort in that they do not permit regular face-to-face meetings for activity planning and problem solving. In terms of whole-team meetings, budget concerns have limited us to setting aside time to meet at events such as AquaFish CRSP annual meetings and WAS annual conferences. These meetings are good but are limited in terms of time. For more efficient future work, we may need to find ways to increase the effectiveness of whole-team working opportunities, either through more frequent actual meetings or perhaps by using modern electronic tools, for example having "virtual" meetings using Skype or other technologies.

Lessons Learned

We have learned this year that language barriers have been much less of an obstacle to communication and learning in our training courses than might have been expected. In bringing aquaculture and fisheries expertise from non-Francophone countries (Kenya and China) to Mali, there was some concern that our training success would be hampered by poor communication and limited learning. However, our Theme Leaders' experiences have been that

communication and learning have been excellent, both in the training sessions held in Mali and those held in Kenya and China. We attribute this to several factors, including the Malian trainees' very high level of interest in gaining skills in aquaculture and fisheries, our emphasis on hands-on learning, the enthusiasm of our trainers, and the use of competent and interested interpreters in the training sessions. A prime example of where language could have been an issue but was overcome is the example of Seydou Toé, who speaks neither French nor English. Seydou attended the first Theme I training session (pond construction and management) in Mali and then traveled to Kenya to study catfish reproduction and hatchery management. He came back from Kenya with a level of understanding that enabled him to construct a working hatchery at the practical training center in Bamako, demonstrate its use to other Malians, and assist in the next Theme I training course held at the center. He has since gone on to expand and improve operations on his own farm (including construction of his own hatchery) and to become involved in the training of other Malians (see "Success Stories," above).

The inclusion of DNP technical staff in our training and planning activities has stimulated more frequent visits to farmers by these staff members. For example, visits to farmers made jointly by theme leaders and DNP staff during the selection of farmers for the Theme I On-Farm Trials allowed them to give constructive criticism while opening their minds to incorrect pond management practices that had been limiting farmers' production.

Other lessons drawn from project activities include the following:

- Our results to date show that the program is an important means for improving the income of the small producers and thus an effective tool in the fight against poverty;
- Fish culture and rice-fish culture are of great interest to impoverished producers; greater support (material support) could positively influence the level of adoption of the technologies that we are making available; women, especially those who are household heads, and the young people would benefit from such an increased level of adoption;
- Financial support for fish farmer organizations (e.g., APAM) would allow a greater diffusion of rice-fish culture technology, methods of pond construction, and management practices for fish farms;
- Further reinforcement of the capacity of the Direction National de la Péche would ensure better coverage of geographical zones not yet reached, where the need is great and the conditions are favorable;
- Particular technologies that may have potential in Mali but have not yet been addressed include fish culture in floating cages, the production of fish feeds, and the production of fresh water crustaceans (shrimps);
- In order to include more female participants in future activities we will need to develop activities that focus on components of the market chain that are traditionally handled by women, i.e., those such as processing and marketing, which come after fish are landed or harvested.

Outcomes and Impacts

Notable impacts realized this year have included:

- *Stimulation of APAM* (*Association des Pisciculteurs et Aquaculteurs du Mali*): Following the first Theme I training course, February 2009, APAM organized meetings and group activities to evaluate the facilities and practices of member farmers, assess those in light of new information learned in the training, and to begin to adapt to work towards greater and more efficient productivity.

- *Success of farmers* like Seydou Toé: Seydou Toé is a real success story. Following training events both as a trainee and as an assistant to trainers, he has greatly improved his own fish farming efforts, is producing catfish fingerlings for sale, and is training other farmers.

- *Improved management of pre-existing fishponds*: Following training sessions participants have gone home to apply their new knowledge to improve their pond management and productivity

- *Construction of new ponds*: Following participation in training sessions trainees have also gone home to construct new ponds based on what they learned about selecting suitable pond sites and using appropriate construction methods.

- *Application of simple methods for catfish propagation and hatchery management*: A new hatchery facility was installed at the *Sotuba Centre de Formation Pratique en Élevage* by participants returning from training in Sagana, Kenya. This facility was used in a subsequent catfish propagation training course for Malian farmers, and continues to be operated by the APAM to produce catfish fry.

- *Formation of the Jigiya Association*: Following participation in the first Theme I training course in February 2009, Moussa Ballo returned home to form the Jigiya ("Hope") Association, an 11-member group that is now building ponds and growing fish together in Kayo, near Koulikoro.

- *Trained cadre of frame survey supervisors and enumerators*: Following training and survey exercises conducted as part of the Theme III (Fisheries Planning) effort this year, Mali now has the capacity to conduct the recommended periodic frame surveys of Lake Sélingué as well as similar surveys on other important lakes in the country.

- *Introduction of rice-fish culture into the Baguineda area*: Four farmers volunteered for participation in the Project's rice-fish demonstrations and produced crops of fish along with their rice. Although analysis of the results has not yet been completed, the participating farmers seem pleased with their results, and many more farmers in the area intend to try rice-fish production when they begin their next crop.

Summary

The Mali Project has made great strides this year, completing eight short-term training activities involving 122 participants, completing the first Frame Survey of Mali's largest inland body of water (Lake Sélingué), adapting Asian rice-fish technologies to Mali, demonstrating rice-fish culture in the fields of four collaborating rice farmers, and conducting on-farm trials in the ponds of six fish farmers. Following their experiences in our training courses, participants have gone on to renovate poorly constructed fish ponds, build new ponds, apply improved management practices to their fish ponds, begin small-scale fingerling production, and become involved in training others. Analysis of the results of on-farm trials and rice-fish demonstrations early in the coming year will reveal more about the successes or shortcomings of these activities and suggest ways to do more and better in the future. The project continues to have the potential to make great contributions to Mali and the region, and the project team looks forward to continuing the momentum built this year and reaching or exceeding the remaining goals and targets that were set for the project.

VIII. CAPACITY BUILDING

Training supported by AquaFish CRSP takes a number of forms, with perhaps the most important being short-term (non-degree) courses and long-term (degree) programs[14]. Short-term training most frequently occurs as seminars, workshops, and short-courses scheduled for periods of half a day to two or three weeks. Trainings focus on specific topics for stakeholders, which are integral to the project objectives. Long-term training encompasses academic programs for a BS, MS, or PhD degree at an accredited university located either in a Host Country or the US as well as high school and certificate programs.

SHORT-TERM TRAINING

During FY09, 47 short-term AquaFish CRSP training sessions for 1,499 trainees have been run under six core research projects[15] (39) and the Mali Assosiate Award Project (8). Of these, 13 training sessions were held in the Asian region (2 in Cambodia, 2 in Indonesia, 4 in the Philippines, 1 in Vietnam, and 4 in China), 19 were held in Latin America and the Caribbean (18 in Mexico, and 1 in Nicaragua), and 15 were held in Africa (7 in Mali, 1 in Ghana, 6 in Kenya, and 1 in Uganda) (Figure VIII-1). See Table VIII-5 at the end of this section for a full listing of trainings.

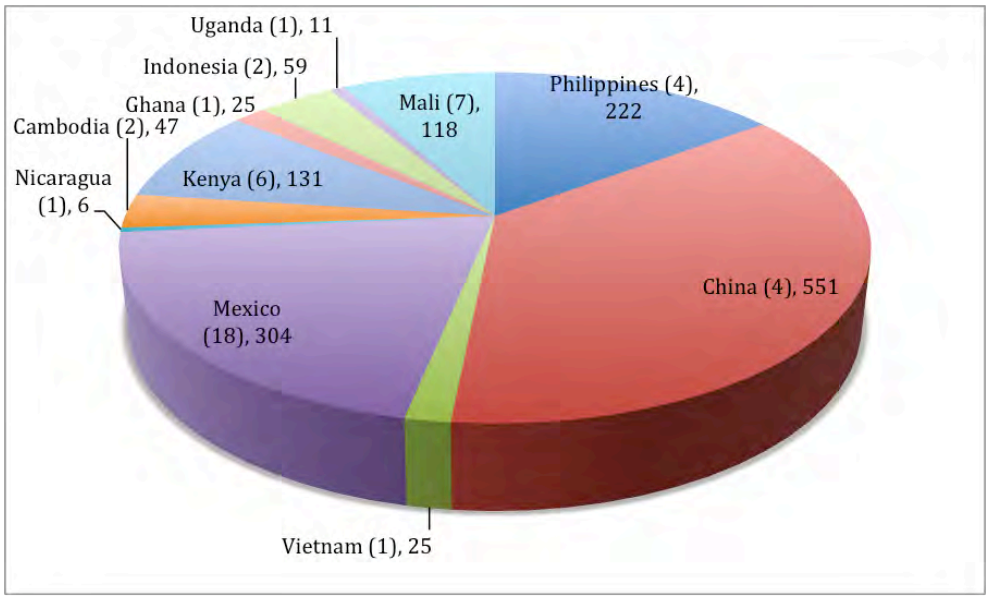

Figure VIII-1. Numbers of participants in AquaFish CRSP short-term training events in FY09, by country. Numbers in parentheses indicate number of short-term training events held in each country.

[14] Data in this report reflect the best information to date (i.e., data drawn from updated and revised project reports on FY09 training received as of February 2010). Therefore, they do not necessarily match metrics reported earlier on 1 November 2009 for the FY09 USAID EG and IEHA indicator reports (see pp. 173–183).

[15] The Auburn University core research project—*Hydrology, Water Harvesting, and Watershed Management for Food Security, Income, and Health: Small Impoundments for Aquaculture and Other Coummunity*—held no trainings in FY09.

Gender Distribution in Short-Term Training

The gender of 1,440 of the 1,499 short-term trainees was clearly indicated in reports received from the field. Of these, 458 (31.8%) were women and 982 (68.2%) were men. Table VIII-1 shows the gender distribution on a country basis.

Table VIII-1. Numbers and percentages of women short-term trainees participaing in FY09 AquaFish CRSP short-term trainings for which gender data were collected.

Country	Trainee Total	Number of Women	% Women
Cambodia	47	19	40.4
China	**551**	**165**	**30**
Ghana	**25**	**9**	**36**
Kenya	**131**	**30**	**22.9**
Mali	**118**	**7**	**5.9**
Mexico	**304**	**137**	**45.1**
Nicaragua	**6**	**6**	**100.0**
Philippines	**222**	**80**	**36.0**
Uganda	**11**	**1**	**9.1**
Vietnam	**25**	**4**	**16.0**
Total	**1,440**	**458**	**31.8**

At least one-third of all trainees were women in Cambodia (40.4%), Ghana (35.7%), Mexico (45.1%), Nicaragua (100%), and the Philippines (36%). All of those trained in Nicaragua were women, reflecting the fact that these trainings were focused specifically on the female heads of households in the communities where they were held. Lower percentages of women trained in events in Africa (Kenya 22.9%, Uganda 9.1%, and Mali 5.9%) largely reflect the fact that fish farming and fishing activities—the main focus of training events held in these countries—are traditionally undertaken by men, whereas women are typically involved in post-harvest activities such as processing and marketing. The composition of participants in training courses on pond construction, pond management, hatchery management, or fishery surveys would thus tend to include more men than women.

Short-Term Training for Participants from IEHA Countries

There were 284 IEHA-country nationals who received training this year, representing 22.7% of all short-term trainees. Trainings occurred in Ghana (1 course, 28 IEHA participants), Kenya (6 courses, 129 IEHA participants), Mali (7 courses, 118 IEHA participants), and Uganda (1 course, 11 IEHA participants. Eight short-term training sessions were conducted under the Mali Associate Award Project, with 122 Malian participants being trained, 118 were trained in Mali and the remaining 4 were trained in a course in Kenya. Seven training sessions were held by Purdue University with 160 Kenyan and Ghanaian participants.

For AquaFish CRSP trainings held prior to FY09, IEHA-country short-term trainees had been participants in the program-wide HCPI Exchange Project (Phase II), where they comprised 11.5% of all short-term trainees in the program. By contrast, all FY09 IEHA participants were trained under activities of either core or associate award projects and the IEHA percentage of all short-term trainees grew significantly from 11.5% to 18.9%.

LONG-TERM TRAINING

Since the inception of the AquaFish CRSP, a total of 187 long-term students have been supported, including 94 men and 93 women (50.3 and 49.7 % respectively), for an almost 50:50 balance[16]. In FY09, the AquaFish CRSP supported the long-term training programs of 169 degree program students. These students represent 19 countries[17], including Cambodia, China, Ecuador, El Salvador, Ghana, Guyana, India, Indonesia, Ivory Coast, Kenya, Mali, Mexico, Micronesia, Nepal, Nicaragua, the Philippines, Tanzania, the U.S., and Vietnam. The distribution of these students by nationality is as shown in Figure VIII-2 and Table VIII-2. For a full listing of students, see Table VIII-6 at the end of this section.

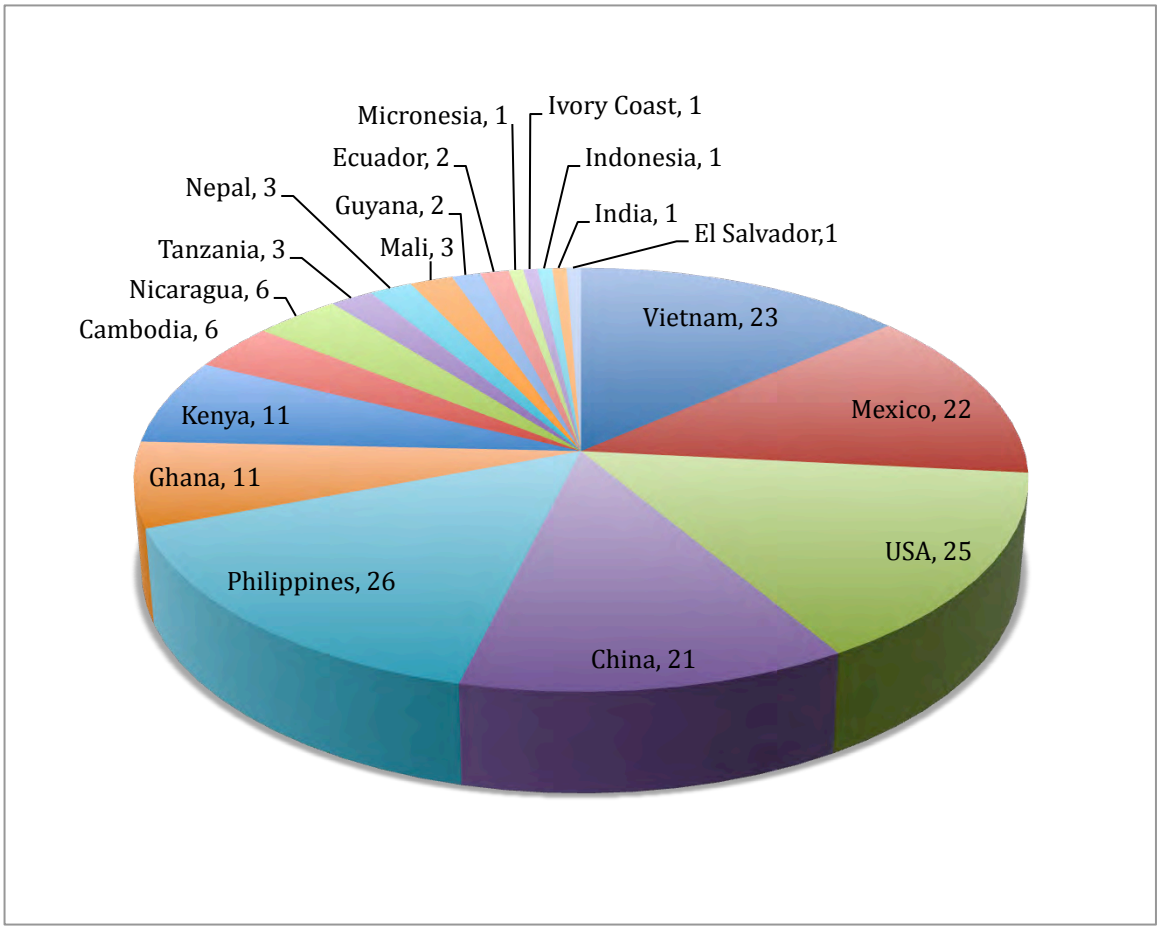

Figure VIII-2. Numbers of students supported by the AquaFish CRSP in FY09, by nationality. The greatest numbers of students were from Vietnam (23), Mexico (22), China (21), the US (25), and the Philippines (26).

[16] Students are reported for the six core projects under the *Implementation Plan 2007–2009*, Mali Associate Award, the OSU Synthesis Project, and the Program Management Office. Student enrollment information for the Auburn University IEHA project was not yet available.

[17] Included in the count of 19 countries are 5 which are not among those specifically targeted in the core and Associate Award projects — Ecuador (2 UH students), El Salvador (1 UH student), India (1 PMO student), Ivory Coast (1 PU student), and Micronesia (1 UH student).

FY09 AquaFish CRSP Long-Term Students

On a regional basis, 81 of the program's long-term students (47.9%) are from Asia[18] and the Pacific, 33 (19.6%) are from Latin America and the Caribbean, 29 (17.3%) are from Africa, and 25 (14.9%) are from the US. On a project basis, 35 (20.7%) are engaged under the North Carolina State University lead project, 27 (16%) under the Purdue University lead project, 23 (13.6%) under the University of Arizona lead project, 25 (14.8%) under the University of Michigan lead project, 27 (16%) are through the University of Connecticut lead project, 20 (11.8%) under the University of Hawaii at Hilo project, and 12 (7%) under projects led by Oregon State University (3 under the Mali Associate Award Project, 1 with the Synthesis Project, and 8 in the Program Management Office).

Table VIII-2. Numbers and percentages of long-term students supported by the AquaFish CRSP in FY09, by nationality.

Nationality	Number of Students	Percent of Total	Number of Men	% Men	Number of Women	% Women
Vietnam	23	13.6	16	69.6	7	31.8
Mexico	22	13	15	68.2	7	31.8
USA	25	14.8	12	42.9	13	52
China	21	12.4	8	38.1	13	61.9
Philippines	26	15.4	10	38.5	16	61.5
Ghana	11	6.5	6	54.5	5	45.5
Kenya	11	6.5	6	54.5	5	45.5
Cambodia	6	3.6	2	33.3	4	66.7
Nicaragua	6	3.6	2	33.3	4	66.7
Tanzania	3	1.8	2	66.7	1	33.3
Nepal	3	1.8	2	66.7	1	33.3
Mali	3	1.8	2	66.7	1	33.3
Guyana	2	1.2	2	100.0	0	0.0
Ecuador	2	1.2	2	100.0	0	0.0
Micronesia	1	0.6	1	100.0	0	0.0
Ivory Coast	1	0.6	0	0.0	1	100.0
Indonesia	1	0.6	0	0.0	1	100.0
India	1	0.6	1	100.0	0	0.0
El Salvador	1	0.6	1	100.0	0	0.0
Total	169	100	90	53	79	47

Degrees Sought by AquaFish CRSP Students

Student enrollment in degree programs currently supported under the AquaFish program are shown in Figure VIII-3: 75 students are seeking bachelor's degrees (44.4%), 73 students are seeking working master's degrees (43.2%), 18 students are seeking doctorates (10.7%). There are also 3 high school or "certificate" students (1.8%).

Gender Distribution of Long-Term AquaFish CRSP Students

Overall the program supported the training of 79 women and 90 men during FY09, for a close-to 50% ratio (46.7% and 53.3%, respectively).

[18] The PMO student from India is not included in this count. See Table VIII-6.

Among students seeking BS degrees, 41 are men (54.7%) and 34 are women (45.3%); among MS candidates, 37 (50.7%) are men and 36 (49.3%) are women; and among those seeking PhD's, 10 (55.6%) are men and 8 (44.4%) are women. Of the 3 students classified as "other" (high school or "certificate" students), 2 are men (66.7%) and 1 (33.3%) is a woman (Figure VIII-3).

Among the 81 long-term students from Asia, 39 (48.1%) were men and 42 (51.9%) were women. In Latin America and the Caribbean, 22 (66.7%) of the 33 students were men and 11 (33.3%) were women; in Africa 15 of the 29 were men (51.7%) and 14 (48.3%) were women, and among the 25 US students,12 (48%) were men and 13 (52%) were women.

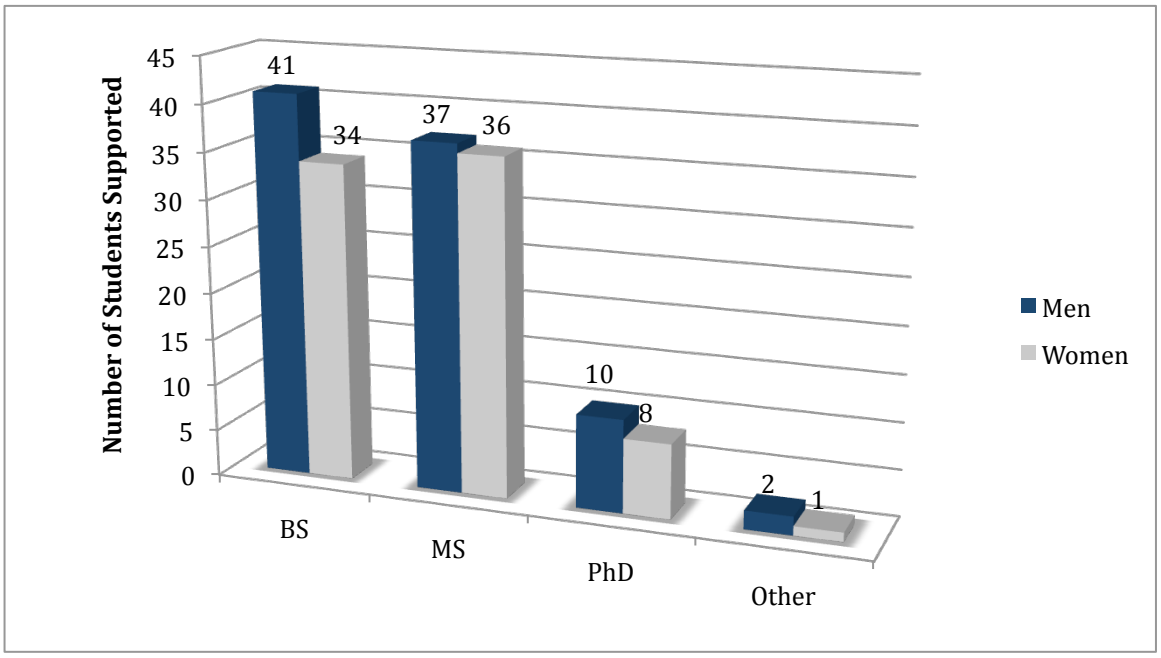

Figure VIII-3. Numbers of all AquaFish CRSP students seeking BS, MS, PhD, and "other" degrees supported during FY09, disaggregated by gender. Students classified as "other" are high school or "certificate" students.

With respect to students supported through each of the AquaFish projects, 19 of 35 students (55.9%) sponsored through the NCSU project are women, 12 of 27 students (44.4%) supported by the Purdue project are women, 7 of 23 students (30.4%) supported through the University of Arizona project are women, 10 of 27 students (37%) through the University of Connecticut project are women, 9 of 20 (45.0%) of those supported through the University of Hawaii at Hilo project are women, 14 of 25 (56%) of those sponsored through the University of Michigan project are women, and 8 of 12 (66.7%) of those supported through Oregon State University are women (Table VIII-3).

Table VIII-3. Numbers and percentages of long-term training participants who are women in AquaFish CRSP core and Associate Award projects.

US Lead Institution	Total Students	Number of Women	% Women
North Carolina State University	35	19	54.3
Purdue University	27	12	44.4
University of Arizona	23	7	30.4
University of Connecticut–Avery Point	27	10	37
University of Hawaii at Hilo	20	9	45.0
University of Michigan	25	14	56.0
Oregon State University	12	8	66.7
Mali Associate Award Project	3	1	33.3
Synthesis Project	1	1	100.0
Program Management Office	8	6	75.0
Total	169	79	47.0

Long-Term Training in IEHA Countries

Of the 29 students from African countries (17.3% of all long-term trainees), 25 (86.2%) were from IEHA countries (Kenya, Ghana, and Mali). Among these 25 students, 11 (44%) were women and 14 (56%) were men. Additionally, 13 (52%) are seeking BS degrees, of which 6 (46.2%) are women and 7 (53.8%) are men, and 12 (48%) are seeking MS degrees, of which 5 (41.7%) are women and 7 (58.3%) are men.

New Students in FY09

This year 40 new CRSP-supported students were enrolled, 34 of whom were taken on by the six core research projects. Of the 40 students, 21 were male (52.5%) and 19 were women (47.5%). Of these new students, there were 8 from Vietnam (22%), 7 from Ghana (17.1%), 7 from the US (17.1%), 5 from Nicaragua (12.2%), 4 from China (9.8%), 3 from Mali (7.3%), 2 from the Philippines (4.9%), and 1 each from Cambodia (2.4%), Micronesia (2.4%), Indonesia (2.4%), and Tanzania (2.4%). Ten (25%) of the new students were from IEHA countries, 3 (30%) from Mali and 7 (70%) from Ghana. Two new students were taken on by the North Carolina State University project, 9 by the Purdue Project, 2 by the University of Arizona, 9 by the University of Connecticut-Avery Point, 9 by the University of Hawaii at Hilo, 3 by the University of Michigan project, and 6 by Oregon State University (3 at OSU and 3 under the Mali Project).

Long-Term Programs Completed in FY09

AquaFish CRSP-supported training for 63 students was completed during the reporting year. These students included 32 women (50.8%) and 31 men (49.2%).

OUTCOMES AND IMPACTS OF AQUAFISH CAPACITY BUILDING EFFORTS

In its core research projects and the Mali Associate Award, AquaFish CRSP has achieved a number of notable accomplishments in its capacity building efforts during the reporting period:

- Each of the original six core projects[19] has fully developed the partnerships needed for collaborative work on capacity building. MOUs are in process for the new IEHA project with Auburn University. The three RCEs have also established additional linkages and partnerships with regional and international organizations and institutions. A three-year Associate Award with the USAID Mission in Mali (1 October 2007 – 30 September 2010) for an aquaculture and fisheries project in Mali has entered its third year, with partnerships established with institutions located in Mali, Kenya, and China.

- As of the end of this reporting year, a cumulative total of 187 long-term students have enrolled in long-term training programs. For FY09, 169 long-term students received CRSP support through the core research projects (160), the Mali Associate Award (3), the Synthesis Project (1), and the Management Office (8). The majority of these FY09 students are Host Country nationals (138) studying in their home countries or the US. Their regional distribution[20] largely reflects the concentration of projects: 28 students for Africa with one core research project and the Mali Associate Award; 80 students for Asia with three core research projects; and 30 students for Latin America with 2 core research projects.

- Cumulative HC-only enrollment is 154 students for the core research projects and the Mali Associate Award Project (77 women/77 men). For FY09, it is 138 students (65 women/73 men). The majority of HC-only FY09 women students are from Asia (64%) with the largest numbers from the Philippines (15) and China (13).

- Overall when combining all country data, the CRSP is very close to the long-term training 50% target of women students.[21] For this reporting period, women represent 49.7% of the cumulative student enrollment (93 women/187 total students). Adjusting the data for HC-only students, the gender ratios are similar with a cumulative enrollment of 50% for women. In FY09, enrollment of women students dropped to 47% due in part to degree completion by 12 women and 4 men students in FY08.

- The gender data reflect the challenges of bringing women into aquaculture, particularly in countries such as Kenya and Mali where they have traditionally been involved mainly with post-harvest activities. The increasing role of women graduates in academic, entrepreneurial, and governmental positions as well as their visibility in trainings and through community and regional involvement is helping to influence enrollment of women students in degree programs. With continued emphasis on gender integration in the *Implementation Plan 2009-2011*, the number of women students is expected to reach the targeted 50% in CRSP countries located in Africa and Latin America.

---

[19] The original six core projects, which are led by North Carolina State University, Purdue University, University of Arizona, University of Connecticut–Avery Point, University of Hawai'i at Hilo, and University of Michigan, initiated their work during FY07. The seventh core project led by Auburn University began in August 2009.
[20] Students from non-CRSP countries are not treated as Host Country nationals in this tally, i.e., students from Ecuador (2), El Salvador (1), India (1), Ivory Coast (1), and Micronesia (1).
[21] Students are reported for the six original core projects under the *Implementation Plan 2007–2009,* Mali Associate Award, the OSU Synthesis Project, and the Program Management Office.

- Short-term trainings are designed to integrate stakeholders at all levels, thereby removing barriers such as those between farmers/fishers and extension agents/fisheries officers. Trainings are also designed to empower trainees to "train" their counterparts. This integrated approach is illustrated by these examples of training approaches and successes:

    - 07HHI03UH; 07HHI04UH (Mexico): By targeting two workshops on sanitation and shellfish culture at a wide audience of stakeholders, the UHH project created an opportunity for the various stakeholders to establish linkages. This integrated approach has helped to open communication channels among stakeholders, a positive step toward strengthening the important working relationship among farmers, policy makers, service providers, researchers, and business.

    - 07QSD02PU (Kenya): Successful baitfish farmer trainees helped train other farmers interested in baitfish production and the cluster enterprise system. They also assisted the Women in Fishing Industry Project, a project collaborator, in training women in pond construction and catfish breeding.

    - 07SFT04AU (Guyana): Members of the Trafalgar Union Women's Cooperative for Tilapia participating in a feed formulation workshop have been able to broaden the reach of the the training by transferring their experience to fellow members of cooperative.

    - 07TAP01UC (Cambodia): A Training of Trainer workshop was held for 21 farmers, Fisheries Officers, and Extension Agents to train them in alternative formulated feed practices for snakehead farming. Farmers and government trainees will play an instrumental role in transfering this sustainable feed technology in the second phase of the University of Connecticut – Avery Point project on sustainable fisheries and aquaculture in the Lower Mekong River Basin.

    - Mali Associate Award, Theme I: Seydou Toé, a Malian trainee who participated in pond culture workshops held in February and April in Bamako, Mali and Sagana, Kenya, helped the project conduct a June Theme I training. Mr. Toé assisted by supervising his colleagues in building a catfish hatchery at the Centre de Formation Pratique en Élevage in Bamako for the June training and then explaining construction techniques and propagation of catfish during the training.

- Training metrics collected for DTAP reporting illustrate another facet of training integration whereby short-term trainees are benefitting from the multi-disciplinary focus in trainings where technologies, practices, or marketing strategies are combined with issues carrying environmental impacts. As illustrated in Table VIII-5, quite a number of AquaFish CRSP short-term trainings have combined the new technology element of DTAP B with environmental management elements of DTAP C (see p. 139 and Table VIII-5).

PROFESSIONAL CONFERENCES & SYMPOSIA

Another capacity building function of the CRSP is its provision of support to PIs, degree students, and others so that they can attend national and international conferences and symposia. Conference attendance is most frequently associated with the *Aquaculture America* and *World Aquaculture* meetings sponsored by the World Aquaculture Association (WAS) and other organizations, including the CRSP. Other relevant meetings that CRSP participants have attended in the past include various regional meetings (e.g., those of the Asian Fisheries Society, the Latin America and Caribbean Chapter of WAS (LACC-WAS), and the Aquaculture

Association of Southern Africa) and internaional symposia and conferences (e.g., International Symposium on Tilapia in Aquaculture (ISTA) series; International Institute of Fisheries Economics & Trade (IIFET) conferences). Attendance at these meetings constitutes an extremely valuable capacity building experience for the participants, regardless of their nationality or institution affiliation.

International and regional conferences offer CRSP researchers access to technical information on aquaculture and fisheries topics as well as opportunities to meet other professionals who are conducting research, training students, or carrying out extension activities (Table VIII-4). Students who attend these conferences often do so because they are ready to report on the results of the research they did as part of their graduate programs. Many are able to present their first scientific paper and experience their first professional conference because of this support from the CRSP.

AquaFish CRSP typically plans its annual meetings to coincide with a professional conference so that participants can attend both on a single trip. Gathering CRSP participants together at annual meetings provides them with the opportunity to meet other project participants, learn what is being done in other CRSP projects and countries, compare notes on what works and what does not work in their respective research, training, and extension efforts, and of course discuss overall program goals and progress.

Table VIII-4. Regional, national, and international conferences attended by US and HC project personnel during FY09.*

Event	Location	Date
•PhilFIN Conference & General Assembly	Quezon City, Philippines	10/2008
• 4th International Workshop on Sustainable Asia	Wuhan, China	10/2008
• 8th International Symposium on Tilapia Aquaculture (ISTA8)	Cairo, Egypt	10/2008
• Luzon Zonal Philippine Association ofr Graduate Education Convetion	Science City of Muñoz, Nueva Ecija, Philippines	11/2008
• International Symposium on Current Research Trends in Fisheries Biology	Science City of Muñoz, Nueva Ecija, Philippines	01/2009
• Society of Integrative & Comparative Biology	Boston, MA, USA	01/2009
• Aquaculture America 2009	Seattle, WA, USA	02/2009
• Visayas Fisheries Forum	Iloilo City, Philippines	03/2009
• 1st & 2nd Regional Seminar on Mekong Integrated Water Resource Management	MRC, Lao PDR	03/2009
• Shrimp Industry Development Forum of China	Zhanjiang, China	04/2009
• SUCCESS Program Closing Event	Chinandega, Nicaragua	04/2009
• 21st Agency in-House review of Completed and On-Going Research and Development Projects	Science City of Muñoz, Nueva Ecija, Philippines	05/2009

Table VIII-4. Regional, national, and international conferences attended by US and HC project personnel during FY09.*

Event	Location	Date
• ASEAN-SEAFDEC Regional Consultation on Emerging Regional Fisheries Policy Issues	Bangkok, Thailand	07/2009
• World Food Prize	Des Moines, IA, USA	09/2008
• Second Meeting of the Regional Advisory Committee on Fisheries Management in Southeast Asia	Bangkok, Thailand	09/2009
•World Aquaculture 2009	Veracruz, Mexico	09/2009
•Ecological Health Monitoring	Udon Thani, Thailand	09/2009
Celebration of Earth Day	Asseradores, Nicaragua	04/2009
• Small Entrepreneurs Conference	Managua, Nicaragua	2009

*Table based on data received from PIs as of October 2009.

Professional-Level Capacity Building Activities

In addition to conference attendance by AquaFish CRSP researchers, four professional level workshops and meetings were organized and conducted during the reporting period. Three of these targeted the international research community, bringing together researchers with common interests in tilapia aquaculture (ISTA8), marine algae (World Aquaculture 2009 workshop), and aquaculture development for the poor (AA09, Seattle). The fourth provided researchers affiliated with the University of Michigan project an opportunity to gather together to review project accomplishments and plan for future steps. Highlights of these activities follow:

- Through the University of Arizona project, AquaFish CRSP co-sponsored the 8th International Symposium on Tilapia in Aquaculture (ISTA8) held in Cairo, Egypt on 12–14 October 2008. There were approximately 500 attendees, of which one-fifth were women. Many US and HC tilapia researchers from Africa, Asia, and Latin America attended the symposium. Papers for the 112 technical presentations are included in the 2-volume symposium proceedings. — 07TAP03UA

- The 2nd International Workshop on the Cultivation and Biotechnology of Marine Algae was held on 29 September at the 2009 World Aquaculture Society Meetings in Veracruz Mexico. Oral and poster presentations covered a range of topics from biology, biodiversity, alginic acid extraction, feed alternatives, industrial applications, culture and production, and growth models. A website will be set up with downloadable files of presentations. The workshop was successful in providing the opportunity for researchers to develop linkages. As immediate outcomes, a similar workshop was held at the November 2009 Asia-Pacific Aquaculture Meeting in Kuala-Lumpur, Malaysia and plans are in process for a Guyana workshop in 2010. — 07BMA03UA

- A full-day session at Aquaculture America 2009 (AA09), in Seattle, Washington, USA on 16 February 2009 brought together 12 presentations covering Asia, Africa, and South and

Central America. The session's topic "International Aquaculture Development for the Poor" naturally drew presentations on CRSP research, but also drew good presentations on other international efforts. A capacity audience (approximately 100 scientists) came away with an indication of the breadth of aquaculture research and develoment underway in poorer countries. The session was organized by Oregon State University's ME.

- The University of Michigan's project "Workshop on Aquaculture, Human Health, and Environment," held 7–10 July 2009, brought faculty, students, and staff together from other all the project institutions as well as the World Wildlife Fund to review their project progress, discuss future plans, and consider the relationship between their research program and needs within China, Nepal, and Vietnam. Attendees produced a list of 26 research priorities and each voted for his/her top two priorities. Results ranked priorities as follows: (1) water quality and effluents; (2) microcystins, and (3) by a three-way tie — (a) sediment management, (b) species introductions and impacts on indigenous species, and (c) quality of seed in hatchery management. These research priorities were used to prepare cross-regional proposals for the University of Michigan's Continuation Plan for research under the AquaFish CRSP *Implementation Plan 2009-2011*. — 07MNE07UM

Table VIII-5. FY09 Short-term trainings for core research projects and the Mali Associate Award

Project	Investigation Code	Event Name	Country	Start Date	End Date	Trainees Total	Trainees Female	Trainees Male	DTAP Indicator†
NCSU	07MNE02NC	On-site Lecture Forum on Kappaphycus	Philippines	2008-11-10	2008-11-11	47	16	31	C-04
NCSU	07MNE02NC	Kappaphycus 'cottonii' Seaweed Biology and Culture	Philippines	2008-11-10	2008-11-11	44	15	29	C-04
NCSU	07MNE02NC	Workshop on Seaweed Culture and Tilapia-Shrimp Polyculture	Philippines	2009-01-15	2009-01-16	47	20	27	C-04
NCSU	07MNE02NC	Soft-shell crab farming training	Indonesia	2009-07-21	2009-07-21	17*	–	–	C-04
NCSU	07MNE02NC	Soft-shell crab farming training	Indonesia	2009-07-23	2009-07-23	42*	–	–	C-04
NCSU	07TAP02NC	Tilapia Podcast Workshop	Philippines	2009-01-12	2009-01-13	84	29	55	B-03
PU	07MER02PU	Fish Farmers Workshop: Training in Fish Supply Chain and Marketing	Kenya	2009-06-15	2009-06-15	30	8	22	B-03
PU	07MER02PU	Training in Fish Supply Chain and Marketing of farmed Fish	Ghana	2009-06-22	2009-06-22	25	9	16	B-03
PU	07QSD02PU	Catfish Bait Producers Training	Kenya	2009-01-21	2009-01-21	23	3	20	B-03
PU	07QSD02PU	Catfish Bait Producers Training	Kenya	2009-01-23	2009-01-23	33	9	24	B-03
PU	07QSD02PU	Catfish Bait Producers Training	Kenya	2009-03-10	2009-03-10	11	1	10	B-03
PU	07QSD02PU	Catfish Farmers Training	Uganda	2009-04-08	2009-04-11	11	1	10	B-03
PU	07QSD02PU	Fish Farmers Workshop: Development of Small Scale Fingerlings as Baitfish	Kenya	2009-06-14	2009-06-14	30	8	22	B-03
UA	07HHI02UA	Recirculating Aquaculture	Mexico	2009-09-22	2009-09-24	27	9	18	B-03,C-04
UA	07IND02UA	Native Cichlid Farmers Training	Mexico	2009-03-18	2009-03-19	15	6	9	B-03
UA	07IND02UA	Native Cichlids Training	Mexico	2009-04-01	2009-04-01	12	0	12	B-03

Table VIII-5. FY09 Short-term trainings for core research projects and the Mali Associate Award

Project	Investigation Code	Event Name	Country	Start Date	End Date	Trainees Total	Trainees Female	Trainees Male	DTAP Indicator†
UA	07MNE06UA	MT-Elimination Public Extension Workshop	Mexico	2008-11-18	2008-11-19	33	13	20	B-03,C-04
UA	07MNE06UA	MT-Elimination Public Extension Workshop	Mexico	2009-06-10	2009-06-12	20	8	12	B-03,C-04
UA	07MNE06UA	MT-Elimination Public Extension Workshop	Mexico	2009-07-07	2009-07-07	20	10	10	B-03,C-04
UC	07TAP01UC	Farmers Training of Trainers Workshop	Cambodia	2009-09-10	2009-09-10	26	11	15	B-03
UC	07TAP01UC	Farmer Field School Training	Cambodia	2009-09-24	2009-09-24	21	8	13	B-03
UHH	07HHI04UH	Regional Workshop on Bivalve Culture and Sanitation	Mexico	2009-09-28	2009-09-29	43	7	36	B-03,C-04
UHH	07HHI05UH	Monitoring of water and Anadara spp. tissue in six sites at the Estuary of Aserradores, Chinandega, Nicaragua.	Nicaragua	2008-10-22	2008-10-22	6	6	0	B-03,C-04
UHH	07IND03UH	Prospeccion para colecta de semilla de ostion	Mexico	2008-10-18	2008-10-18	3	0	3	B-03,C-04
UHH	07IND03UH	Spat and data collection	Mexico	2008-10-25	2008-10-25	3	0	3	B-03,C-04
UHH	07IND04UH	Spat collection visit to culture sites	Mexico	2008-10-18	2008-10-18	20	13	7	B-03,C-04
UHH	07IND04UH	Farm visits and spat collection	Mexico	2008-10-24	2008-10-24	15	10	5	B-03,C-04
UHH	07IND04UH	Data collection	Mexico	2008-11-19	2008-11-19	15	10	5	B-03,C-04
UHH	07IND04UH	Data collection	Mexico	2008-12-19	2008-12-19	10	7	3	B-03,C-04
UHH	07IND04UH	Data collection	Mexico	2009-01-30	2009-01-30	10	7	3	B-03,C-04
UHH	07IND04UH	Data collection	Mexico	2009-02-25	2009-02-25	15	10	5	B-03,C-04
UHH	07IND04UH	Data collection	Mexico	2009-03-27	2009-03-27	15	10	5	B-03,C-04
UHH	07IND04UH	Wrap-up workshop	Mexico	2009-05-29	2009-05-29	25	16	9	B-03,C-04
UHH	07WIZ02UH	Field trip to sampling area	Mexico	2008-10-05	2008-10-05	3	1	2	B-03,C-04

Table VIII-5. FY09 Short-term trainings for core research projects and the Mali Associate Award

Project	Investigation Code	Event Name	Country	Start Date	End Date	Trainees Total	Trainees Female	Trainees Male	DTAP Indicator†
UM	07MNE03UM	Alien-Indigenous Species Workshop-China-1	China	2009-03-12	2009-03-12	108	43	65	B-03
UM	07MNE03UM	Alien-Indigenous Species Workshop-China-2	China	2009-05-30	2009-05-30	93	38	55	B-03
UM	07MNE03UM	Alien-Indigenous Species Workshop-Vietnam-1	Vietnam	2009-07-25	2009-07-25	25	4	21	B-03
UM	07MNE04UM	Shrimp Waste Management Workshop	China	2009-03-01	2009-03-01	250	62	188	C-04
UM	07MNE04UM	Carp Polyculture Waste Management Workshop	China	2009-05-22	2009-05-22	100	22	78	C-04
				Project Trainee Total		**1391**	**453**	**879**	
Mali AA	Theme I	First Pond Culture Workshop in Mali	Mali	2009-02-02	2009-02-06	24	3	21	na‡
Mali AA	Theme I	First Pond Culture Workshop in Kenya - Catfish propagation and hatchery management	Kenya	2009-04-06	2009-04-17	4	1	3	na
Mali AA	Theme I	Second Pond Culture Workshop in Mali - Catfish propagation and hatchery management	Mali	2009-06-21	2009-07-03	22	2	20	na
Mali AA	Theme I	Pre-On-farm Trials workshop for technical staff/supervisors	Mali	2009-06-29	2009-06-29	5	0	5	na
Mali AA	Theme I	Pre-On-farm Trials workshop for supervisors and participating farmers	Mali	2009-06-30	2009-06-30	15	1	14	na
Mali AA	Theme III	First Fisheries Management Workshop (Frame Survey Training for Supervisors), Mali	Mali	2009-02-09	2009-02-10	11	0	11	na
Mali AA	Theme III	First Fisheries Management Workshop (Frame Survey Training	Mali	2009-02-11	2009-02-12	20	0	20	na

Table VIII-5. FY09 Short-term trainings for core research projects and the Mali Associate Award

Project	Investigation Code	Event Name	Country	Start Date	End Date	Trainees Total	Trainees Female	Trainees Male	DTAP Indicator†
		for Enumerators), Mali							
Mali AA	Theme II	Up-to-date techniques for rice-fish culture in China	Mali	2009-06-26	2009-06-26	21	1	20	na
					Associate Award Trainee Total	**122**	**8**	**114**	
					Total FY09 Trainees	**1513**	**461**	**993**	

*Gender information for trainees attending the two July 2009 soft-shell workshops (07MNE02NC) was not available. Therefore, those 59 trainees for the soft shell crab workshops were dropped from the overall trainee total for calculating gender ratios. See pp. 99-100.

† Short-term training metrics for the DTAP indicators B-02 (Number of people trained in use of technological practices) and C-03 (Number of people trained in practices that promoted soil conservation and/or improved water quality) were captured within the short-term training data submitted by core project PIs.

‡There is no reporting under DTAP by the Mali Associate Award project.

IX. SYNTHESIS

Oregon State University's vision for the AquaFish CRSP brings together highly creative and knowledgeable people in functional advisory groups. Advisory groups provide linkages to the broad global community engaged in aquaculture and fisheries development issues. This innovative structure evolved from past ACRSP structure, as originally envisioned by BIFAD (Board for International Food & Agricultural Development). A flexible structure allows a common organizational framework to emerge across all CRSPs as they are re-competed and re-organized. Commonalities can lead to cost-saving standardization and facilitated management by USAID, as well as amplification of benefits across focal areas and themes. Technical advisory groups (RCE and DTAP) have responsibility for synthesizing information across regions and themes. A Synthesis Project has responsibility for providing metadata analysis and broad evaluative syntheses.

DEVELOPMENT THEMES ADVISORY PANELS (DTAP)

DTAP provides technical advice on emerging issues and gaps in the portfolio from a thematic perspective. The four panels are aligned with the four themes mentioned in the Program Description. Lead Coordinators of the thematic panels assist the ME in integrating cross-cutting needs identified by USAID, but adding additional emphases on conserving biodiversity; preventing further degradation of aquatic ecosystem health; reducing poverty among small-scale farmers and fishers; maintaining and restoring capture fisheries productivity; developing IPM strategies; improving soil-and-water quality; and using biotechnology approaches cautiously. The Lead Coordinators are also responsible for writing annual reports, assisting the ME in evaluating workplan changes, performing assessments, and working together to provide quality information for thematic synthesis and lessons learned reporting. The DTAP can recommend policies for technical hot-topics, e.g., certification for organic standards, biotechnology applications, and toxics standards for fish consumption.

The following reports cover progress to date on accomplishments that are measured by the DTAP thematic impact indicators. Investigation reports on DTAP Indicators are included in *Monitoring & Evaluation* (Tables X-1 to X-8).

DTAP A: Improved Health and Nutrition, Food Quality, and Food Safety of Fishery Products

Printed as Submitted by Maria Haws (University of Hawai'i at Hilo), Lead Coordinator

Up to 50% of the world's seafood supply may be lost or decreased in value due to poor production and post-harvest practices. Aquaculture now accounts for at least 50% of the world's aquatic products supplies. There is also a strong relationship between environmental quality, aquaculture practices, and product quality/safety. Additionally, some of the world's most vulnerable demographic segments are particularly dependent upon aquaculture and fisheries for food. These same groups are also the most vulnerable to foodborne illnesses and

economic losses when products are affected by decomposition or contamination or harbor pathogens. Improving the quality, safety, and availability of aquaculture products is crucial for improving food security, assuring that aquatic products are produced in a sustainable and safe manner, and increasing economic benefits to all stakeholders.

Several of the CRSP projects have made significant advances towards addressing specific issues related to this theme. Utilization of bycatch and low-value fisheries products is a global issue, particularly when considered in the context of aquaculture which depends on fishmeal or whole, low-value fish as feed, particularly for carnivorous species. The University of Connecticut-led project in Vietnam and Cambodia has made significant advances in researching the dynamics of the use of low-value fish and developing alternative uses and markets for these species. This not only improves the long-term sustainability of aquaculture and fisheries, but provides additional economic benefits for a wide range of stakeholders.

Shellfish sanitation is an emerging issue of concern in many developing nations as human populations become more vulnerable to shellfish-borne diseases and as ecosystem degradation impacts shellfish quality. Since 2004, efforts in Mexico and Nicaragua have focused on certifying shellfish growing grounds and developing simple methods of shellfish depuration that can be adopted by local communities and responsible agencies. Responsible agencies are now taking steps to certify shellfish growing grounds and producers are experimenting with relay/depuration techniques to be able to sell certified shellfish products. Similar environmental and human health outcomes are being achieved by the University of Michigan-led project in China and Southeast Asia in which methods are being developed to reduce microcystins in tilapia and catfish. Detection and reduction of microcystins will improve both fish, livestock, and human health. Additionally, the ability of aquaculturists to produce aquatic products which are free from pathogens, toxins, and parasites not only has direct impacts on human health, but increases the positive perception of consumers, both locally and internationally. Many developing countries stand to benefit from the ability to develop wider internal markets as well as export markets if product safety and quality can be assured.

DTAP B: Income Generation for Small-Scale Fishers and Farmers

Printed as Submitted by Kwamena Quagrainie (Purdue University), Lead Coordinator

Transformations in fish farming, especially in the developing world require improvements in technology, production practices, and management. A key factor to growing the aquaculture industry in rural areas is the domestic capacity to develop and extend locally-adaptable technologies. Consequently, the Aquafish CRSP projects were targeted at developing technologies for adoption in rural communities to enhance local fish and shellfish production capacity and aquatic resource management. The technologies developed focused on improving the genetics and culture of native species, efficiencies in fish production management, and health and safety of aquatic products and developing low-cost and affordable feed and effective outreach.

For shellfish, emphasis was placed on developing various techniques for depuration that maximized the natural filtering activity to enhance food safety. This helps to address some public health issues associated with shellfish consumption. The improved shellfish sanitation technologies would result in better product quality that will attract higher product prices and expanded markets for coastal communities.

A major area of the program focused on developing feed technology and optimal feeding strategies. Several projects investigated replacing fishmeal with alternative, local sources of protein from plants and animal and plant waste materials. There are still knowledge gaps in aquaculture nutrition, and perhaps more important is the development of low cost and affordable feed utilizing local feedstuffs. Feed constitutes a significant proportion of production cost in aquaculture, ranging from 40 – 80% of operational costs. Improved feed technologies helped small-scale fish farms to obtain higher productivity with reduced feed costs. Optimal feeding strategies also contributed to reduced production costs ensuring economic sustainability and minimal environmental impact of fish culture. Other technologies developed to minimize environmental externalities from fish culture included techniques to clean tilapia masculinization, low-cost UV systems that ensure the safe use of effluents as irrigation water, and different hatching systems for tilapia fry production. The technologies developed were necessary for a sustainable and profitable fish farming industry in the targeted regions.

Technology was also developed for an effective outreach to stakeholders that enabled greater adoption of technologies. Podcasting was developed as an extension tool to disseminate information to the aquaculture industry in the Philippines. With increased Internet access in developing countries, podcasting can be an effective tool for communicating aquaculture news and technological advancements to stakeholders.

DTAP C: Enviromental Management for Sustainable Aquatic Resources Use

Printed as Submitted by James S. Diana (University of Michigan), Lead Coordinator

Aquaculture uses significant natural resources to convert energy into the production of a fish crop and, at the same time, disposes of waste products through water or solid waste that is produced in the culture system. It also converts landscapes to something different from the natural landscape and is more akin to agricultural fields. All of these transformations are concerns related to aquaculture and require management to move toward more sustainable resource use. Environmental management includes not only minimizing resource inputs, such as feeds, fertilizers, and water, but also reducing nutrient loads in outflows. In addition, environmental management includes understanding the effects of escaped organisms on native ecosystems. The Aquafish CRSP has been working in all of these areas, and this research has involved an assessment of current methods and an evaluation of future options to improve the environmental impact of aquaculture systems.

One method to improve environmental impact of aquaculture is to reuse water or reduce nutrient levels in effluents. A project in Mexico by the University of Arizona, focuses on using aquaponics as a means to reuse water. This project has developed a recirculating aquaculture system, which re-utilizes the fish effluent and eliminates discharge. The water that is eventually discharged is used for irrigation. The project is also training local women and men on these methods. Similarly, a project in the Philippines by North Carolina State University is focusing on seaweed polyculture as a means to remove nutrients from shrimp culture ponds. This technology reduces the pollution burden in ponds and in effluents discharged. Also, as nutrients are retained in other crops, there is less need for flushing of the pond. Finally, a project in China by University of Michigan is surveying methods to manage ponds, then providing workshops for local Chinese women and men to learn technologies that reduce nutrient burdens.

The Aquafish CRSP has also actively evaluated natural aquatic systems and the effects of alien species on their function. In Zhange Reservoir, China, the introduction of Taihu icefish has

resulted in major changes in the fish community, in particular, increases in the populations of predatory culters. These culters are important fish that are harvested from the lake, and now the icefish has become an important prey item in this ecosystem. Coupled with this change has been the loss of another top predator, the yellow cheek, as well as increases in a planktivore, the bighead carp. Conditions in the reservoir have changed dramatically, in part due to aquaculture, but also to other kinds of human influences there. Similar studies in Tri An Reservoir, Vietnam have shown that introduction of tilapia has resulted in an increase in the reservoir fishery and some changes in the overall community that remains. Thus, invasive species have had positive fishery effects but also negative ecosystem effects.

Finally, the Aquafish CRSP has also focused research on the ecological footprint of shrimp culture. Life cycle analysis has rarely been used in aquaculture, but this study evaluated the footprint of shrimp culture in Hainan Island, China. Environmental impacts were assessed by estimating energy and material use in various components of the system, as well as emissions of greenhouse gases, eutrophying nutrients, and other environmental stressors. The farming component of the shrimp system exhibited the major energy portion of use and also produced major environmental impacts. Energy use for production of shrimp in China for export overseas only consumed about 70% of the energy of U.S.-based recirculating systems, but used 1.4 times more water and produced 15-80% more global warming emissions. Improvements in the shrimp farming phase may be the best method to reduce the ecological footprint of shrimp culture in outdoor pond systems.

Other significant research contributions include sustainable feed studies to reduce levels of fishmeal (Guyana, Philippines, Tanzania, Vietnam), experimental work to develop indigenous species culture (Mexico, Nicaragua, Nepal), and assessments of estuarine (Mexico) and riverine (Cambodia, Vietnam) water systems on which to base sustainable management plans.

DTAP D: Enhanced Trade Opportunities for Global Fishery Markets

Printed as Submitted by Robert Pomeroy (University of Connecticut-Avery Point), Lead Coordinator

In FY09, there has been the development of new products for new markets (domestic and international) and work on developing new markets for existing products (domestic and international). New markets were being developed for three species – cockles, oysters and tilapia. In Nicaragua, cockles have been depurated and are now undergoing market testing. If successful, it is expected that depurated cockles will be ready for market under a certified label in FY10. In Mexico, work on depurated oysters has been ongoing but new market development has been slowed by small size oysters due to El Niño effects and lack of certification of the depurated oysters. Work on developing new markets and determining whether sales are possible will continue in FY10. In the Philippines, there is work ongoing with marketers and retailers to develop new domestic markets for tilapia. In Cambodia, a market analysis on domestic and international markets for value-added products (fish paste and fish sauce) produced from small-size/low-value fish has been conducted. Since many woman in poor households do fish processing, the development of new domestic and international markets has the potential to improve the lives of the rural poor. The recommendations on new markets and market channels for these products will be transferred to government (national and provincial) in late 2009. Management guidelines for (1) supply chain and (2) group marketing for fish farmers in Kenya and Ghana to enter urban markets have been developed. In FY10, these guidelines will be transferred as an extension manual for the supply chain and a brochure for the group marketing. Along Lake Victoria, six new markets have been developed for the catfish-

baitfish market where farmers can sell their baitfish to traders. The development of these new markets will improve the lives of the poor farmers around Lake Victoria.

In FY09, there has been the development of a number of new aquatic products available for human consumption and continued work on new aquatic product development. In Cambodia, best management practices (BMP) for processed low-value/small size fish, value-added products (fish paste and fish sauce) have been developed to improve food quality and safety for consumers. Fish paste and fish sauce are important products for small-scale producers and improved quality and safety of the product will improve the value of the product received by poor rural households. The BMPs are being transferred to small-scale processors. In Indonesia and the Philippines, seaweed products from shrimp-fish polyculture systems have been grown for human consumption. There has been training on agar extraction from the seaweed for local people although the agar has not reached the product stage yet. In FY10, value-added approaches for seaweed products will be undertaken. In Nepal, the polyculture of native sahar with tilapia has resulted in cultured sahar now being available for human consumption, although market development is still ongoing. In Mexico and Nicaragua, certified depurated oysters and cockles, respectively, will lead to safer products for human consumption.

REGIONAL CENTERS OF EXCELLENCE (RCE)

RCEs provide technical advice on emerging issues and gaps in the portfolio from a regional perspective. Centers will develop useful materials for Missions, other regional stakeholders and end-users, and gauge opportunities for collaboration based on regional or national needs. Three centers have been formed and each coordinates activities within a specified region: Asia, Africa, and Latin America and the Caribbean (LAC). The center for Africa will also coordinate, synthesize, and report on activities related to IEHA goals. Additional RCEs may be added depending on the portfolio of projects funded through Associate Awards. Lead Coordinators (one for each center) will take an active role in integrating Associate Award partners into the portfolio and in assisting in the management of any Associate Awards that fall under its purview. Lead coordinators will also assist the ME in cases where a screening process is required in advance of an Initial Environmental Examination.

RCE-Africa Annual Report

Printed as Submitted by Charles Ngugi (Moi University, Kenya), Lead Coordinator

INTRODUCTION

Agriculture is the primary source of livelihood for about 65% of Africans representing 30–40% of Africa's GDP and accounting for almost 60% of Africa's export income. Since small-scale farms account for more than 90% of Africa's agricultural production and are dominated by the poor, AquaFish development platforms emphasize that Aquaculture interventions must be centered on the small farmer. Elimination of chronic poverty requires mechanisms to manage the risk, vulnerability and other constraints that undercut the nutritional, health and educational investments needed to bolster the human capital of the next generation and break the inequitable inter-generational transmission of poverty. Within this context, the pathway taken by AquaFish is poverty alleviation and food security improvement through sustainable aquaculture development and aquatic resources management.

The Aquaculture & Fisheries CRSP (AquaFish CRSP) is committed to directing at least 25% of its total budget to support the Presidential Initiative to End Hunger in Africa (IEHA) launched in 2002. This is a multi-year effort designed to help increase agricultural income and fulfill the United Nations' Millennium Development Goal. This initiative focuses on promoting agricultural growth and building an African-led partnership to cut hunger and poverty by investing in agriculture oriented toward small-scale farmers. The six countries currently included in IEHA are Kenya, Ghana, Mali, Mozambique, Uganda and Zambia.

The AquaFish CRSP Strategy for Achieving Development Impact focuses on research, capacity building, information dissemination, and IEHA country involvement. Focal areas included in this report cut across improving nutrition and health, maximizing water, soil quality and productivity, advancing IPM practices, broadening market access, increasing incomes, and improving food quality, processing, and safety. This is building on the Expert Panel meeting held in Nairobi in 2002 funded by ACRSP that opened the way for collaboration among African countries and US institutions. During this meeting, various scientists discussed and agreed on a set of priorities for aquaculture development in Africa.

Presently Aquafish CRSP is focused on complementary themes in different IEHA countries as shown in:

- Kenya — Marketing and conservation of endemic fish species
- Tanzania — Production technology and technology transfer
- Ghana — Fish feed, environmental impact assessment for cage culture on Lake Volta and marketing
- Mali — Aquatic Resource use and conservation for sustainable freshwater aquaculture and fisheries
- Uganda — Hydrology, Water Harvesting, and Watershed Management for Food Security, Income, and Health: Small Impoundments for Aquaculture and Other Community Uses

RCE Responsibility

The role of the Regional Centers of Excellence (RCE) is to build community among all CRSP participants; identify potential additional partnerships with the public and private sector, NGOs, USAID, and others; and bridge the knowledge gap from local-regional perspectives to global development outcomes.

Dissemination Strategy

AquaFish CRSP research investments require well-coordinated and managed dissemination strategies. Capacity building is critical to an effective dissemination strategy. The AquaFish CRSP targeted four general audiences for its dissemination strategy, each requiring different levels of investment and approaches for effective communication. Within this period, RCE established linkages with FAO, NEPAD/COMESA, ANAF, and SARNISSA among other stakeholders.

RCE facilitated networking with US scientists interested in African aquaculture at WAS and regional meetings through:

- Personal contacts/relationships
- Through HC PI networking
- CRSP matchmaking

The key interventions were to:

1. provide technical advice on emerging issues and gaps from a regional perspectives
2. develop useful materials for missions and other regional stakeholders and end users
3. gauge opportunities for collaboration based on regional and national needs
4. coordinate synthesize and report on activities related to IEHA goals
5. additional responsibilities based on leader with Associate Award

We achieved the interventions through:

1. Advancing AquaFish CRSP research and extension technologies and practices in Mali, Uganda, Ghana, Malawi, Tanzania and South Africa
2. Setting up forward working interpretations to facilitate various aquaculture tasks in the region particularly with regards to ANAF as special programs for Aquaculture development in Africa
3. Carrying out efforts to source leverage funds from USAID mission, CIDA and government Ministries
4. Developing further linkages with the World Fish Centre and FAO to complement AquaFish CRSP research and extension efforts in IEHA countries.

End-Users

Technology transfer is frequently more efficient if end-users can see firsthand the results of novel technologies and management strategies. AquaFish CRSP participants used on-farm trials wherever possible to expedite the adoption of results and technologies. This was done in Ghana, Kenya, Mali Uganda and Tanzania projects as reported in project quarterly reports.

RCE-Africa facilitated regional Networking by developing posters in English and French for Malians under the Mali Associate Award, developing a fish farmers' manual in English, developing aquaculture fact sheets and teaching modules, facilitating information exchange and proposal writing. Currently there are FAO/ TCP aquaculture projects going on in Uganda, Kenya, and Ghana. The Ghana project is listed here as an example: "Aquaculture Investments for Poverty Reduction in the Volta Basin: Creating Opportunities for Low-Income African Fish Farmers through Improved Management of Tilapia Genetic Resources – Regional Project GCP/RAF/417/SPA".

Other Developed Proposals Submitted for Research and Leverage:

- Kenya, South Africa linked with Brazil and wrote a proposal in August 2008. Funds for this project have been released and activities have begun
- Developed an urban and peri-urban proposal with University of Stirling and three NGOs (submitted on September 1st 2008)
- Basic Research to facilitate Expansion of Aquaculture in Developing (BREAD) regions of Brazil and Kenya using indigenous and local resources — NSF–Gates Foundation
- ASARECA - Enhancing fish farmer — led enterprise for sustainable productivity and livelihoods in East Africa
- Inkubate LTD – K-Rep project — to undertake Market Research and profiling of Agribusiness Sectors in Kenya.
- ASCU/17/08-09 Functional Analysis of the Ministry of Fisheries Development
- Research-into-Use Programme — Call for 'Best Bets' Concept Notes: Agricultural Development in East and Central Africa

Host Country Decision Makers, Researchers, Educators and Extension Agents

Host Country decision makers were engaged so that aquaculture and fisheries policies would incorporate relevant research findings. We were delighted to receive invitations to participate in local stakeholder meetings. RCE-Africa provided input on research directions while also accessing up-to-date information on research and outreach activities from government agencies and other stakeholders (see ANAF meeting, in Uganda, and stakeholder workshop photos).

<u>Contacts in Ghana, Kenya, Mali, Uganda and Tanzania</u>

We have established links and contacts with senior government officers in these countries

- In Ghana, we are working with FAO Africa Representative John Moehl on information exchange.
- In Kenya we are in close collaboration with The Ministry of Fisheries Development and have been invited to several meetings to discuss the Aquaculture stimulus programme and the Aquaculutre development plan
- In Tanzania, the Principal Fisheries Officer is a member of ANAF
- In Uganda we have established a linkage with Kajanssi Research Centre and the Uganda Commissioner for Fisheries who attended the BOMOSA conference in September 2009.

USAID Mission

USAID personnel Kenya and Mali were informed of the option to received AquaFish CRSP publications, including *Aquanews*, Annual Administrative and Technical Reports, manuals, fact sheets, etc. to keep the Mission properly informed of AquaFish CRSP activities. The AquaFish USAID personnel were also invited to participate in planning and assessment meetings to remain completely informed of progress and constraints facing the Project. In Mali, the USAID mission funded the Leader with Associate Award project on "Aquatic Resource Use and Conservation for Sustainable Freshwater Aquaculture and Fisheries in Mali". In Kenya, we have worked with the USAID Mission through the Kenya Business Development Services (KBDS) and recent discussions on future collaboration were held during the visit by Dr. Kwamena Quagrainie in June 2009. The RCE leader presented a summary of CRSP work to the USAID and BIFAD team visting Kenya in Fall 2008.

Cross-cutting Theme: Biodiversity Conservation and Environmental Impact
The proposal recognizes that fragile environments require careful management to maximize benefits for people without overexploiting the resources upon which they depend for future sustainability. Where possible, efforts were made to inform stakeholders on the need to preserve or conserve watershed to the benefits of communities that derive their livelihood from such resources. RCE-Africa engaged policy makers in discussing the need to implement the aquaculture economic stimulus package in Kenya in a responsible manner without polluting the environment.

NGOs and IGOs

FAO Regional Office, Ghana, John Moehl
NEPAD and COMESA, Dr. Sloans Chimatiro,
Fish Africa, Dr. Koffi
Citadel of Hope, Suzanne Njeri
WIFIP, Jennifer Atieno

Figure 1. Kenyan catfish farmers visit the Uganda Hatchery at Philip Borel.

Figure 2. RCE-Lead Dr. Charles Ngugi (right) with Uganda Ugachick CEO and owner.

Figure 3. Dr. Charles Ngugi (2nd from left) at the Asian Institute of Technology with fellow SARNISSA members on their Asia tour.

Figure 4. Attendees of the SARNISSA workshop in Cameroon.

Figure 5. Technical staff from Mali doing practicals on catfish at Sagana training.

RCE-Asia Annual Report

Printed as Submitted by Remedios B. Bolivar (Central Luzon State University, Philippines), Lead Coordinator

This annual report covers the activities of the RCE-Asia during the FY09 reporting period.

To provide opportunities for exposure to international and national scientific meetings and to make contact with other aquaculture scientists, the following were conducted through partial or full support from the AquaFish CRSP RCE-Asia:

1. Philippine Fisheries Institutions Network (PhilFIN) Conference and General Assembly held at the University Hotel, University of the Philippines- Diliman, Quezon City, Philippines on October 8-9, 2008. This conference was attended by Remedios B. Bolivar (HCPI), Hernando L. Bolivar (Collaborating Partner, GIFT Foundation), Ravelina R. Velasco (Ph. D. student), Eddie Boy T. Jimenez (MS student and Project Staff), Sherwin B. Celestino (Project Staff), Reginor Lyzza B. Argueza (MS student and Project Staff) and Roberto Miguel V. Sayco (Project Staff).

2. Eighth International Symposium of Tilapia in Aquaculture (ISTA8) held in Cairo International Convention Center, Cairo, Egypt on October 12-14, 2008. This symposium was a great opportunity to meet with mostly Egyptian Scientists working with tilapia in

Egypt. The symposium was attended by Remedios B. Bolivar HCPI) and two project staff, Eddie Boy T. Jimenez and Roberto Miguel V. Sayco.

3. To strengthen regional linkages, an informal planning meeting with Dr. Yang Yi was held during ISTA8 in Cairo, Egypt on the First International Symposium on Aquaculture & Fisheries Education (SAFE) to be held in November 2009 at the Asian Institute of Technology (AIT), Thailand. This symposium was jointly organized by AIT, Shanghai Ocean University, China, and the Asian Fisheries Society (AFS).

4. Luzon Zonal Philippine Association for Graduate Education (PAGE) Convention held at the Wesleyan University-Philippines, Cabanatuan City, Nueva Ecija, Philippines on November 26, 2008. This convention was attended in by Remedios B. Bolivar (HCPI).

5. The University Academic Research Council (UARC) of the Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines was launched and pioneering members were inducted on December 3, 2008. Remedios B. Bolivar, AquaFish CRSP HCPI is a pioneering member of the UARC.

6. International Symposium on Current Research Trends in Fisheries Biology was held at the Philippine Carabao Center (PCC), Science City of Muñoz, Nueva Ecija, Philippines on January 20, 2009. This was attended by officials of local government, fisheries institutions, international scientists from Thailand and Taiwan among other countries. AquaFish CRSP attendees included Remedios B. Bolivar (HCPI) who also served as the Master of Ceremony of the symposium, Eddie Boy T. Jimenez (MS student and Project Staff), Sherwin B. Celestino (Project Staff), Reginor Lyzza B. Argueza (MS student and Project Staff), Roberto Miguel V. Sayco (Project Staff) and nine AquaFish CRSP funded undergraduate and graduate students.

7. AquaFish CRSP Annual Meeting held at the Grand Hyatt Seattle, Seattle, Washington, USA on February 15, 2009 was attended by Dr. Remedios B. Bolivar (HCPI) as member of the Technical Committee, Dr. Emmanuel M. Vera Cruz (co-HCPI), Dr. Ruben C. Sevilleja (CLSU AquaFish Project Administrator) and Mr. Hernando L. Bolivar (Collaborating Partner, GIFT Foundation).

8. Aquaculture America 2009 of the World Aquaculture Society held at the Washington Convention Center, Seattle, Washington, USA on February 15-18, 2009. Paper presentations were given by Remedios B. Bolivar, Hernando L. Bolivar and Emmanuel M. Vera Cruz. Partial travel supports were provided to Dr. R. Sevilleja and Mr. H. Bolivar.

9. Four participants (2 undergraduate students and 2 Freshwater Aquaculture Center Technical Staff) were funded by RCE-Asia to attend the Symposium on Catfish Aquaculture in Asia organized by Can Tho University held in Can Tho City, Vietnam on December 5-7, 2008. The two undergraduate students were Ms. Millicent Pantaleon and Ms. Merry Jane Castro while the two FAC Technical Staff were Mr. Leo Pascual and Mr. EduardoTadeo.

10. 21st Agency In-house Review of Completed and On-going R & D Projects held at CLSU, Science City of Muñoz, Nueva Ecija, Philippines on May 29, 2009. The following persons were presenters: Remedios B. Bolivar (HCPI), Eddie Boy T. Jimenez (Project Staff & MS student) and Roberto Miguel V. Sayco (Project Staff). The event was also attended by two other project staff: Sherwin B. Celestino and Reginor Lyzza B. Argueza.

Some of the workshops organized and conducted through the AquaFish CRSP were:

1. On-site Lecture-Forum on *Kappaphycus cottonii* (Distribution, Biology-ecology, Farming, Crop Management/Diseases, Post-Harvest, Marketing and Product Applications) held at Punta Punting Beach Resort, Sabang, Sibunag, Guimaras, Philippines on November 10-11, 2008. There were 50 participants to this workshop.

2. Tilapia Podcast Workshop held at the Freshwater Aquaculture Center (FAC), CLSU, Science City of Muñoz, Nueva Ecija, Philippines on January 12-13, 2009. There were 84 participants in this workshop. The participation of some students in this workshop was made possible through the AquaFish CRSP RCE-Asia.

3. Workshop on Seaweed Culture and Tilapia-Shrimp Polyculture held at the Golden Sunset Resort in Calatagan, Batangas, Philippines on January 15-16, 2009. This workshop was attended by 47 participants who were fishpond operators from Batangas, seaweed farmers/traders, tilapia cage operators/traders from Batangas, local government unit staff from Balayan, Calatagan, Nasugbu, and Taal, Batangas and from the Batangas Provincial Agriculture Office, Bureau of Fisheries and Aquatic Resources staff of Region 4-A, and from BFAR Inland Fisheries and Aquaculture Division-Mariculture Section, representatives from feed companies, Southeast Asian Fisheries Development Center visiting scientists, CLSU and Aquafish CRSP Project staff, and US AquaFish CRSP visitors.

A training course was organized for two staff of an orphanage called "Helping People to Help Themselves" (HP2HT) from Surigao del Norte, Philippines. A one-week training on Fish Culture was conducted at the Freshwater Aquaculture Center, CLSU, Science City of Muñoz, Nueva Ecija, Philippines. The participants were Mr. Apolinario Sa-ang and Mr. Leonardo Doligol.

To strengthen the human capacity building in fisheries/aquaculture, some deserving graduate and undergraduate students of CLSU, Science City of Muñoz, Nueva Ecija, Philippines were provided funds to carry out their degree-programs. Financial support was granted to twelve (12) undergraduate BS Fisheries students, seven (7) of whom graduated last April 2009, and to 11 graduate students (8 MS students - 1 graduated last Summer 2009 and 3 PhD students- 1 graduated last April 2009. Also, partial thesis support was provided to some students (1 DVM, 2 MS and 2 PhD).

The project supported two visitors during the period: Dr. Charles Stark on April 18-26, 2009 and Mr. Rafael Garcia-Martinez on August 3-10, 2009.

RCE-LAC Annual Report

Printed as Submitted by Wilfrido Contreras-Sanchez (Universidad Juárez Autónoma de Tabasco, Mexico), Lead Coordinator

Several activities have been conducted to achieve the objectives conceived for the RCE.

Support to research and extension agents from Costa Rica, Guatemala and Nicaragua has been provided regarding tropical gar culture and for design and establishment of nurseries. Successful spawnings were conducted by Gabriel Marquez (UJAT) and researchers from the Universidad Nacional (Costa Rica) in 2008 and 2009. A female student from Guatemala (Iris Castañeda) spent two and a half months in our facilities training on native species aquaculture and live food production. She used this academic visit for obtaining her degree on aquacultural engineering from the Universidad de San Carlos (Guatemala). She is currently planning on getting a masters degree at UJAT. Alejandro Macdonal (our extension agent) provided governmental agents from Nicaragua with a proposal to build a tropical gar hatchery in 2010. The same proposal was sent to Pablo Gonzales to promote alligator gar culture in Tamaulipas; the idea is to transfer the technological package for tropical gars to be used in alligator gars in 2010. We have built strong new partnerships in collaborative research in aquaculture and fisheries.

We were very active promoting tilapia and native cichlids aquaculture. Several workshops were conducted during the last months. Our best training activity consisted in promoting aquaculture among Chontales, Choles, and Zoques from Tabasco and Chiapas. These indigenous groups have initiated tilapia culture activities in their communities. Furthermore, in Caridad Guerrero (a community located between Tabasco and Chiapas), we will initiate building an aquaponic system in early 2010. Tilapias and vegetables will be produced in this community. As mentioned in a previous report; faculty from UJAT was invited by the Secretary of Natural Resources & Environmental Protection of Tabasco (SERNAPAM) to provide a workshop on tilapia aquaculture at Universidad Intercultural, located in Oxolotan, Tabasco (this University focuses on indigenous groups that live in the mountains of Tabasco and Chiapas and is looking at aquaculture as an alternative for good-quality food production). This particular workshop was a success creating strong bonds between both universities and the farmers. We will continue promoting tilapia culture in this region.

Another important workshop was offered to former UJAT students that are working, or planning on working in aquaculture; additionally, students may obtain their university title after passing the courses. Forty-three former students participated in this workshop consisting of seven sections. Examinations for title attainment are scheduled for January 2010.

The 2nd Snook Biology & Aquaculture workshop held in Villahermosa was a great success. We were able to bring together aquaculture and fisheries experts interested in snook. As a result of several meetings after the plenary sessions, we built an international network with structure and objectives (Ronald Taylor from the Fish & Wildlife Research Institute located in Florida was named first president of the network). We have commitments for searching for international funds and write multidisciplinary and multi-institutional proposals. The third symposium will be held in Florida in 2011.

Our International Network has continued working; the third meeting was held this year at Universidad Nacional in Costa Rica with the presence of more than 50 researchers, students, and extension agents from Mexico, USA, Nicaragua, Costa Rica, and Cuba. UJAT had a very strong presence with eleven talks including both researchers and students. The next meeting of

this network was scheduled for 2012 at Nicholls State University, Louisiana. Gabriel Marquez, from UJAT is the former president of this network. We will continue promoting gar culture and conservation in the Americas.

Communication is maintained with former members of the ACRSP in the region, particularly with Maria Celia Portella. Maria got approval from the Special Secretariat for Aquaculture & Fisheries in Brazil for the two projects on tilapia aquaculture and environmental assessment in Brazil involving CRSP researchers.

In our laboratory we continue training students hands-on; more than forty students (undergraduate and graduate levels) participate in research projects, fish production and training activities.

We have continued increasing human resource capacity by promoting workshops, training students in a tilapia farm program (Arizona) and USA Universities (Maria Contreras visited Dr. Allyse Ferrara at Nicholls State University; Rosa Pérez visited Dr. Gerg Lutz at Louisiana State University) and presenting talks in different meetings. We will continue sending two students each semester to Arizona to participate in a tilapia farm program and to gain hands-on experience. UJAT is paying for plane tickets and part of the student stipend.

Communication with the USAID mission in Mexico has not been successful. USAID considerably reduced its personnel in Mexico and only one person has been in charge of all environmental programs since early 2007. No other missions have been contacted in Central or South America.

SYNTHESIS PROJECT (SP)

The overall Synthesis Project at the ME includes a research component undertaken by a PI and a project support component. During this reporting period, the research component has begun its metadata analysis which will lead to recommendations for minimum dataset sizes to reduce duplication and streamline data collection. The Annual Report that follows for this research component covers the period 1 October 2008 to 30 September 2009.

Annual Report: Evaluating AquaFish Accomplishments in a Systems Framework

Printed as Submitted by Steven Buccola (Oregon State University), Lead PI

The objective of this Synthesis Project is to characterize and assess the AquaFish CRSP investigations from a systems viewpoint. The subject matters—including the environmental, economic, and cultural settings—of the AquaFish CRSP investigations are highly varied. So also are the investigations' functions, which range from experimental-control research, to statistical-control research, to outreach and training. This heterogeneity poses a significant problem for any assessment or characterization study like the present one, which must rely to some degree on a common assessment framework. Much of our work during 2008—2009 was to develop such a framework in a way that does not sacrifice the AquaFish investigations' subject, topic, and functional variety.

Five tasks were accomplished.

First, the summaries and reports of the CRSP projects and investigations were examined to familiarize us with their objectives and procedures. We then developed a basic characterization framework consisting of a depiction of each investigation in terms of: (a) the problem it addresses, such as the decline of a desirable wild fish species; (b) the technology involved, modeled as a set of input-output relationships; (c) the study method employed, such as a controlled experiment or podcast development; (d) the benefits intended, such as pollution reduction in an estuary; and (e) training objectives. The framework will be revised as we gain additional familiarity with the investigations.

Second, we developed a general approach which allows an analysis of all the AquaFish CRSP investigations in terms of the above characteristics. The approach consists of depicting the investigators' expectations of the benefits that will be achieved from the investigation, that is the expected investigation influences on the outputs which constitute the intended benefits. For example, in Investigation 07HHI01UM, "Monitoring and Reducing Microcystins in Tilapias and Channel Catfish Cultured in a Variety of Aquaculture Systems," the expected benefit would consist of the expected percent change, realized from the ongoing research, in the microcystin content of tilapia and catfish flesh These expected outputs will be assessed in conjunction with the investigations' inputs, including the numbers and types of investigator-hours, total investigation costs, and special circumstances of the investigation's social, economic, and natural environment.

Third, we developed the groundwork of a procedure for enumerating these very investigator-expected benefits. The procedure is Bayesian in the sense that investigators' expectations can be updated in a logically consistent manner as their study proceeds and as new study information comes to light. The new information can take the form of objective (measurable) data such as new research results. Or it can take the form of subjective (intuitive) assessments of the general

situation facing the investigation, gleaned from a recent sequence of poorly measurable but collectively significant information events like news from collateral research projects. Our procedure for developing that groundwork was to examine and summarize the literature on Bayesian probability updating and on the elicitation of subjective probabilities. We then cast the expectation updating procedure in the form of a sequence of research steps whereby we will elicit the benefit expectations from HC investigators or project principal investigators.

Fourth, we developed a procedure whereby the expected study benefits and inputs can be understood in a systems framework, organized by AquaFish CRSP Topic Area or groups of Topic Areas. The procedure is to examine – with statistical or mathematical programming methods – the average relationships between expected investigation benefits and inputs and the likely reasons why those relationships vary across investigations.

Fifth, we constructed a broad outline of how the results of this synthesis project can be made conformable to an allied study which might assess the social, economic, and environmental impacts of the AquaFish CRSP investigation benefits.

Project Participants

Oregon State University
Steve BUCCOLA- US Lead PI
Lin QIN- Graduate Student Research Assistant

Conferences

2009 AquaFish CRSP Annual Meeting; Seattle, Washington; February 2009

2009 Aquaculture America Conference; Seattle, Washington; February 2009; CRSP Session: International Aquaculture Development for the Poor.

X. MONITORING & EVALUATION

The Monitoring and Evaluation (M&E) Plan was formalized in the *AquaFish CRSP 2nd Annual Report.* It functions under two sets of internal impact indicators — (1) theme-driven DTAP indicators .and (2) key development target indicators tied to the USAID research, capacity building, information dissemination, IEHA, and gender integration targets for the CRSPs. Tables X-9 to X-13 cross reference these internal AquaFish CRSP indicators to the applicable EGAT and IEHA indicators under which AquaFish CRSP reports[22].

DTAP INDICATORS

The DTAP indicators are tied to the four AquaFish CRSP global themes. They were developed by the MT in consultation with the US and HC Lead PIs in the May 2007 *Pre-Synthesis & Orientation Meeting* and updated in May 2008 at the Annual Meeting. In June 2009, the MT assigned a unique number to each indicator and in consultation with the DTAP Lead Coordinators broadened the scope of DTAP indicator B-01 by replacing the term "biotechnologies" with "technologies" and defining it broadly to include practices, products, and markets. This change in definition was intended to track with the broad definition of "technology" encompassed in the USAID EG indicators 5.2-14 to 5.2-16. The current set of DTAP indicators under which core research projects reported in FY09 are listed below.

DTAP A: Improved Health and Nutrition, Food Quality, and Food Safety of Fishery Products
A-01: Number of aquaculture products developed to improve food safety or quality

DTAP B: Income Generation for Small-Scale Fishers and Farmers
B-01: Number of new technologies developed
B-02: Number of institutions with access to technological practices
B-03: Number of (people) trained in use of technological practices

DTAP C: Environmental Management for Sustainable Aquatic Resources Use
C-01: Number of management practices developed or adopted to improve natural resource management
C-02: Number of hectares under improved natural resource management
C-03: Number of management practices developed to support biodiversity
C-04: Number of people trained in practices that promote soil conservation and/or improved water quality

DTAP D: Enhanced Trade Opportunities for Global Fishery Markets
D-01:Number of new markets for aquatic products
D-02: Number of aquatic products available for human food consumption

[22] Indicators for the USAID Economic Growth & Trade program form the EG 5.2 (Agriculture Sector Productivity) series. Indicators for the IEHA (Presidential Initiative to End Hunger in Africa) program comprise two categories: Output Indicators (EG 5.2 indicators) and Intermediate Results (IRs).

Tables X-1 – X-8 compile the DTAP reports submitted by each of the six AquaFish CRSP core research projects which were actively engaged in research during FY09. Since short-term training data were collected under a separate internal reporting mechanism, FY09 reports for indicators B-03 and C-04 are included in the short-term training compilation (Table VIII-5). The DTAP Lead Coordinator Reports summarize impacts for FY09 (See *Synthesis*, pp 121–125).

The first steps in using the DTAP indicators were to gauge the process under which data would be collected. Therefore, targets were not set for FY08 and FY09. The FY10 targets reported here *only* apply to predicted indicator metrics for continued accomplishments that may occur after the NCE completion of investigations initiated under the *Implementation Plan 2007–2009*. FY10 targets do not reflect predicted metrics for new work that will begin on 1 January 2010 under the *Implementation Plan 2009–2011*.

Table X-1. AquaFish Investigation Indicator Reports for DTAP A-01: Number of aquaculture products developed to improve food safety or quality

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	A-01 Report Text
07FSV01UC Low-Value Fish Product Development	1	1	BMPs for low-value/small fish processed, value-added products with improved food quality and safety under preparation for transfer in FY10 via 07TAP01UC. See also D-01, D-02.
07HHI01UM Microcystin Control	1	1	Product development of microcystin-free fish will progress as technology is adopted. See B-01.
07HHI05UH Nicaragua: Depurated Cockles	1	1	Depurated cockle product (2 species sold together) in market testing for adoption in FY10 as certified product. Also reported for A-01 (product) and D-01 (market).

Table X-2. AquaFish Investigation Indicator Reports for DTAP B-01: Number of new technologies developed

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-01 Report Text
07HHI01UM Microcystin Control	2	1	Two new effective treatments developed and tested: (1) chitosan-modified clay and (2) PAC-modified clay. Transfer of chitosan-modified clay as more environmentally friendly to 5 researchers. Adoption will spread via researchers in FY10. See also A-01, D-02.
07HHI02UA Aquaponics with Tilapia Effluent	1	1	Aquaponics system for leafy greens irrigated with tilapia effluent developed and tests conducted to evaluate levels of bacteria on lettuce. See also C-01.
07HHI05UH Nicaragua Depuration of Cockles	1	1	Depuration technology trials for 2 cockles (*Anadara* sp.). See also A-01, D-01, D-02.
07IND02UA Native Cichlid Culture	2	2	Developing technology for genetic improvement and alternative feeding of native cichlids: (1) Families of *Cichlosoma urophthalmus* have been selected from three different locations and placed in hapas for grow-out. *Petenia splendida* adults are in breeding tanks and family selection is in progress; (2) substitution of fishmeal for poultry meal.
07IND03UH Mexico Spat Collection	1	1	Technology development for women oyster growers of spat collection and grow out of native oyster in Santa Maria Bay. See also D-01, D-02.
07IND04UH Mexico: Oyster Depuration	1	0	Relay and depuration technology trials for oyster conducted at 2 sites.

Table X-2. AquaFish Investigation Indicator Reports for DTAP B-01: Number of new technologies developed

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-01 Report Text
07MER03PU Tilapia-Catfish Predation Culture	1	1	Farmer cooperators field testing research-based extension recommendations for mixed-sex tilapia-catfish predation polyculture to improve profitability.
07MNE06UA MT Elimination	3	3	Development of clean tilapia masculinization technologies: (1) MT degradation by TiO2 (transfer in FY10); (2) bacterial degradation; (3) MT measurement using ELISA.
07QSD01NC Tilapia Seedstock	1	1	Qualitative assessment of different hatching systems for Nile tilapia fry production and fingerling growout. Transfer of recommended technology in FY10.
07SFT01UC Snakehead Feed Technology	4	4	Alternative feed technologies for 2 species of snakehead under research & development: (1) Weaning of hatchery-raised snakehead (2) Pelleted feed for hatchery-raised *C. striata* (3) Pelleted feed for hatchery-raised *C. micropeltes* (4) Rice bran substitution as protein source for fishmeal in mixed fish-soybean-cassava meal
07SFT02NC Feeding Strategies for Tilapia	3	3	Technologies under development and field testing: (1) IGF-I assay as a biomarker for tilapia growth status (biotechnology) (2) Reduced feeding strategies to reduce costs for producing Nile Tilapia in ponds (3) Fishmeal replacement with food by-products
07SFT03NC Feeding Strategies for Milkfish	2	2	Technologies under development and field testing: (1) Reduced feeding strategies to lower costs for producing milkfish in tanks (transfer in FY10) (2) IGF-I assay to test milkfish growth status in progress (biotechnology: development and testing in FY10)

Table X-2. AquaFish Investigation Indicator Reports for DTAP B-01: Number of new technologies developed

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-01 Report Text
07SFT04UA Local Feed for Tilapia & Pacu	5	5	Local ingredients as fishmeal feed replacement for Tilapia and Pacu: In Transfer Stage (FY09-10): (1-2) Copra meal and shrimp meal are now being used in some production diets at several farms. In Development & Testing Stage: (3) Poultry by-products (testing in FY09-FY10; transfer in FY10) (4) Brewers waste (testing in FY09-FY10) (5) Palm nut oil cake (development stage into FY10)
07SFT05UA Fishmeal Substitution	2	2	Feed formulation and manufacture of local ingredient substitutes: (1) Under development: new feed formulation technology for copra meal, shrimp meal, and brewers wastes. (testing and transfer in FY10) (2) Under adoption (FY09-10): on-farm diet formulations and manufacture methods with hammer mill and compression pelleting equipment.
07SFT06PU Locally Available Feed for Tilapia	1	1	Local plant species as low-cost alternatives to soybean meal in fish feed: *Moringa oleifera* and *Leucaena leucocephala* leaf meals found effective when supplemented with soybean as protein source. Testing underway of commercial formulation by feed mill. Transfer to farmers scheduled for FY10 (November 2009).
07TAP01UC Feed Technology & Fisheries Management	na	na	Transfer of 4 snakehead feed technologies developed in 07SFT01UC to farmers in FY10. See C-01.
07TAP02NC Tilapia Podcast	1	2	Developed and introduced *Tilapia Cast* as internet-based extension podcast for tilapia farmers. 2 additional podcasts scheduled for production and transfer in FY10.

Table X-3. AquaFish Investigation Indicator Reports for DTAP B-02: Number of institutions with access to technological practices

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-02 Report Text
07BMA02UM Sahar-Tilapia Polyculture	1	1	**Technology: Polyculture of sahar and tilapia** **Organizations** Rural Integrated Development Society (NGO) - Nepal (RIDS)
07HHI02UA Aquaponics with Tilapia Effluent	5	5	**Technology: Leafy greens irrigated with tilapia effluent** **Organizations** (1) UAT; Universidad Autonoma de Tamaulipas (EDUC/RES) (2) SAGARPA; Secretaria de Agricultura Ganaderia, Recursos naturales y Pesca. (GOVT) (3) DIF; Desarrollo integral de la familia (GOVT: Youth at Risk program) (4) State of Tamaulipas; Gobierno del Estado de Tamaulipas (GOVT) (5) Farmers cooperatives: not available
07HHI04UH Shellfish Regional Workshop	12	12	**Technology transfer: Regional Workshop on Shellfish Culture and Sanitation** **Universities** (1) FACIMAR-UAS (2) UAS-Culiacan (3) Universidad Tecnológica de la Costa Nayarit (4) UNAM **Government** (1) ConsejoEstatal de Ciencia y Tecnología) (2) CESAIBC (ComiteSanidad Acuic.BC) (3) IAES (Instituto de Acuac. Edo.Sonora (4) InstitutoPolitecnicoNacional-Acuacultura (5) COSAES(ComiteSanidad Acuic.Son) (6) CIAD Mazatlan (7) CECASIN (8) ConsejoEstatal de Ciencia y Tecnología)
07HHI05UH Nicaragua Depuration of Cockles	3	3	**Technology: Depuration of cockles** **Educational:** CIDEA/UCA **Government**: Ministry of the Environment (MARENA); Municipal government

Table X-3. AquaFish Investigation Indicator Reports for DTAP B-02: Number of institutions with access to technological practices

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-02 Report Text
07IND03UH Mexico Spat Collection	8	8	**Technology: Spat Collection & Culture of native oyster** **Govt. institutions:** CIAD, CESASIN, 3 municipal govt. **Universities:** UAS, Universidad Tecnológica de la Costa Nayarit, UNAM
07IND04UH Mexico Depuration	6	6	**Technology: Depuration of oysters** **Government institutions:** CIAD, CESANAY, Municipal govt. **Universities:** UAS, Universidad Tecnológica de la Costa Nayarit, UNAM
07MNE02NC Sustainable Coastal Aquaculture	14	14	**Technology: Transfer of seaweed-shrimp-fish polyculture and soft shell farmer technologies in trainings** (1) Ujung Batee Aquaculture Center - Government, (2) SEAFDEC - Government, (3) BFAR - Government, (4) MFARMC - Municipal Fisheries and Aquatic Resources Management Council, LGU -local government unit; (5) BFARMC - Barangay Fisheries and Aquatic Resources Management Council, LGU; (6) FAC/CLSU-University; (7) Aquaculture without Frontiers - NGO; (8) IFC - NGO; (9) ACIAR - Government; (10) NACA; (11) Caritas Czech Republic; (12) PRGI ; (13) ADB ETESP - Asian Development Bank; (14) (GIFT - Foundation)
07MNE06UA MT Elimination	1	1	**Technology: MT elimination from aquaculture masculizing systems** **Organizations:** Universidad Juarez Autonoma de Tabasco
07MNE07UM Workshop on Aquaculture, Human Health & Environment	7	7	**Professional Research Transfer: Workshop on Aquaculture Human Health & Environment** **Organizations and institutions**: (1) Shanghai Ocean University; (2) World Wildlife Fund; (3) Institute of Agriculture & Animal Science, Nepal; (4) Directorate of Fisheries Development, Nepal; (5) Nong Lam University, Vietnam; (6) Hainan University, China; (7) Huazhong Agricultural University
07QSD01NC Tilapia Seedstock	4	4	**Technology: Qualitative assessment of different hatching systems:** (1) (CLSU-Fisheries Aquaculture Center; CLSU – University; (2) GiFT – NGO; (3) BFAR - Government; (4) Genomar - NGO)

Table X-3. AquaFish Investigation Indicator Reports for DTAP B-02: Number of institutions with access to technological practices

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-02 Report Text
07SFT02NC Feeding Strategies for Tilapia	3	3	**Technology: Feed Reduction and Alternative Feeding Strategies for Tilapia** **Organizations** (1) CLSU - University, (2) SEAFDEC-government, (3) BFAR
07SFT03NC Feeding Strategies for Milkfish	1	1	**Technology: Alternative Feeding Strategies for Milkfish** **Organizations** SEAFDEC
07SFT04UA Local feed for Tilapia & Pacu	4	4	**Technology: Local ingredients as fishmeal feed replacement for Tilapia and Pacu** **Organizations** (1) Ministry of Agriculture-Fisheries Office (GOVT) (2) University of Guyana (EDUC/RES) (3) National Aquaculture Association of Guyana (NGO) (4) GTIS (GOVT) (5) Trafalgar Union Women's Cooperative for Tilapia
07SFT05UA Fishmeal Substitution	3	3	**Technology: Local ingredient feed formulation and manufacture** **Organizations** (1) Ministry of Agriculture-Fisheries Office (GOVT) (2) University of Guyana (EDUC/RES) (3) National Aquaculture Association of Guyana (NGO)
07SFT06PU Locally Available Feed for Tilapia	1	1	**Organizations** Ministry of Natural Resources & Tourism, Aquaculture Development Division

Table X-3. AquaFish Investigation Indicator Reports for DTAP B-02: Number of institutions with access to technological practices

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	B-02 Report Text
07TAP01UC Feed Technology & Fisheries Mgmnt	17	17	**Organizations: Educational & Government** (1-10) Vietnam Provincial Department of Agriculture and Rural Development in 10 provinces (An Giang, Cantho, Ben Tre, Bac Lieu, Dong Thap, Soc Trang, Long An, Kien Giang, Tien Giang, Hau Giang); (11) Research Institute for Aquaculture #2, Cantho University, (12) Ministry of Agriculture and Rural Development Sub-Department of Aquaculture; (13-16) Cambobia Department of Fisheries provincial offices (Kompong Cham, Prey Veng, Kandal, Siem Reap); (17) Department of Fisheries.
07TAP02NC Tilapia Podcast	2	2	**Technology: Tilapia podcasting** CLSU (university), SEAFDEC (government)
07WIZ01PU Ghana Water Quality	8	8	**Technology: BMPs developed for effluent control in aquaculture to be transfered to farmers** These government agencies will benefit via trainings and partnership: (1) Kwame Nkrumah University of Science and Technology (KNUST); (2) University of Ghana; (3) University of Cape Coast; (4) Water Resources Research Institute; (5)Institute of Aquatic Biology; (6) Water Resources Commission; (7) the Fisheries Directorate - Ministry of Agriculture; (8) Environmental Protection Agency.
07WIZ02UH Mexico Carrying Capacity	6	6	**Management Plan Recommendations on Carrying Capacity Submitted to Mexican Government:** **Government institutions:** CIAD, CESANAY, Municipal govt. **Universities:** UAS, Universidad Tecnológica de la Costa Nayarit, UNAM

Table X-4. AquaFish Investigation Indicator Reports for DTAP C-01: Number of management practices developed or adopted to improve natural resource management

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-01 Report Text
07HHI02UA Aquaponics with tilapia effluent	3	3	Aquaponics on-farm practices (under testing): (1) gravity to irrigate from ponds (2) hose to better use the effluents. (3) Recirculating aquaculture to utilize resources more efficiently
07MER01UC Low-value fish for feed or food	1	1	Policy framework for aquaculture/capture fisheries interactions, sustainable management of low value fish, and food security in the lower Mekong River basin (Economic component of management strategy). For FY10 transfer, see TAP01UC (C-01). Companion study to 07MNE01UC. See C0-3.
07MNE02NC Sustainable coastal aquaculture	1	2	Management Practices transferred via Trainings: (1) Seaweed polyculture for sustainable coastal pond aquaculture of shrimp and fish to reduce pollution in ponds and preserve coastal habitat; (2) Softshell crab aquaculture techniques as alternative to shrimp farming (added as an extra training in July 2009). See also D-02.
07MNE04UM Waste Mgmnt Practices	2	2	Two effective practices identified from surveys for outreach: (1) stocking density and (2) aeration as means to improve water quality and eliminate the need for flushing ponds.
07MNE05UM Shrimp Culture impacts	2	2	Optimum practices identified in assessment: (1) moderate stocking density and (2) aeration, reducing effluent and electricity use.
07QSD02PU Catfish-Baitfish Farming	5	5	Management Practices under adoption: (1) Catfish fry/fingerling production and artificial propagation techniques; (2) Predator control for better growth and higher survival; (3) Pond construction techniques; (4) Construction of simple hatcheries for catfish propagation; (5) Pond management techniques and pond dynamics. See C-03 for biodiversity practice.

Table X-4. AquaFish Investigation Indicator Reports for DTAP C-01: Number of management practices developed or adopted to improve natural resource management

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-01 Report Text
07SFT02NC Feeding Strategies for Tilapia	1	1	On-farm feed reduction management strategy for reducing costs of culturing tilapia in ponds. Feed ration reduction through delayed, alternate-day, or subsatiation feeding or a combination does not signifcantly alter growth of tilapia, but reduces feed requirements of fish and amount of nutrient input into ponds. Reported as technology in B-01. See also C-03.
07TAP01UC Feed Technology & Fisheries Mgmnt	1	1	One set of BMPs for fish feeding developed to be transfered in FY10 (see B-01) Transfer of 2 management recommendations for managing abundance and catches of low value fish at national/subregional levels developed in 07MER01UC and 07MNE01UC (C-03) to provincial level fisheries departments and extension agents in FY10.
07WIZ01PU Ghana water quality	3	3	Management practices to minimize waste and contamination of the environment: (see C-03) BMPs under development for waste control: (1) Improving feed and fertilizer source/uses and bacteriological quality on farms; (2) Feeding regimes to minimize waste in ponds and receiving waters; (3) Improving harvesting practices, effluent releases and production water reuse
07WIZ02UH Mexico carrying capacity	1	0	Study provided estimates of the carrying capacity of the Boca de Camichin area by which to establish limits on oyster farm size to help prevent negative impacts on water quality and aquatic diseases. Finding presented to the Boca de Camichin management committee. Government has imposed a ban on establishing new oyster farms.

Table X-5. AquaFish Investigation Indicator Reports for DTAP C-02: Number of hectares under improved natural resource management

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-02 Report Text
07FSV01UC Low-Value Fish Product Development	250	25	Hectare estimate for fishers who have adopted practices for low-value fish resource management
07HHI05UH Nicaragua depuration	150	15	150 ha for participants in experiments and training whose sites spread throughout the estuary which is 492,900 ha (measured)
07IND03UH Mexico spat collection	120	12	120 ha is being farmed
07MER01UC Low value fish for feed or food	500	50	Hectare estimate for fishers and farmers who have adopted practices for maintaining sustainable aquaculture/capture fisheries interactions
07MNE02NC Sustainable coastal aquaculture	20	3	Farms using seaweed polyculture to grow shrimp or fish
07MNE04UM Waste Mgmnt Practices	200	24	Estimate of 200 ha for 200 trainees who adopted practices, each with a farm size of 1 ha

Table X-5. AquaFish Investigation Indicator Reports for DTAP C-02: Number of hectares under improved natural resource management

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-02 Report Text
0MNE06UA MT Elimination	1	2	Hectare estimte for hatcheries using MT elimination technology in aquacultural masculinization systems (local to Mexico or Central American region), including estimte for farmers who procure all-male fingerlings from hatcheries
07MNE01UC Low-Value Fish diversity	500	50	Hectare estimate for fishers who have adopted community-based, low-value fishery management practices
07QSD02PU Catfish-Baitfish Farming	4	2	67 fish farmers have a combined total of 3.4 hectares of ponds being used for catfish fingerling production
07SFT01UC Snakehead Feed Technology	50	5	Hectare estimate for farmers who have adopted alternative feed strategy promoted in outreach materials.
07SFT02NC Feeding Strategies for Tilapia	1453	727	Farms using alternate feeding strategies for Nile tilapia culture.
07SFT06PU Locally available feed for tilapia	0	2	FY10 ha estimate for farmer trainees who will adopt alternative plant protein feed for tilapia and other feeding strategies to minimize adverse effects on water quality

Table X-5. AquaFish Investigation Indicator Reports for DTAP C-02: Number of hectares under improved natural resource management

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-02 Report Text
07TAP01UC Feed Technology & Fisheries Mgmnt	100	750	FY09: Hectare estimate for farmers who have adopted alternative feed technology and feed practices transferred in farmer trainings = 100 ha FY10: Hectare estimate for farmers who are expected to adopt practices promoted by the implementation of an Aquaculture Development Policy = 750 ha
07WIZ01PU Ghana water quality	0	1,071	51 hectare estimate for farmers who will adopt BMPs for controlling aquacultural effluent 1,020 ha estimate for other agricultural/aquacultural hectares in the watershed, which will benefit from improved water management resulting from farmer adoption of BMPs.
0WIZ02UH Mexico carrying capacity	195	0	Entire Boca de Camichin area is 195 ha and all is under improved management as the result of this investigation

Table X-6. AquaFish Investigation Indicator Reports for DTAP C-03: Number of management practices developed to support biodiversity

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	C-03 Report Text
07BMA02UM Sahar-tilapia polyculture	1	1	Optimal management practice for sahar density: 0.125 fish per square meter. Under adoption by cooperators. Product status in D-02
07MNE01UC Low value fish diversity	1	1	Recommendation to fisheries managers in Cambodia and Vietnam on management strategies to protect important fish juvenile spawning areas (Biological component of management strategy). For FY10 transfer, see TAP01UC (C-01). Companion study to 07MER01UC. See C0-1
07MNE03UM Controlling alien species	2	2	Eliminate stocking from reservoirs of the 2 introduced fish species (icefish in China and tilapia in Vietnam).
07QSD02PU Catfish-Baitfish Farming	1	1	Developing aquaculture of catfish fingerlings as baitfish to replace collection of wild catfish for Nile perch fisheries in Lake Victoria. See C-01 for related natural resource practices
07WIZ01PU Ghana water quality	1	1	BMP for biodiversity conservation: (1) responsible stocking and species translocation practices to prevent aquatic invasive and nuisance species spread and problems of homogenization of fish assemblages. For 3 other related practices, see C-01

Table X-7. AquaFish Investigation Indicator Reports for DTAP D-01: Number of new markets for aquatic products

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	D-01 Report Text
07FSV01UC Low-Value Fish Product Development	1	1	Recommendations on market channel and trade and economic aspects of processed low value fish, value added products (fish paste and fish sauce) for local and international trade. Transfer to government scheduled for December via mechanisms set up in 07TAP01UC. See also A-01, D-02.
07HHI05UH Nicaragua: depurated cockles	1	1	Depurated cockles undergoing market testing. Adoption of certified, depurated label expected in FY 10. As product, covered in A-01 and D-02
07IND03UH Mexico: spat collection	0	1	Local test-marketing of cultured native oyster delayed to FY10 due small-sized oysters caused by to El Nino effects. As product, covered in D-02
7MER02PU Supply Chain & Group Marketing	2	2	Management guidelines for (1) supply chain and (2) group marketing developed for fish farmers in Kenya and Ghana to enter urban markets. Transfer of extension manual (supply chain) and brochure (group marketing) in FY10. See 07QSD02PU for market development status.
07MER04NC Tilapia Export Markets	1	1	Currently investigating new markets for tilapia and what's needed to enter markets
07QSD02PU Baitfish Farming	1	1	Six market locations along Lake Victoria for farmers to sell cultured catfish-baitfish to traders.

Table X-8. AquaFish Investigation Indicator Reports for DTAP D-02: Number of aquatic products available for human food consumption

Investigation Code	FY09 DTAP Actual	FY10 DTAP Target	D-02 Report Text
07BMA02UM Sahar-Tilapia polyculture	1	1	Cultured sahar are now available for human consumption by farmers but sahar has not yet reached the market
07FSV01UC Low-Value Fish Product Development	1	1	BMPs for low-value/small fish processed, value-added products with improved food quality and safety under preparation for transfer in FY10 via 07TAP01UC. See also A-01, D-01.
07HHI01UM Microcystin control	1	1	Product development of microcystin-free fish will progress as technology is adopted. See B-01.
07HHI05UH Nicaragua: depurated cockles	1	1	Depurated cockle product (2 species sold together) in market testing for adoption in FY10 as certified product. See also A-01 and D-01.
07IND03UH Mexico: spat collection	0	1	Product expected for FY10. Local test-marketing of cultured native oyster delayed to FY10 due small-sized oysters caused by to El Nino effects. See also D-01.
07MNE02NC Sustainable coastal aquaculture	2	2	Product development initiated with trainings on seaweed and soft shell crab culture. Product availability expected in FY10. See C-01.
07SFT01UC Snakehead Feed Technology	1	1	Consumer food choice tests under development for FY10 to test product potential of snakehead fed on alternative plant-based diet.

KEY DEVELOPMENT TARGETS: INDICATORS & BENCHMARKS

AquaFish CRSP measures achievements in meeting key development targets through a set of internal indicators. The benchmarks provide a means to explore measures of performance different from those measured by the more quantitative DTAP or USAID indicator metrics. The Targets and Benchmarks tracked below are consistent with those in the Program Description of the USAID CA/LWA for this CRSP.[23] Year 1 Benchmarks cover 2006–2007. Benchmarks for Years 2–5 are appended and completed to show progress through this reporting period, which is Year 3.

This conceptual framework helps ensure that targets and benchmarks are adequately addressed across the AquaFish CRSP global portfolio for facilitating feedback and continuous learning in order to improve processes and outcomes. We report on the four key development targets of research, capacity, information dissemination, and IEHA. As the fifth target, gender strategy ensures strong programmatic commitment toward gender inclusion through plans implemented at the project level. Gender is both integrated into the four other targets and highlighted independently.

Research Target

Produce sustainable end-user aquaculture and fisheries research results that increase productivity, enhance international trade opportunities, and contribute to responsible aquatic resource management.

"Program-wide Research Indicators (refers to p.13 under *Technical Approach* in the CA/LWA Program Description):

(1) Developed and adopted innovative technologies that increase profitability and environmental stewardship in aquaculture and fisheries.
(2) Addressed biodiversity conservation issues to ameliorate threats to biodiversity and developed technologies and strategies to protect biodiversity habitat and populations.
(3) Continuously funded research projects that meet the expectations of external peer-review panels.
(4) Conducted appropriate biotechnology research to develop technologies that increase farm productivity.
(5) Engaged local stakeholders in research design, implementation, and results reporting through active participation in stakeholder meetings.
(6) Published AquaFish CRSP research in regional, national, and international peer-reviewed journals."

Year 1 Benchmarks (Successfully completed):

(a) Request for Proposals approved by USAID and widely advertised, and submitted proposals externally peer-reviewed.
RFP process through proposal finalist selection was completed on 31 March 2007.

(b) Favorably reviewed proposals have activities initiated.
Project work began in May 2007 with attendance at the Presynthesis & Orientation Meeting, formation of the advisory technical panels, and training on indicators, IEE, gender, and POP (Program Operating Procedures).

[23] The Targets and Benchmarks were again approved as part of the AquaFish CRSP M&E Plan in 2008.

Years 2–5 Benchmarks:
Benchmarks for this reporting period are drawn largely from the *Implementation Plan 2007–2009*. Benchmark reporting will progress under the peer-reviewed continuation plans that will be incorporated in the *Implementation Plan 2009–2011*.

(a) 1 innovative aquaculture and fisheries technology or strategy developed and disseminated throughout each region:
Africa: *Kenyan farmers participating in Purdue University's group marketing and supply chain project (07QSD02PU/07MER02PU) are currently marketing their farmed baitfish in markets along the shores of Lake Victoria. One highly successful group marketing cooperative is promoting the market cluster model and has taken the initiative to train fish farmers in this marketing strategy.*

Asia: *As a result of the multifaceted approach of the University of Michigan project in China and Vietnam, there are significant achievements in developing technologies and strategies for sustainable environmental management of various components of aquaculture and fisheries systems. In these studies, stakeholders have been actively engaged in the research through on-farm trials, surveys to assess the status of fish populations in the reservoirs, and surveys relating to aquaculture practices. For pond aquaculture, two new technologies are under transfer: (1) effluent reduction measures for pond aquaculture (07MNE04UM) and (2) an environmentally benign treatment to remove toxin-producing, blue-green algae blooms (07HHI01UM).*

On the basis of detailed assessments, AquaFish CRSP researchers have (1) recommended adoption of management plans to eliminate stocking of icefish (China) and tilapia (Vietnam) to protect the native fish biodiversity in three freshwater reservoirs (07MNE03UM) and (2) determined the ecological footprint of shrimp farming for domestic and international markets (07MNE05UM). Dissemination of this work is taking place in trainings and through networking of AquaFish CRSP researchers (07MNE07UM).

Latin America
Based on AquaFish CRSP recommendations developed from carrying capacity studies in the Boca Camichin Estuary, the Mexican government has imposed a ban on new oyster farms to control water quality and aquatic diseases. By including oyster producers in the monitoring work, AquaFish CRSP researchers developed an effective community-based collaboration with rural stakeholders. Community meetings with the oyster producers were designed to train them in culture and sanitation techniques for improved oysters safe for human consumption (07WIZ02UH).

(b) AquaFish CRSP activities remain locally appropriate by receiving regular input through the Regional Centers of Excellence and Development Theme Advisory Panels.
The RCEs have been active in establishing regional linkages with NGOs, governmental and academic institutions, and stakeholder groups. These linkages are serving to promote information exchanges and technology sharing among researchers, policymakers, government officers, and local stakeholders. RCE emphasis on empowering students and funding their participation in trainings and conference attendance is further strengthening the long-term training goals of the core research projects. These activities have helped the MT and project leaders in assessing needs for research and activities under the continuation plans.

The DTAP Lead Coordinators have played an instrumental role in evaluating work plan changes under the Implementation Plan 2007–2009. They have also provided substantive feedback to the MT through the DTAP impact reporting, which has guided the MT reviews of the continuation plans.

(c) Measured increases in farm productivity, farmer incomes, market access, and export value achieved following adoption of AquaFish CRSP recommendations and technologies.
Technologies and recommendations produced during this reporting year are improving the aquaculture and fisheries economic sectors for various levels of stakeholders. Stakeholders have

participated in research activities (University of Hawaii, University of Michigan, and University of Arizona projects), provided input into the development of management practices and policy recommendations (North Carolina State University, Purdue University, University of Connecticut, and University of Michigan projects), and actively trained fellow stakeholders (Purdue University).

Measured increases in income, market access, and export value will be evluated in the upcoming reporting year for the following achievements:

Farm/Fishery Productivity
Improvements are due to the following:

- *adoption of practices to mitigate pollution of receiving waters from pond effluents in China (07MNE04UM) and Ghana ((07WIZ01PU)*
- *adoption of management practices or improved technologies: catfish fingerling aquaculture (07QSD02PU), tilapia-catfish polyculture (07MER003PU), tilapia-sahar polyculture (07BMA02UM), seaweed-fish-mollusc-shrimp polyculture and soft-shell mud crab aquaculture (07MNE02NC), and Nile tilapia seedstock (07QSD01NC)*
- *implementation of management plans to control alien species introduction in three freshwater reservoirs in Vietnam and China as a step to maintain sustainable fisheries (07MNE03UM)*
- *improved implementation of management plans to control carrying capacity of an estuary for oyster production (07WIZ02UH) and to protect important spawning areas in the Lower Mekong River Basin (07MNE01UC)*

Also, see DTAP C-02 reports showing number of hectares under improved natural resource management (Table X-5).

***Farmer Income**: Farmers, processors, and vendors benefitting from improved productivity as listed above will see increases in income. Similarly, farmers adopting sustainable feed technologies (07SFT01UC, 07SFT02NC, 07SFT04UA, 07SFT05UA, 07SFT06PU) will be able to lower a major production cost and thereby improve their profit margins; producers of depurated cockles will potentially improve their income in FY10 if there is market success with certified, depurated cockles (07HHI05UH).*

***Market Access**: Baitfish farmers who are now successfully selling at six market locations along the shores of Lake Victoria are already experiencing improved market access (07QSD02PU/07MER02PU). Ghanaian farmers who adopt the supply chain/group marketing model will have more opportunities in urban markets (07MER02PU). Depurated cockles can potentially provide access to more markets if there is demand for this value-added product.*

***Export Value**: Tilapia farmers in the Philippines who adjust production to meet the specific requirements of the export markets will have expanded income opportunities (07MER04NC). Markets for processed fish in Cambodia/Vietnam will potentially expand through value-added product development of processed small, low-value fish products (07FSV01UC).*

(d) Threats to biodiversity resulting from aquaculture activities ameliorated and biologically significant areas positively impacted.
A management recommendation to eliminate alien species introductions in three freshwater reservoirs in China and Nepal will protect the biodiversity of native species in the reservoirs and help ensure a sustainable native fishery (07MNE03UM). In Kenya, the successful development of catfish-baitfish aquaculture offers an alternative source of baitfish to Nile perch fishers on Lake Victoria, thereby protecting the threatened wild catfish fishery (07QSD02PU).

Several sustainable feed technology investigations target reduction of fishmeal in aquaculture feed as both a cost-savings measure and sustainable practice to reduce pressures on wild-caught fish used for fishmeal (07SFT01UC, 07SFT02NC, 07SFT04UA, 07SFT05UA, 07SFT06PU). The move away

from fishmeal serves to protect local and international wild-caught fisheries used as sources of fishmeal inputs (e.g., small, low-value fishery in the Mekong River).

The Director and US Lead PI Jim Diana began planning a symposium entitled "Effects of Aquaculture on Biodiversity" to be held in 2011. The Symposium is intended to highlight the benefits of aquaculture for protecting and improving biodiversity as well as biodiversity issues associated with aquaculture systems. Planning is underway for identifying co-funders and invited speakers, arranging for publication of symposium papers in a dedicated issue of an international journal, scheduling and location of the symposium, and finalizing details and logistics for the symposium event.

(e) Cost-effective biotechnology appropriate for use in developing countries developed.
Innovative technologies developed with biotechnological techniques will bring cost efficiencies to MT residue control and growth performance monitoring which will translate to improved productivity in aquaculture systems. Removal of MT residues from pond water with either a TiO_2-UV system or bacterial degradation (07MNE06UA) will address an environmental impact issue associated with masculinization systems used in tilapia hatchery production. The IGF-1 assay will serve as a simple tool for measuring fish growth performance in the field (07SFT02NC).

(f) Continuous academic output of AquaFish CRSP data as publications within recognized journals and presentations provided at regional, national, and international forums.
AquaFish CRSP researchers have published over 30 scientific articles since the start of the program and have submitted a significant number of articles for peer-review publication. They have also presented their work in a wide array of international, national, and regional conferences and symposia, taught academic seminars and participated in professional workshops and meetings.

Capacity Building Target

Focus AquaFish CRSP investments on building local capacity in aquaculture and aquatic resource management and ensuring long-term program impacts at local and national levels through strategic informal and formal training opportunities. Integrate items related to gender.

"Capacity Building Indicators – Regional (refers to p.13 under *Technical Approach* in the CA/LWA Program Description):

(1) Forged professional and managerial relationships between US and Host Country researchers and institutions.
(2) Established track record of successful formal long-term training of Host Country and US students and researchers.
(3) Delivered relevant short-term training opportunities that provide positive Host Country societal benefits beyond the life of the AquaFish CRSP.
(4) Identified gender issues in aquaculture and fisheries and adopted gender program-wide integration policies."

Year 1 Benchmarks (Successfully completed):

(a) An additional year of the highly successful Host Country Principal Investigator Exchange Project continued to exchange information on cichlid aquaculture to additional countries including two IEHA countries.
Phase II exchange visits to South Africa and Ghana (October 2007), Vietnam (December 2007), and Vietnam (February 2008) were conducted and the HCPI project was successfully completed in the previous reporting period.

(b) The jointly funded NOAA Sea Grant Technical Assistance program continued
The Director and Jim Murray, Deputy Director of NOAA/Sea Grant discussed model cases in Korea and finalized the exchange visit for Paul Olin, Director of the California Sea Grant Extension Program. Three Lead US PIs (James Diana, Maria Haws, and Robert Pomeroy) actively engaged in

management of their regional Sea Grant Programs, and have networked CRSP efforts into Sea Grant on a regional basis.

(c) Gender integration strategies adopted within all sub-awards
All six projects adopted a strategy consistent with the CRSP integrated approach; USAID (Julie Swanson) reviewed all six projects and met with PIs during the May 2007 orientation meeting.

(d) Regional Centers of Excellence established to reflect the AquaFish CRSP regions for research activities (i.e., Asia, Africa, and Latin America and the Caribbean)
Three RCEs were established and the Director appointed, with USAID consultation, Lead Coordinators at the May 2007 orientation meeting.

(e) Formal Memoranda of Understanding adopted between all US and Host Country partners
MOUs and/or Subcontracts are completed for all projects that began in Year 1 with the exception of University of Arizona's MOUs and subcontracts that are still in process.

Years 2-5 Benchmarks:

(a) Partnerships strengthened among US and Host Country universities, NGOs, NARS, and USAID Missions through Associate Awards.
Partnerships are fully developed for each of the six core projects and MOUs are in process for the new IEHA project with Auburn University. The three RCEs have also established additional linkages and partnerships with regional and international organizations and institutions. A three-year Associate Award with the USAID Mission in Mali (1 October 2007– 30 September 2010) for an aquaculture and fisheries project in Mali has entered into its third year.

(b) At least 100 degree students enrolled through formal long-term training opportunities in US, Host Country, and Regional universities.
Since program inception, 184 students have been enrolled in long-term training. Of these 18 (14 women/4 men) completed their degrees in FY07–FY08. As of the end of FY09, 169 degree students from the US and 17 countries are enrolled in long-term academic programs associated with core research projects, the Synthesis Project, and the Management Office. Of these, 138 students are Host Country nationals. In the Host Country group, two-thirds of the students are from four countries: Vietnam (23, 17%), Mexico (22, 16%), China (21, 15%), and Philippines (26, 19%). There are also 3 high school or certificate degree students.

(c) Equal numbers of women and men trained through short- and long-term training opportunities.
***Short-Term Training**: The total number of individuals receiving training since program inception is 2,402 (FY08: 903; FY09: 1,499). Of these, gender data were available for 2,328 trainees. Women comprised a total of 759 or 32.6% of the trainees (FY08: 301; FY09: 458).*

***Long-Term Training**: The 50% cumulative enrollment of Host Country women (76 women) in degree programs has met the program's 50% target. Overall, including US and non-Host Country students, there is also a 50% cumulative enrollment (92 women). The three Mali Associate Award Project students are excluded from these data.*

(d) Numerous train-the-trainer workshops convened to provide Host Countries with highly skilled extension specialists
Short-term trainings are designed to integrate stakeholders at all levels, thereby removing barriers between farmers/fishers and extension agents/fisheries officers, etc. An additional component of trainings is the empowerment of trainees to "train" their counterparts. Successes of this integrated approach are exemplified by the catfish farmer trainings in Kenya (07QSD02PU), feed formulation trainings in Guyana (07SFT06AU), as well as shellfish sanitation workshops (07HHI03UH, 07HHI04UH). Other trainings specifically designed as Train-the-Trainer include the following:

- *07BMA05UH: intensive training and internship on bivalve culture and sanitation*
- *07IND01UA: international workshop on snook biology for professionals*
- *07MNE06UA: technical workshop for extensionists and students on MT elimination*
- *07MNE07UM: project level workshop on aquaculture, human health, and the environment*
- *07TAP01UC: farmers training of trainer workshop on alternative feed for snakehead aquaculture*

(e) Biotechnology and biodiversity training activities conducted as identified.
Biotechnology short-term trainings:
MT elimination (07MNE06UA): 2 workshops
Biotechnology of marine algae (07BMA03UA): 1 workshop

Biodiversity short-term trainings:
Seaweed-fish-mollusc-shrimp polyculture trainings (07MNE02NC): 8 workshops
Tilapia-sahar polyculture (07BMA02UM): 1 workshop
Alien species introductions (07MNE03UM): 3 workshops
Native cichlid farmer trainings (07IND02UA): 2 workshops
Native oyster culture trainings (07IND03UH): 1 workshop

Information Dissemination Target:

Disseminate AquaFish CRSP research results to foster broad application of results among local stakeholders within governmental and non-governmental organizations, as well as for end-users.

"Information Dissemination Indicators – Regional (refers to pp.13-14 under *Technical Approach* in the CA/LWA Program Description):
(1) Successful diffusion of AquaFish CRSP research results and technologies between countries within a region having comparable social and environmental conditions.
(2) Increased awareness of local stakeholder constraints and opportunities related to responsible aquaculture and fisheries management.
(3) Applicable extension activities associated with each research project conducted to ensure wide dissemination of research results
(4) AquaFish CRSP results and technologies for farm operations adopted and policies for responsible aquatic resource management created.
(5) Applicable technologies developed and adopted by the US and other countries' aquaculture and fisheries sectors."

Year 1 Benchmarks (Successfully completed):
(a) Dissemination efforts have continued through *Aquanews*, EdOp Net, and a new searchable online publication database.
Publication services continued uninterrupted during the transition from the former ACRSP into the first year of AquaFish CRSP: quarterly issues of Aquanews (Vol. 22, Nos. 1-3; Vol. 23, No.1); 12 monthly issues of EdOp Net; CRSP Notices of Publication for 22 peer-reviewed research reports by CRSP researchers.

(b) The importance of extension evident through integration of at least one outreach activity within each funded project.
The RFP institutionalizes the integration of research and outreach by requiring proposals to contain at least one outreach investigation and to include an Outreach and Dissemination Plan. Proposals were revised as necessary to include one or more outreach activities prior to being approved as core projects.

(c) Research adoption encouraged by prioritizing the use of on- and off-farm trials to conduct research.

On- and off-farm trials and other types of field trials were included as appropriate within each project to promote research adoption as follows:

- *07BMA02UM: tilapia-sahar stocking density trial in collaboration with the Rural Integration Development Society*
- *07HHI01UM: on-farm microcystin controls and consultation with farmer cooperators*
- *07HHI02UA: aquaculture effluent-irrigation trial with farmer cooperator*
- *07HHI05UH: test marketing of depurated black cockle*
- *07IND01UA: farm trials to assess tranferability of experimental snook aquaculture*
- *07IND03UH: women's oyster cooperatives involved with spat collection*
- *07IND04UH: active participation by community members in oyster depuration trials*
- *07MER03PU: on-farm trials using small-scale farmers' ponds*
- *07SFT05UA: on-farm trial of experimental diets using local ingredients.*

Years 2-5 Benchmarks:

(a) Intra- and inter-regional diffusion of AquaFish CRSP results and technologies accomplished.
On a regional basis, short-term trainings and workshops are successfully transferring research results, management practices, technologies, and recommendations to the various levels of stakeholders from rural farmers to stakeholders. Professional-level workshops and CRSP-sponsored conferences (e.g., Workshop on Marine Algae, ISTA8) have served as vehicles for the diffusion of results and technologies beyond the areas targeted by AquaFish CRSP investigations. Through their promotion of linkages and collaborative networks, the RCEs have also actively contributed to inter-regional diffusion.

(b) Training manuals with local and regional scopes published following completion of AquaFish CRSP research projects.
Outreach materials with local and regional scope that are currently available include the following:

- *(07TAP02NC) Tilapia Podcast*
- *(07MNE04UM) BMPs for Effluent Control in Aquaculture transferred in trainings*
- *(07QSD02PU) Fact Sheets on Pond Production: Pond Fertilization, Pond Liming, Feeding, Stocking & Harvesting*
- *(07MER02PU) Extension Brochure: Marketing Strategies for Smallholder Fish Farmers in Sub-Saharan Africa*
- *(07MER02PU) Extension Manual: Forming an Effective Fish Farmers' Cooperative in Sub-Saharan Africa*

(c) At least 30 workshops convened over the course of the 5-year AquaFish CRSP.
Scheduling of workshops began in Year 2 (FY08). Since then, 77 workshop/trainings have been held across the six core projects: 30 in FY08 and 47 in FY09.

IEHA Country Involvement Target:

Expand AquaFish CRSP science and technology efforts in IEHA Host Countries to increase local capacity and productivity thereby contributing to national food security, income generation, and market access.

"IEHA Indicators – Within each participating IEHA Host Country (refers to p.14 under *Technical Approach* in the CA/LWA Program Description):

(1) Development and adoption of innovative technologies that increase profitability and environmental stewardship in the context of aquaculture and fisheries.
(2) Students enrolled in formal long-term training programs within Host Country, Regional, and US universities;

(3) Increased awareness of stakeholder constraints and opportunities related to responsible aquaculture and fisheries management.
(4) Applicable extension activities associated with each research project conducted to ensure wide dissemination of research results.
(5) AquaFish CRSP results and technologies adopted for farm operations and policies for responsible aquatic resource management created.
(6) Increased farm income and local economic growth through enhanced market access in project areas."

Year 1 Benchmarks (Successfully completed):

(a) Formal strategy initiated to maximize locally appropriate results in participating IHEA Host Countries.
The Purdue University IEHA project is designed to improve competitiveness by empowering small holders and developing local economies and markets through capacity building, improved technology, and management of supply chain and natural resources.

(b) Sites selected and formal connections established with suitable research institutions and government departments within each IHEA Host Country.
The Purdue University IEHA project is currently negotiating MOUs and establishing linkages.

(c) The Africa Regional Center of Excellence has representation from IEHA countries to design research and outreach activities.
The RCE Lead Coordinator has established initial linkages within IEHA countries.

Years 2-5 Benchmarks:

(a) Formal linkages, collaborative research, and outreach activities fostered between US universities and IEHA site institutions.
The Purdue University project which conducts research in the two IEHA countries of Ghana and Kenya has formally partnered with Moi University (Kenya), Kwame Nkrumah University of Science & Technology (Ghana), and Virginia Polytechnic Institute & State University (US). These linkages encompass collaborative research on three investigations. To date, outreach activities in Kenya and Ghana have included seven farmer trainings and production of (1) Fact Sheets covering stocking and harvesting, feeding, pond liming, and pond fertilization, (2) BMPs for Effluent Control in Aquaculture, (3) an Extension Brochure "Marketing Strategies for Smallholder Fish Farmers in Sub-Saharan Africa" and an Extension Manual, "Forming an Effective Fish Farmers' Cooperative in Sub-Saharan Africa." The BMPs and extension publications were completed in November 2009.

The new IEHA project with Auburn University as the lead has been in the process of establishing formal linkages with the following US and Host Country institutions through MOUs:

- *Alabama A&M University (US)*
- *University of Georgia (US)*
- *Gulu University (Uganda)*
- *Makerere University (Uganda)*
- *Uganda National Fisheries Resources Research Institute (Uganda)*
- *Stellenbosch University (South Africa)*

Through the RCE-Africa as well as other efforts by CRSP researchers, additional collaborations and linkages are being developed with FAO, SARNISSA, NEPAD, ANAF, FishAfrica, local NGOs (e.g., Women in Fishing Industry Project – Kenya), government agencies (e.g., Uganda Commission for Fisheries), and the USAID Missions in Kenya and Mali. Collaborative research has also been pursued by the RCE-Africa through other funding sources.

Linkages developed by the Mali Associate Award project include the following regional and international institutions: Direction Nationale de la Pêche, Moi University, Shanghai Ocean University, Network of Aquaculture Centres in Asia-Pacific, Department of Fisheries-Kenya, Sichuan Aquacultural Engineering & Technology Research Center.

(b) Long-term research projects addressed specific needs of each IEHA Host Country.
Bringing Kenyan farmers into a successful farming enterprise to raise catfish fingerlings for sale as baitfish for Nile perch fishers has addressed needs of several stakeholders: fish farmers for whom the group marketing clusters will ensure a viable business enterprise; baitfish traders who can depend on a steady supply of farmed fish to sell to fishers; rural communities along the shores of Lake Victoria whose livelihoods and food security depend on a sustainable catfish fishery that will be protected from overexploitation with the availability of farmed catfish fingerlings.

Development of BMPs for aquaculture farmers in Ghana will help ensure cost-effective production practices that will reduce feed waste and effluent output from ponds into receiving waters. With improved production methods, Ghanaian farmers can improve their income.

(c) Diffusion of knowledge facilitated between separate research projects ongoing within each IEHA Host Country.
Kenyan farmers visited fish farm facilities in Uganda in a collaborative training conducted in FY09 (07QSD02PU). Kenyan researchers are serving as partners on the Associate Award Project in Mali, benefiting that project with their expertise that has been built over the long term through CRSP research activities.

Also, the HCPI Phase II Project involved Ghanaian and Kenyan researchers in a regional exchange in Africa.

(d) A measured increase in farm productivity, farmer incomes, market access, and export value has followed adoption of AquaFish CRSP recommendations and technologies in project areas.

Catfish farmers who have adopted baitfish culture practices and become members of group marketing clusters have improved pond productivity by following AquaFish CRSP management practices. Their total production of catfish fingerlings has reached 250,000 fry/fingerlings since 2006, when production was virtually non-existent. Since CRSP's initiation of this farmed baitfish program, survival rate of fingerlings has increased from less than 10% to 50% representing an increase in productivity of 400%. Six (6) new baitfish market centers have been opened along Lake Victoria, and baitfish farmers have recorded about 50% increase in sales. Most baitfish farmers recorded about 65% increase in farm income from baitfish production. (07QSD02PU/02MER02PU).

Gender Integration Strategy

The AquaFish CRSP is dedicated to improving gender inclusiveness in the Aquaculture and Fisheries sectors, and in the CRSP arena. Gender Integration is implicit and interwoven into in the above "target" benchmarks and indicators requested by USAID in its 2006 RFA. Additional explicit guidance, in the form of an improvement plan, was established for CRSP operations.

Year 1 Initiatives:

(a) Require that all funded projects address gender inclusiveness within their planned scope-of-work.
The RFP requires that all projects have a strategy for integrating and addressing gender (a Gender Strategy). Strategies for gender inclusiveness have been incorporated into revisions to the proposals submitted in June 2007.

(b) Seek out USAID review of projects' gender inclusiveness plans and respond by improving plans prior to project implementation.
The ME submitted revised proposals with gender inclusiveness plans to USAID in June 2007. Proposal revisions addressed USAID suggestions prior to receiving funding, and prior to implementation.

(c) Promote the participation of women in formal and informal education and training opportunities provided through the CRSP. The CRSP has set a 50% benchmark for training women in formal and informal education. In addition, the 50% benchmark applies to attracting and retaining women scientists and administrators in all CRSP activities, as project researchers, advisory group members, and managers.
Projects are committed to promoting the participation of women at all levels from target populations to top-level researchers. Women are well represented in CRSP management, Advisory Groups, and in the group of Principal Investigators and collaborators. Women are the focus of stand-alone studies, which are included in the portfolio to reflect a gendered perspective.

Years 2–5 Initiatives:

(a) Collect disaggregated gender data from individual research and outreach projects funded by the CRSP.
Data for short-term and long-term training activities are disaggregated and are covered in the Capacity Building sections of this and the Second Annual Report.

(b) Analyze disaggregated data on an annual basis to gauge gender inclusiveness success and take appropriate action as indicated through data analysis.
To date, the analysis has shown that long-term training is close to meeting the targeted 50% gender integration goal, reaching it in FY08 at 50.4% and falling slightly short in FY09 at 46.7%. The short-term training goal of 50%for FY08–FY09 is still short of the target (at 33%). Renewed efforts under the continuation plan will go into effect in 2010 to improve gender integration in short-term trainings by addressing constraints that limit the number of women currently engaged in aquaculture and fisheries.

(c) Involve field projects in monitoring and evaluating gender integration as the program progresses with time. Evaluate the effects of specific projects on gender and ensure that any possible negative effects due to gender bias are mitigated.
Disaggregated gender data are currently reported for all long- and short-term trainings as well as for field trials. Gender of all US and HC staff is also currently reported. Each core project has a gender integration strategy that outlines steps to increase the number of, and mitigate bias against, female participation. Work under continuation plans (2009-2011) includes at least one activity focusing specifically on gender issues.

(d) Focus one component of a lessons learned and synthesis assessment specifically on the social context and impact of CRSP research and outreach activities on the lives of women.
The second RFP (May 2009) specifically requires new projects to design and implement an activity focusing on women as follows:

Technical Considerations for Award of a CRSP Project *(p. 6, Items 3 & 5):*

3. Proposals must include at least one experiment or study. Proposals must also include at least one outreach activity that focuses on women.

5. Investigations must integrate gender to the extent possible to meet program targets. Overall, proposals will include a gender inclusiveness strategy (RFP website: Gender Inclusivity Strategy). ***The existing strategy can be revised or resubmitted if it is still applicable to the work proposed. If resubmitting the gender strategy from 2007-09, additional details incorporating gender will need to be apparent in the new investigations.***

(e) Tailor specific extension and technical services related to sustainable aquaculture and aquatic resource management to women producers.
The following activities were tailored specifically for women producers:

- *Community-level shellfish culture and sanitation trainings: collaboration with women's producer organizations/cooperatives (07HHI04UH, 07IND03UH) and focus on women participating in community trainings (07HH05UH, 07IND04UH, 07WIZ02UH)*
- *Tilapia-Sahar polyculture: collaboration with RIDS-Nepal to include 50% women in the farmer training (07BMA02UM)*
- *Women processors: assessments of utilization and processing practices for small, low-value fish from the Mekong River fishery include a specific focus on the role of women (07FSV01UC)*
- *Women's Cooperative: collaborative assistance of the Trafalgar Women's Cooperative in the feed formulation trainings associated with the sustainable feed studies in Guyana (07SFT04UA/07SFT05UA)*

(f) Engage extension specialists sensitive to diversity issues and access to resources of underrepresented groups and women will be included as an integral part of their delivery team to ensure women farmers and fishers feel welcome in CRSP training opportunities. *Each core project has a gender integration strategy that outlines steps to increase the number of women participating in short-term trainings and enrolling in long-term degree programs: (1) female researchers and students are being given positions as worshop presenters to establish connections with women trainees, (2) constraints limiting attendance in workshops are being addressed (e.g., more flexibility in workshop location and scheduling), (3) extension specialists are being trained to be more gender sensitive, (4) women are being invited to participate in on-farm trials, (5) women's producer cooperatives have been actively sought out to collaborate with AquaFish CRSP researchers, and (6) research focus and strategy are taking into account women's roles as food providers and preparers as well as their key positions in production/marketing.*

USAID – DTAP INDICATORS CROSS-REFERENCING

The AquaFish CRSP DTAP and Key Development Target Indicators are specifically tailored for assessing program-specific achievements, impacts, targets, and benchmarks. Tables X-9 to X-13 cross-reference these program indicators with USAID's broader, more general EG and IEHA Indicators listed below:

Agriculture Program Element Indicators (EG 5.2 Agriculture Sector Productivity)

- **5.2-14:** Number of new technologies or management practices under research as a result of USG assistance.
- **5.2-15:** Number of new technologies or management practices being field tested as a result of USG assistance.
- **5.2-16:** Number of new technologies or management practices made available for transfer as a result of USG assistance.
- **5.2-17:** Number of additional hectares under improved technologies or management practices as a result of USG assistance.
- **5.2-19:** Number of rural households benefiting directly from USG interventions
- **5.2-20:** Number of producers organizations, water users associations, trade and business associations, and community-based organizations (CBOs) receiving USG assistance
- **5.2-21:** Number of agriculture-related firms benefiting directly from USG supported interventions.
- **5.2-22:** Number of public-private partnerships formed as a result of USG assistance.
- **5.2-26:** Number of individuals who have received USG supported short-term agricultural sector productivity training – Female & Male
- **5.2-27**: Number of individuals who have received USG supported long-term agricultural sector productivity training – Female & Male
- **5.2-28:** Number of women's organizations/associations assisted as a result of USG interventions.

IEHA Performance (Outcome) Indicators[24]

- IR 1.1 Adoption of New Technology: Fish (Aquaculture)

[24] For FY09, AquaFish CRSP only reported on IR1.1. IEHA Output Indicators are not included here given their direct correspondence with the EG 5.2 indicators listed above.

Cross-Referencing

AquaFish CRSP and USAID's EG and IEHA indicators do not have a one-to-one correspondence. In most cases, the USAID indicators apply only in part and usually form a mixed combination for a given AquaFish CRSP program indicator.

Tables X-9 to X-13 illustrate (1) how the CRSP indicators are an extension of USAID's EG and IR indicator sets and (2) how general features of the USAID set can be encompassed within a specific AquaFish CRSP indicator. Where there is no correspondence between the two indicator sets, the USAID indicator cell is marked "NA" (Not Applicable) in Tables X-9 to X-13.

Table X-9 AquaFish CRSP Development Themes

USAID EG 5.2 Indicators[25]	AquaFish CRSP Impact Indicators
5.2-14 5.2-15 5.2-16	**DTAP A**: **Improved Health and Nutrition, Food Quality, and Food Safety of Fishery Products** *A-01: Number of aquaculture products developed to improve food safety or quality*
5.2-14 5.2-15 5.2-16 5.2-19 5.2-20 5.2-21 5.2-22 5.2-26 5.2-27 5.2-28	**DTAP B: Income Generation for Small-Scale Fishers and Farmers** *B-01: Number of new technologies developed* *B-02: Number of institutions with access to technological practices*[26] *B-03: Number of (people) trained in use of technological practices*
5.2-14 5.2-15 5.2-16 5.2-17 5.2-20 5.2-21 5.2-26 5.2-27 5.2-28	**DTAP C: Environmental Management for Sustainable Aquatic Resources Use** *C-01: Number of management practices developed or adopted to improve natural resource management* *C-02: Number of hectares under improved natural resource management* *C-03: Number of management practices developed to support biodiversity* *C-04: Number of people trained in practices that promote soil conservation and/or improved water quality*
5.2-14 5.2-15 5.2-16	**DTAP D: Enhanced Trade Opportunities for Global Fishery Markets** *D-01: Number of new markets for aquatic products* *D-02: Number of aquatic products available for human food consumption*

[25] Cross referencing for the CRSP DTAP indicators is at the thematic level.
[26] To broaden the reporting capability, the term "institution" in DTAP B-02 was defined to include two categories: (1) organizations of all types, e.g., public entities, NGOs, cooperatives, businesses; and (2) rural communities.

Table X-10. AquaFish CRSP Research Targets

USAID EG 5.2 Indicators	AquaFish CRSP Research Indicators
5.2-14 5.2-15 5.2-16 5.2-19 5.2-20 5.2-21 5.2-22 5.2-26 5.2-27 5.2-28	(1) Developed and adopted innovative technologies that increase profitability and environmental stewardship in aquaculture and fisheries.
NA	(2) Addressed biodiversity conservation issues to ameliorate threats to biodiversity and developed technologies and strategies to protect biodiversity habitat and populations.
NA	(3) Continuously funded research projects that meet the expectations of external peer-review panels.
5.2-14	(4) Conducted appropriate biotechnology research to develop technologies that increase farm productivity.
5.2-19 5.2-20 5.2-21 5.2-22 5.2-28	(5) Engaged local stakeholders in research design, implementation, and results reporting through their active participation in stakeholder meetings.
NA	(6) Published AquaFish CRSP research in regional, national, and international peer-reviewed journals.

Table X-11. AquaFish Capacity Building Targets

USAID EG 5.2 Indicators	AquaFish CRSP Capacity Building Indicators
5.2-14 5.2-15 5.2-22	(1) Forged professional and managerial relationships between US and Host Country researchers and institutions

Table X-11. AquaFish Capacity Building Targets

USAID EG 5.2 Indicators	AquaFish CRSP Capacity Building Indicators
5.2-27	(2) Established track record of successful formal long-term training of Host Country and US students and researchers.
5.2-16 5.2-19 5.2-20 5.2-21 5.2-22 5.2-26 5.2-28	(3) Delivered relevant short-term training opportunities that provide positive Host Country societal benefits beyond the life of the AquaFish CRSP.
5.2-28	(4) Identified gender issues in aquaculture and fisheries and adopted program-wide, gender-integration policies.

Table X-12. AquaFish CRSP Information Dissemination Targets

USAID EG 5.2 Indicators	AquaFish CRSP Information Dissemination Indicators
NA	(1) Successful diffusion of AquaFish CRSP research results and technologies between countries within a region having comparable social and environmental conditions.
NA	(2) Increased awareness of local stakeholder constraints and opportunities related to responsible aquaculture and fisheries management.
5.2-16 5.2-26	(3) Applicable extension activities within each research project conducted to ensure wide dissemination of research results.
5.2-16 5.2-26	(4) Adoption of AquaFish CRSP results and technologies for farm operations and policies created for responsible aquatic resource management.
5.2-14 5.2-15 5.2-16 5.2-19 5.2-20 5.2-21 5.2-22 5.2-26 5.2-28	(5) Applicable technologies developed and adopted by the US and other countries' aquaculture and fisheries sectors.

Table X-13. IEHA Country Involvement Targets

USAID EG 5.2 & IEHA Indicators	AquaFish CRSP IEHA Indicators
5.2-14 5.2-15 5.2-16 5.2-19 5.2-20 5.2-21 5.2-22 5.2-26 5.2-28 IR 1.1	(1) Development and adoption of innovative technologies that increase profitability and environmental stewardship in the context of aquaculture and fisheries.
5.2-27	(2) Students enrolled in formal long-term training programs within Host Country, regional, and US universities.
NA	(3) Increased awareness of stakeholder constraints and opportunities related to responsible aquaculture and fisheries management.
5.2-16 5.2-26 IR 1.1	(4) Applicable extension activities associated with each research project conducted to ensure wide dissemination of research results.
5.2-16 5.2-22 5.2-26 IR 1.1	(5) AquaFish CRSP results and technologies adopted for farm operations and policies for responsible aquatic resource management created.
NA	(6) Increased farm income and local economic growth through enhanced market access in project areas.

USAID IMPACT REPORTING

AquaFish CRSP reports under USAID's various impact reporting frameworks to achieve outcomes that have meaning for stakeholders, including Missions, HC decision makers, and end-users. The indicator reports that were filed with USAID for this reporting year are presented in this section.

USAID-EGAT Indicator Reporting

For this reporting period, AquaFish CRSP only reported under USAID-EGAT 5.2 Agriculture Sector Productivity indicators (Table X-14). Tables X-15 to X-17 provide supporting data for the technologies, practices, products, and markets reported under the technology indicators, 5.2-14 to 5.2-16.[27]

Table X-14. AquaFish CRSP FY09 USAID-EGAT Indicator Report as submitted on 1 November 2009

4.5.2 Agriculture Sector Productivity	FY 2009 Targets	FY 2009 Results	FY 2010 Targets
5.2-14: Number of new technologies or management practices under research as a result of USG assistance.	12	58	58
5.2-16: Number of new technologies or management practices made available for transfer as a result of USG assistance.	6	24	24
5.2-15: Number of new technologies or management practices being field tested as a result of USG assistance.	13	21	21
5.2-17: Number of additional hectares under improved technologies or management practices as a result of USG assistance.	na	3,543	2,774
5.2-19: Number of rural households benefiting directly from USG interventions	1200	1,003	1,000
5.2-20: Number of producers organizations, water users associations, trade and business associations, and community-based organizations (CBOs) receiving USG assistance	6	10	10
5.2-21: Number of agriculture-related firms benefiting directly from USG supported interventions.	6	10	10
5.2-28: Number of women's organizations/associations assisted as a result of USG interventions.	6	6	6
5.2-22: Number of public-private partnerships formed as a result of USG assistance.	9	21	21
5.2-26: Number of individuals who have received USG supported short-term agricultural sector productivity training - Female	500	437	500
5.2-26: Number of individuals who have received USG supported short-term agricultural sector productivity training - Male	500	944	500
5.2-27: Number of individuals who have received USG supported long-term agricultural sector productivity training - Female	65	72	75
5.2-27: Number of individuals who have received USG supported long-term agricultural sector productivity training - Male	62	75	75

[27] Metrics are based on the best available data at the time of the 1 November 2009 reporting date. They vary from updated data received after 1 November. See Tables X-15–17 for supporting documentation on the revised 5.2-14 to 5.2-16 technology indicator metrics and *Capacity Building* (pp. 99–120) for revised FY09 short- and long-term training data for the 5.2-26 and 5.2-27 indicator metrics.

Table X-15: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-14: Number of new technologies or management practices under research as a result of USG assistance, revised based on information reported after 1 November 2009.

Investigation Code	5.2-14 Technology (Tech)	Tech Total	5.2-14 Practice (Prac)	Prac Total	5.2-14 Product (Prod)	Prod Total	All Total
07BMA02UM		0	Sahar-Tilapia polyculture stocking density	1	Cultured sahar are available for consumption	1	
07FSV01UC		0		0	Recommendations for developing value-added processed low-value fish products with food quality and safety	1	
07HHI01UM	Technique for testing microcystin content in fish and pond water: (1) chitosan-modified clay, (2) PAC-modified clay	2		0	Microcystin-free cultured tilapia and catfish	1	
07HHI02UA	Aquaponics with aquaculture pond effluent	1	Bacteria-free pond effluent for food crop irrigation water: (1) gravity irrigationfrom ponds; (2) hose for the effluent; (3) recirculating aquaculture system	3		0	
07HHI05UH	Depuration of cockles (*Anadara* spp.)	1		0	Certified, depurated cockles	1	
07IND01UA	Snook seed production: (1) holding system for maintaining healthy adults, (2) feeds that encourage gamete development, and (3) induced spawning	3		0		0	
07IND02UA	(1) Genetic improvement of native cichlids (2) Alternative feed substitution for fishmeal	2		0		0	
07IND03UH	Spat collection of native oyster (*Crassostrea* corteziensis)	1		0	Cultured native oyster species	1	
07IND04UH	Relay and depuration of oysters	1		0	Certified, depurated oysters	1	
07MER01UC		0	Development of policy framework for aquaculture/capture fisheries interactions, sustainable management of low-value fish, and food security in the lower Mekong River basin	1		0	
07MER02PU					Management guidelines for (1) supply chain and (2) group marketing developed for fish	2	

Table X-15: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-14: Number of new technologies or management practices under research as a result of USG assistance, revised based on information reported after 1 November 2009.

Investigation Code	5.2-14 Technology (Tech)	Tech Total	5.2-14 Practice (Prac)	Prac Total	5.2-14 Product (Prod)	Prod Total	All Total
					farmers		
07MER04NC		0		0	Currently investigating new markets for tilapia in the Philippines.	1	
07MNE01UC		0	Recommendation to fisheries managers in Cambodia and Vietnam on management strategies to protect important fish juvenile spawning areas	1		0	
07MNE03UM		0	Develop management recommendation for stocking of introduced (1) icefish and (2) tilapia in reservoirs located in China and Vietnam	2		0	
07MNE04UM		0	Waste management practices for freshwater and marine aquaculture identified: (1) stocking density; (2) aeration	2		0	
07MNE05UM		0	Life Cycle Assessment of sustainability of flow through and reuse systems for shrimp farms and hatcheries identified optimum practices: (1) moderate stocking densiy, (2) aeration to reduce effluent and electricity use	2		0	
07MNE06UA	Clean tilapia masculinization technologies: (1) MT degradation by TiO2; (2) bacterial degradation (3) MT measurement using ELISA	3		0		0	
07QSD01NC	Hatching system for Nile tilapia fry production and fingerling growout	1		0		0	

Table X-15: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-14: Number of new technologies or management practices under research as a result of USG assistance, revised based on information reported after 1 November 2009.

Investigation Code	5.2-14 Technology (Tech)	Tech Total	5.2-14 Practice (Prac)	Prac Total	5.2-14 Product (Prod)	Prod Total	All Total
07SFT01UC	Alternative feed technologies for snakehead: (1) Weaning of hatchery-raised snakehead to adapt to pelleted diet (2) Pelleted feed for hatchery-raised C. striata snakehead and C. micropeltes snakehead. (3) Rice bran substitution as protein source for fishmeal in mixed fish-soybean-cassava meal	3	Determined species composition, size and chemical composition of the main freshwater trash/low-value fish species used as feed for finfish aquaculture in the Mekong Delta of Vietnam.	1	Consumer food choice tests for product preference of snakehead fed on alternative plant-based diet	1	
07SFT02NC	Biotechnology: (1) IGF-I assay as a biomarker of tilapia growth status Technology: (2) Reduced feeding strategies to reduce costs for producing Nile tilapia in ponds; (3) Fishmeal replacement with food by-products	3		0		0	
07SFT03NC	(1) Biotechnology: IGF-I assay as a biomarker of milkfish growth status (2) Technology: Reduced feeding strategies to reduce costs for producing milkfish in tanks	2		0		0	
07SFT04UA	Substitution of fishmeal with local feed materials: (1) copra meal, () shrimp meal (3) poluty by-product, (4) brewers waste, (5) palm nut oil cake	5		0		0	
07SFT05UA	(1) Feed formulation techniques with local ingredients, (2) improved methods of feed manufacture	2		0		0	
07SFT06PU	Substitution of local plant species as protein source in fish feed.	1		0		0	

Table X-15: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-14: Number of new technologies or management practices under research as a result of USG assistance, revised based on information reported after 1 November 2009.

Investigation Code	5.2-14 Technology (Tech)	Tech Total	5.2-14 Practice (Prac)	Prac Total	5.2-14 Product (Prod)	Prod Total	All Total
07TAP01UC		0	Developing resource management strategy for sustainable fisheries of low-value fish	1		0	
07TAP02NC	Tilapia podcasting technology development	1		0		0	
07WIZ01PU		0	BMPs for pond aquaculture to minimize waste and contamination of the environment and protect native aquatic biodiversity: (1) improving feed and fertilizer source/uses and bacteriological quality on farms (2) feeding regimes to minimize waste in ponds and receiving waters (3) improving harvesting practices, effluent releases and production water reuse (4) Responsible stocking and species translocation practices	4		0	
07WIZ02UH		0	Assessment of carrying capacity of Boca de Camichin estuary for managing development of local oyster culture industry	0		0	
	Total Technologies under development	32	Total Practices under development	18	Total Products under development	10	60

Table X-16: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-15: Number of new technologies or management practices being field-tested as a result of USG assistance, revised based on information reported after 1 November 2009.

Code	5.2-15: Technology	Tech Total	5.2-15: Practice	Prac Total	5.2-15: Product	Prod Total	All Total
07BMA02UM		0	On-farm trials of best stocking density of tilapia-sahar	1		0	
07HHI01UM	On-farm field testing of microcystin content in fish and pond water: (1) chitosan-modified clay, (2) PAC-modified claypling of microcystins in fish and water and consultation with farmers on monitoring	2		0		0	
07HHI02UA		0	On-farm testing of bacteria-free pond-effluent irrigation water on vegetable crops: (1) gravity irrigationfrom ponds; (2) hose for the effluent; (3) recirculating aquaculture system	3		0	
07HHI05UH		0		0	Test marketing certified, depurated cockles underway	1	
07IND01UA	Testing of Snook seed production technologies (1) holding system for maintaining healthy adults, (2) feeds that encourage gamete development, and (3) induced spawning	3		0		0	
07IND03UH	Spat collection and grow out of native oyster in Santa Maria Bay by women oyster growers.	1		0		0	
07IND04UH	Oyster relay and depuration trials conducted at 2 sites.	1		0		0	
07MER03PU	Management protocols for on-farm verification of tilapia-catfish polyculture.	1		0		0	
07SFT02NC	(1) Field testing of IGF-1 assay for tilapia growth; (2) feed reduction and (3) fishmeal replacement	3		0		0	

Table X-16: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-15: Number of new technologies or management practices being field-tested as a result of USG assistance, revised based on information reported after 1 November 2009.

Code	5.2-15: Technology	Tech Total	5.2-15: Practice	Prac Total	5.2-15: Product	Prod Total	All Total
07SFT03NC	Field testing of growth performance under alternate feeding strategies	1		0		0	
07SFT05AU	Testing local ingredients as feed: copra meal, shrimp meal, poultry by-product, brewers waste.	1		0		0	
07SFT06PU	Testing commercial leaf meal diets developed by feed mill collaborator	1		0		0	
07TAP02NC	Podcast on tilapia aquaculture under trial at Central Luzon State University computing center	1		0		0	
07WIZ02UH		0	Community members participate in field research in estuary carrying capacity study	1		0	
	Total Technologies under field testing	15	Total Practices under field testing	5	Total Products under field testing	1	**21**

Table X-17: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-16: Number of new technologies or management practices made available for transfer as a result of USG assistance, revised based on information reported after 1 November 2009.

Code	5.2-16:Technology	Tech Total	5.2-16: Practice	Prac Total	5.2-16: Product	Prod Total	All Total
07BMA02UM		0		0	Cultured sahar available for consumption but no market has yet developed	1	
07HHI01UM	Transfer of chitosan-modified clay technique to researchers	1		0		0	
07IND01AU	Transfer of holding system in workshop training	1		0		0	
07MNE02NC		0	(1) Seaweed polyculture with shrimp and fish; (2) Soft shell crab farming	2	(1) seaweed (2) soft shell crab	2	
07MNE03UM		0	Recommendation to eliminate stocking of the 2 introduced fish species (1) icefish and (2) tilapia in reservoirs in China and Vietnam	2		0	
07MNE04UM		0	Waste management practices for freshwater and marine aquaculture transferred in workshop trainings: (1) stocking density; (2) aeration	2		0	
07QSD02PU		0	Training of small-scale farmers (1) to adopt catfish fingerling aquaculture as resource management practice to replace collection of wild baitfish for Nile perch fisheries on Lake Victoria (2) Catfish fry/fingerling production and artificial propagation techniques (3) Predator control for better growth and higher survival (4) Pond construction techniques (5) Construction of simple hatcheries for catfish propagation (6) Pond management techniques and pond dynamics	6	Farmed baitfish market successfully established	1	
07SFT04UA	Feed formulation alternatives to fishmeal adopted for tilapia and pacu: (1) Copra meal ;(2) shrimp meal	2		0		0	
07SFT05UA	Training of farmers/cooperatives in on-farm diet manufacture methods	1		0		0	

Table X-17: Supporting documentation for AquaFish CRSP FY09 Report on USAID-EGAT Indicator 5.2-16: Number of new technologies or management practices made available for transfer as a result of USG assistance, revised based on information reported after 1 November 2009.

Code	5.2-16:Technology	Tech Total	5.2-16: Practice	Prac Total	5.2-16: Product	Prod Total	All Total
07TAP02NC	Podcast launched at farmers training and available for download from ITunes	1		0		0	
07WIZ02UH		1	Based on recommendations, Mexican government has imposed a ban on establishing new oyster farms.	1		0	
Total Technologies under transfer/adoption		7	Total Practices under transfer/adoption	13	Total Products under transfer/adoption	4	**24**

USAID IEHA Indicator Reports

AquaFish CRSP reported on the folowing IEHA Indicators for FY2009:

- IEHA Output Indicators (Table X-18) which directly correlate with the Program Element EG 5.2 Indicators (see Table X-14)
- IEHA Intermediate Results Indicator IR 1.1 in FY2009

Table X-18. IEHA Output Indicators

EG Indicator No.	Definition	FY2009 Target	FY2009 Actual*
5.2-26	Male attendance at short-term agricultural sector productivity training in this reporting year as a result of USG assistance	70	124
5.2-26	Female attendance at short-term agricultural sector productivity training in this reporting year as a result of USG assistance	70	36
5.2-27	Male attendance at long-term agricultural sector productivity training in this reporting year as a result of USG assistance	9	12[28]
5.2-27	Female attendance at long-term agricultural sector productivity training in this reporting year as a result of USG assistance	9	10
5.2-14	Number of new technologies or management practices under research as a result of USG assistance: Fish (Aquaculture)	1	4
5.2-15	Number of new technologies or management practices under field testing in this reporting year as a result of USG assistance: Fish (Aquaculture)	1	2
5.2-16	Number of new technologies made available for transfer in this reporting year as a result of USG assistance: Fish (Aquaculture)	1	7
5.2-19	Number of rural households benefiting directly from USG interventions	252	255
	All New Beneficiaries: Of which, the number of households benefiting from assistance in productivity	90	90
	All New Beneficiaries: Of which, the number of households benefiting by being linked to a market	36	51
	Male New Beneficiaries: Of which, the number of households benefiting from assistance in productivity	45	71
	Male New Beneficiaries: Of which, the number of households benefiting by being linked to a market	18	37
	Female New Beneficiaries: Of which, the number of households benefiting from assistance in productivity	45	19
	Female New Beneficiaries: Of which, the number of households benefiting by being linked to a market	18	14
5.2-22	Number of public-private partnerships formed in this reporting year as a result of USG assistance	1	1

[28] The FY09 IEHA Indicator Report submitted on 14 January 2010 reported 13 long-term male students. On the basis of new information after the IEHA report submission, one student was removed from the tally due to a duplication error.

IR 1.1 Adoption of New Technology: Fish (Aquaculture)

Commodity\Indicator	Unit	Sex of Adapter	2009	
			Target	Actual
Additional area under new technology	Hectares	All	4.00	4.00
		Male	2.00	3.30
		Female	2.00	0.70
Number of farmers who have adopted new technologies	Quantity	All	70.00	82.00
		Male	35.00	68.00
		Female	35.00	14.00

XI. LESSONS LEARNED

Due to the no cost extension status for the six core research projects, a formal presentation of lessons learned at the project level is not yet available. The annual report for the Mali Associate Award presents lessons learned that are specific to that project. The lessons learned which are presented below are from an overall program perspective.

- On 14 July 2009, USAID released an RFA in the form of a letter to the ME for additional activities under the CRSP. The Director submitted a proposal in September 2009 and following negotiation with USAID/OAA, the *Modification of Assistance* of the CA/LWA was signed by USAID on 25 September 2009. These new funds ($3.92 million) will be programmed in FY 2010 and FY 2011. The purpose of the new funding is to promote the extension of CRSP technologies and assess the impacts and communicate the importance of CRSP research. Although new program requirements associated with this funding were less than desirable (including major changes to *Section A.10 - Substantial Involvement*, a request to report on Aquaculture CRSP, a program that is no longer active, and a requirement to submit annual Work Plans), we recognize the need for this work and greatly appreciate that resources are now available to achieve USAID's stated goals. Receipt of the supplemental $3.92 million funding presented challenges resulting from USAID's request to restrict funding to non-research projects and the requirement that the additional funds be spent by 29 September 2011 (a two-year time period). We learned how valuable it is to have good relationships with subcontracting partners who can respond quickly to emergency RFPs and can absorb and program awards in a short period of time.

- Considerable achievements have been made on the Mali Associate Award Project during this reporting period. On-farm trials and demonstrations were begun in collaboration with ten farmers, eight short-term training sessions were conducted, and a survey of Lake Sélingué was completed. Nonetheless, this Associate Award has incurred higher-than-anticipated costs for the ME. Many project tasks, although similar to those necessary to run the core AquaFish CRSP program, must be handled separately and thus require extra time and effort to complete. The additional unique reporting requirements of our AA are an excellent example of this. In future thinking/planning for AAs, we will need to keep this in mind and adjust estimates of the time and funding needed to successfully manage an AA. Increasing MT staffing to manage extra projects and better assimilate such projects into the AquaFish CRSP program are two ways to improve the management of AAs in the future. The consensus among AquaFish CRSP researchers at the 2009 Annual Meeting was that we should consider treating future Associate Awards in line with core research projects, and adhere to technical review, organizational, and reporting (i.e., DTAP) requirements. Although at times burdensome, this Associate Award provides the AquaFish CRSP with an opportunity to contribute to aquaculture and fisheries development through a greater West African presence.

- During this year, we were saddened by the loss of Dr. Yang Yi, a long-time CRSP participant, a friend to many in the CRSP community, and one of the great CRSP success stories. Yang Yi's association with CRSP started in graduate school (his doctoral work was funded through CRSP projects) and he continued for many years as a CRSP investigator. Most recently Yang Yi served in vital roles as a Host Country Lead Principal Investigator (HC Lead PI) and a Theme leader in our Mali Associate Award Project. Consequently, he was a central player in overall AquaFish CRSP efforts. Yang Yi formed many strong linkages with his associates, and, although difficult, we are slowly beginning to fill his many CRSP roles with well-qualified CRSP colleagues who had worked closely with him. From a

management standpoint, the lesson we have learned is that it requires a lot of time and great care to identify and fully train replacements for key, long-time CRSP participants.

- Reporting under the USAID EGAT and IEHA indicator sets (and associated year-end achievement reporting) has occasionally presented problems due to (1) insufficient guidance for producing the indicator metrics, (2) overly general definitions of terminology for which greater specificity would be helpful, (3) delays in receiving notice of indicators on which to report, and (4) rushed requests for information that interrupt tight scheduling for year-end reporting. These issues present challenges for both scheduling and consistent reporting. They also affect the scheduling of project PIs who are ultimately the ones who must produce the information on which reporting is based. From a management standpoint, the lesson learned is the need for consistency and importance of guidance both from USAID and in what the MT provides the project PIs.

- With two years of DTAP reporting completed, there are a number of lessons learned from that activity that relate to the mechanisms for reporting and the correlations between DTAP and USAID indicator reporting. Overall, AquaFish CRSP reporting on USAID indicators is more robust as a result of the comprehensive scope of the information gathered with the DTAP indicators. Attempts to bring consistency to the framework for data gathering have proven important, e.g., applying the broad USAID definition of “technologies” to the DTAP indicator set. Lessons learned include the need to further streamline the process to remove duplicative reporting burdens for the PIs and the need to improve the specificity of the DTAP report, as well as its usefulness for USAID reporting, by developing a pre-agreed set of result metrics on which each core research project reports.

XII. FINANCIAL SUMMARY

The following data show obligations from USAID to the ME, and allocations to projects and activities from the AquaFish CRSP ME. Please note that the funds received in late September 2009 were not programmed for this reporting period. They will be programmed for the following fiscal year. As stated in the *Introduction*, the total award amount for AquaFish CRSP was raised at the end of this reporting period from $8.90 million to $12.82 million.

AquaFish CRSP

USAID Funding from inception through 9/30/09

Date of Award*	Description	Total Estimated Award Amount	Amount Obligated Core
9/29/06	Original grant	$8,900,000	$900,000
9/18/07	Modification 1		$2,760,000
8/28/08	Modification 2		$3,160,000
9/29/09	Modification 3	$3,920,000	$3,058,096
	Total	**$12,820,000**	**$9,878,096**

Associate Awards up to $3,000,000, as noted in USAID's RFA for the CA/LWA for this CRSP

10/1/07	Mali Associate Award	$750,000	$250,000
11/6/08	Modification 1		$250,000
	Total	**$750,000**	**$500,000**

* note that date of award usually diverges from date of signature by USAID to notification of the ME by days, or in some cases, weeks.

These financial data are intended to supplement and not replace the official financial reports filed by the University with USAID SF269 reports and other financial data are sent to the offices indicated in the CA/LWA on a quarterly basis. This section provides a snapshot of program funding through this reporting period.

Of the $3.16 million awarded to CRSP for the current reporting period, 85% ($2.69 million) was allocated to core research projects. Approximately 10% was allocated to central research and capacity building activities, and 5% allocated to management.

USAID's $3.06 million allocation, received at the end of this reporting period for the next fiscal year(s), will go towards funding new projects to promote the extension of CRSP technologies through outreach, commercialization and partnership, and to assess the impact and communicate the importance of CRSP research. These funds will also be used to continue funding successful and promising core research projects and central activities. The obligation provides funding into the fourth year of operations.

AquaFish CRSP Allocation Summary for the FY2009 reporting period.

INDEX	LOCATION / PI	Projected end date for current contract	Allocated Funds in FY 2009
Core Research Projects			
11G-A	University of Arizona	Sep 29 2011*	$305,120
11G-B	University of Michigan	Sep 29 2011*	$425,000
11G-C	North Carolina State University	Sep 29 2011*	$350,000
11G-D	Purdue University	Sep 29 2011*	$450,000
11G-E	Univeristy of Connecticut	Sep 29 2011*	$350,000
11G-F	University of Hawaii	Sep 29 2011*	$350,000
11G-G	Auburn University	Sep 29 2011	$450,055
	Indirect on subcontracts less than $25,000 paid for by ME on behalf of subcontractors		$10,375
	**Contract finalization in progress.*		
	Total Core Research Projects		**$2,690,550**
Central Research, Outreach and Capacity Building Projects			
11C	Capacity Building and Host Country	Sep 29 2011	$187,581
11N	Synthesis Project	Sep 29 2011	$120,000
	Total Central Research		**$307,581**
Management			
11A	Management	Sep 29 2011	**$161,869**
	TOTAL ALLOCATED FROM USAID OBLIGTIONS IN THE REPORTING PERIOD FY 2009		**$3,160,000**
	Additional USAID obligation posted 25 Sep 2009 These funds are slated for programming in the next FY(s) for awards under outreach and assessment activities as well as core research continuations, central research projects and amanagement.		$3,058,096

At nearly 29%, the IEHA allocation in FY09 exceeds the 25% target for this CRSP, primarily due to the addition of a new core research project in Uganda. Note that through the Mali Associate Award, central activities and management effort support an additional IEHA country.

IEHA Allocation in FY 2009	
Ghana (Purdue Project)	$198,992
Kenya (Purdue Project)	$134,193
Uganda (Auburn Project)	$420,292
Apportionment of Central Projects/Activities	$104,577
Apportionment of Management	$55,035
Total IEHA Allocation	**$913,089**
25% of programmed allocation (of $3,160,000)	$790,000

Country level reporting shows attributions across the board. The idea is that all aspects of the program support the CRSP mission primarily in various countries, and secondarily to a much lesser extent in the US.

Estimated allocated funds to regions by Central Activities and Management for FY09 (based on project Award Coversheets).	
Africa (primarily IEHA)	$193,648
Asia	$181,912
Latin America & Caribbean	$93,890
Total Central Activities/Management	**$469,450**

Estimated breakdown of country-level allocations to be made by Core Research Projects in FY09 (based on 2009–2011 project Award Coversheets).	
Bangladesh	$32,568
Cambodia	$131,355
China	$239,207
Ghana	$198,992
Guyana	$64,802
Indonesia	$13,786
Kenya	$134,193
Mexico	$531,984
Nepal	$39,056
Nicaragua	$58,333
Philippines	$336,214
South Africa	$39,102
Tanzania	$116,815
Thailand	$67,848
Uganda	$410,954
Vietnam	$264,966

APPENDIX 1. PROGRAM PARTICIPANTS

Management Team Staff

Oregon State University, Corvallis, Oregon USA

Hillary Egna	Director
Ford Evans*	Research Projects Manager
Jim Bowman	Capacity-Building & HCPI Project Coordinator (0.25 FTE)
Dwight Brimley	Accountant
Patty Heublein	Office Specialist

*from December 2008 to present

Synthesis & Communications

Oregon State University, Corvallis, Oregon USA

Hillary Egna	Director
Laura Morrison**	Reporting Coordinator
Steve Buccola	Investigator

**from February 2009 to present

United States Agency for International Development

Washington, DC USA

Harry Rea	Agreement Officer's Technical Representative

Advisory Bodies

External Program Advisory Council

Christine Crawford	Chair, University of Tasmania, Hobart, Australia
Jason Clay / Aaron McNevin	World Wildlife Fund, Washington, DC
Nathanael Hishamunda	FAO, Rome, Italy
Marcia Macomber	CGIAR Challenge Program on Water & Food

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	Oregon State University

Development Themes Advisory Panel: Lead Coordinators

Maria Haws	DTAP A	University of Hawai'i at Hilo
Kwamena Quagrainie	DTAP B	Purdue University
James Diana	DTAP C	University of Michigan
Robert Pomeroy	DTAP D	University of Connecticut–Avery Point

Regional Centers of Excellence: Lead Coordinators

Charles Ngugi	Africa	Moi University, Kenya
Remedios Bolivar	Asia	Central Luzon State University, Philippines
Wilfrido Contreras-Sanchez	LAC	Universidad Juárez Autónoma de Tabasco, Mexico

Core Research Project Participants

Auburn University

Participants	Status	Country
		USA
Joseph Molnar	US Lead PI	Auburn University
Claude E. Boyd	Investigator	Auburn University
Karen Veverica	Investigator	Auburn University
James O. Bukenya	US Co-PI	Alabama A&M University
E. William Tollner	US Co-PI	University of Georgia
		Uganda
Levi Kasisira	HC Lead PI	Makerere University
Theodora Hyuha	Investigator	Makerere University
Monica Karuhanga Beraho	Investigator	Makerere University
Levi Kasisira	Investigator	Makerere University
Peter Mulumba	Investigator	Makerere University
Nelly Isyagi	HC Co-PI	Gulu University
Alfonse Opio	Investigator	Gulu University
Gertrude Atakunda	HC Co-PI	Uganda National Fisheries Resources Research Institute (NaFiRRI)
John Walakira	Investigator	Uganda National Fisheries Resources Research Institute (NaFiRRI)
		South Africa
Khalid Salie	HC Co-PI	Stellenbosch University

North Carolina State University

Participants	Status	Country
		USA
Russell Borski	US Lead PI	North Carolina State University
Peter R. Ferket	Investigator	North Carolina State University
Upton Hatch	Investigator	North Carolina State University
Charles R. Stark	Investigator	North Carolina State University

North Carolina State University		
Kevin Fitzsimmons	US Co-PI	University of Arizona
Christopher Brown	Collaborator	US Department of Commerce-NOAA
Michael New	Collaborator	Aquaculture without Frontiers
		Philippines
Remedios B. Bolivar	HC Lead PI	Central Luzon State University
Wilfred Jamandre	Investigator	Central Luzon State University
Emmanuel M. Vera Cruz	Investigator	Central Luzon State University
Nelson A. Lopez	HC Co-PI	Bureau of Fisheries & Aquatic Resources
Hernando L. Bolivar	HC Co-PI	GIFT International Foundation
Evelyn Grace T. de Jesus-Ayson	HC Co-PI	SEAFDEC-AQD
Felix G. Ayson	Investigator	SEAFDEC-AQD
Nelson Golez	Investigator	SEAFDEC-AQD
Josette Gonzaga	Investigator	SEAFDEC-AQD
Anicia Hurtado	Investigator	SEAFDEC-AQD
		Indonesia
Hassan Hassnuddin	HC Co-PI	Ujung Batee Aquaculture Center, Banda Aceh
		Australia
Michael Rimmer	Collaborator	Australian Centre for International Agricultural Research
		Thailand
May Myat Noe Lwin	Collaborator	C NN Aquaculture & Supply Company

Purdue University		
Participants	**Status**	**Country**
		USA
Kwamena Quagrainie	US Lead PI	Purdue University
Jennifer Dennis	Investigator	Purdue University
Rebecca Lochmann	US Co-PI	University of Arkansas at Pine Bluff
Carole Engle	Investigator	University of Arkansas at Pine Bluff
Emmanuel Frimpong	US Co-PI	Virginia Polytechnic Institute & State University
		Kenya
Charles Ngugi	HC Lead PI	Moi University
John Makambo	Investigator	Moi University
Julius Manyala	Investigator	Moi University
Jennifer Atieno	Collaborator	Women in Fishing Industry Project

Purdue University

		Ghana
Stephen Amisah	HC Co-PI	Kwame Nkrumah University of Science & Technology
Paul Sarfo-Mensah	Investigator	Kwame Nkrumah University of Science & Technology
		Tanzania
Sebastian Chenyambuga	HC Co-PI	Sokoine University of Agriculture
Bernard Mnembuka	Investigator	Sokoine University of Agriculture
Kajitanus Osewe	HC Co-PI	Ministry of Natural Resources & Tourism, Aquaculture Division

University of Arizona

Participants	**Status**	**Country**
		USA
Kevin M. Fitzsimmons	US Lead PI	University of Arizona
Reynaldo Patiño	US Co-PI	Texas Tech University-Lubbock
Dennis McIntosh	Collaborator	Delaware State University
		Mexico
Wilfrido Contreras-Sánchez	HC Lead PI	Universidad Juárez Autónoma de Tabasco
Alfonso Alvarez-González	Investigator	Universidad Juárez Autónoma de Tabasco
Gabriel Márquez Couturier	Investigator	Universidad Juárez Autónoma de Tabasco
Salomon Páramo Delgadillo	Investigator	Universidad Juárez Autónoma de Tabasco
Mario Fernández-Pérez	Investigator	Universidad Juárez Autónoma de Tabasco
Arlette Hernández Franyutti	Investigator	Universidad Juárez Autónoma de Tabasco
Ulises Hernández-Vidal	Investigator	Universidad Juárez Autónoma de Tabasco
Rosa Martha Padrón-López	Investigator	Universidad Juárez Autónoma de Tabasco
Pablo Gonzales Alanis	HC Co-PI	Universidad Autónoma de Tamaulipas
Mauricio A. Ondarza	Investigator	Universidad Autónoma de Tamaulipas
Roberto Arosemena	HC Co-PI	Instituto Sinaloense de Acuacultura, Mazatlán
		Guyana
Pamila Ramotar	HC Co-PI	Department of Fisheries
Kalima Singha	Investigator	Department of Fisheries
Vivek Joshi	Investigator	Department of Fisheries
		Venezuela
Paul Rincones	Collaborator	BIOTECMAR

University of Arizona

		Egypt
Ahmed Said Diab	Collaborator	Central Laboratory for Aquaculture Research
		Lebanon
Imad Saoud	Collaborator	American University of Beirut

University of Connecticut–Avery Point

Participants	**Status**	**Country**
		USA
Robert S. Pomeroy	US Lead PI	University of Connecticut-Avery Point
Sylvain De Guise	Investigator	University of Connecticut-Avery Point
Tessa Getchis	Investigator	University of Connecticut-Avery Point
David A. Bengtson	US Co-PI	University of Rhode Island
Chong M. Lee	Investigator	University of Rhode Island
		Cambodia
So Nam	HC Lead PI	IFReDI
Hap Navy	Investigator	IFReDI
Prum Somany	Investigator	IFReDI
Kao Sochivi	Investigator	IFReDI
		Vietnam
Tran Thi Thanh Hien	HC Co-PI	Can Tho University
Le Xuan Sinh	Investigator	Can Tho University

University of Hawai'i at Hilo

Participants	**Status**	**Country**
		USA
Maria Haws	US Lead PI	University of Hawai'i at Hilo
Sharon Ziegler-Chong	Investigator	University of Hawai'i at Hilo
William Steiner	Investigator	University of Hawai'i at Hilo
John Supan	US Co-PI	Louisiana State University
		Mexico
Eladio Gaxiola Camacho	HC Lead PI	Universidad Autónoma de Sinaloa-Culiacán
Ambrocio Mojardin Heraldez	Investigator	Universidad Autónoma de Sinaloa-Culiacán

University of Hawai'i at Hilo		
Guillermo Rodriguez Domínguez	HC Co-PI	Universidad Autónoma de Sinaloa-Mazatlán
Gustavo Rodriguez	Investigator	Universidad Autónoma de Sinaloa-Mazatlán
Olga Zamudio Armenta	Investigator	Universidad Autónoma de Sinaloa-Mazatlán
Omar Calvario Martinez	HC Co-PI	CIAD
		Nicaragua
Carlos José Rivas Le Clair	HC Co-PI	CIDEA-UCA
Nelvia Hernandez del Socorro	Investigator	CIDEA-UCA
Erick Sandoval Palacios	Investigator	CIDEA-UCA

University of Michigan		
Participants	**Status**	**Country**
		USA
James S. Diana	US Lead PI	University of Michigan
Flavio Corsin	Collaborator	World Wildlife Fund in Asia
		China
Yang Yi	HC Lead PI	Shanghai Ocean University (to July 2009)
Liu Liping	HC Lead PI	Shanghai Ocean University (from August 2009)
Jiang Min	Investigator	Shanghai Ocean University
Lai Qiuming	HC Co-PI	Hainan University
Wang Weimin	HC Co-PI	Huazhong Agricultural University
Song Biyu	HC Co-PI	Wuhan University
		Nepal
Madhav K. Shrestha	HC Co-PI	Institute of Agriculture & Animal Science
		Vietnam
Le Thanh Hung	HC Co-PI	University of Agriculture & Forestry

APPENDIX 2. PERSONNEL CHANGES APPROVED IN THE REPORTING PERIOD

University of Michigan Project: Host Country Principal Investigator Change

Dr. Yang Yi, the HC Lead PI, passed away on 31 July 2009. His colleague at Shanghai Ocean University, Dr. Liu Liping, who also was serving as an HC investigator on the University of Michigan's AquaFish CRSP project, agreed on 26 August 2009 to take over Dr. Yang Yi's role as HC Lead PI for the project.

APPENDIX 3. LEVERAGED FUNDING

Fiscal Year 2009 funds from non-AquaFish CRSP sources were acquired as a consequence CRSP funding, including funds used for non–AquaFish CRSP objectives but generated as a result of AquaFish CRSP funding. Funding sources include grants, training, travel support, equipment, facilities, and other forms of provided services and supplies.

US Lead Institution	Reported for Quarter Ending	Amount ($)	Funding Source
University of Arizona			
	December 2008	27370	USAID/GTIS - Guyana
	December 2008	25000	USDA Foreign Ag Service, (ISTA8).
	December 2008	10000	Intervet Schering Plough (ISTA8)
	December 2008	10000	American Soybean Association, (ISTA8)
	December 2008	100000	Egypt Center for Aquaculture Research-Dept of Agriculture
	June 2009	2132	Farmer to Farmer - Guyana
University of Michigan			
	June 2009	13000	National Agricultural Research and Development Fund (Nepal)
North Carolina State University			
	December 2008	20000	Bourlag LEAP Fellowship, USAID
	March 2009	64701	NC SeaGrant Fisheries Resource Grant
		1700	NPEDA (India)
Purdue University			
	June 2009	25000	SARNISSA
University of Hawaii at Hilo			
	December 2008	300000	European Union, grant to CIDEA/UCA (Nicaragua)
	March 2009	25000	European Union
	Total	623903	

APPENDIX 4. LINKAGES

Institutions, NGOs, and organizations listed below participate as partners in the EGAT-funded AquaFish CRSP research projects.

Symbols indicate the following:

* US and Host Country PI affiliations and direct funding recipients through subcontracts and MOUs. Entities with affiliations based on financial support via travel reimbursement or personal services agreements, or other shorter term funding arrangements are not included in this group.

** Subcontracts and MOUs underway for the Auburn University project.

† Linkage through the Mali Associate Award Project.

US Partners

Alabama A&M University**
American Soybean Association
Cornell University
Delaware State University
Department of Commerce, NOAA*
Fisheries Industry Technology Center–University of Alaska
Florida International University
Louisiana State University*
National Oceanic & Atmospheric Administration–International Sea Grant
North Carolina State University*
Oregon State University*
Pacific Aquaculture & Coastal Resources Center–University of Hawaii at Hilo*
Pacific Shellfish Growers Association
Purdue University*
Texas A&M University
Texas Parks & Wildlife Department
Texas Tech University*
University of Arizona*
University of Arkansas at Pine Bluff*
University of Connecticut–Avery Point*
University of Georgia**
University of Hawaii at Hilo*
University of Michigan*
University of Rhode Island*
University of Rhode Island–Coastal Resources Center
University of Texas
US-Mexico Aquaculture TIES Program
U.S. Food & Drug Administration
Virginia Polytechnic Institute & State University*
World Wildlife Fund*

International Partners

Aquaculture without Frontiers (USA)
Australian Centre for International Agricultural Research
International Development Research Centre (Canada)
Lake Victoria Environmental Management Project (Kenya, Tanzania, Uganda)
Network of Aquaculture Centers in Asia (Thailand)
United Animal Feed Producers
United Cooperative of Fishermen
United Nations Food & Agriculture Organization (Italy)
USAID SUCCESS Program (USA)
World Aquaculture Society (USA)
WorldFish Center (Malaysia)

Australia

Australian Centre for International Agricultural Research

Brazil

Centro de Acüicultura, UNESP

Cambodia

Fisheries Administration
Inland Fisheries Research & Development Institute (IFReDI)*
Prek Leap National School of Agriculture (PLNSA)

China

Hainan University*
Huazhong Agricultural University*

China (continued)
Huiting Reservoir Fisheries Management Company
Shanghai Ocean University*† (formerly Shanghai FisheriesUniversity)
Sichuan Aquacultural Engineering Research & Technology Research Center†
Wuhan University*
Zhanghe Reservoir Fisheries Management Company

Costa Rica
University of Costa Rica

Ecuador
Ecocostas

Egypt
Academy of Scientific Research & Egyptian Universities
Central Administration of Agricultural Foreign Relations
Central Laboratory for Aquaculture Research
Egyptian Society of Agribusiness
Ministry of Agriculture & Land Reclamation

Ghana
Fisheries Department, Ministry of Food & Agriculture
Kwame Nkrumah University of Science & Technology*
Water & Sewerage Company

Guatemala
San Carlos University

Guyana
Department of Fisheries
Maharaja Oil Mill
Mon Repos Aquaculture Center*
National Aquaculture Association of Guyana
USAID/GTIS Programme–Guyana
Von Better Aquaculture

Honduras
Zamorano University

Indonesia
Ujung Batee Aquaculture Center, Banda Aceh*
Indonesian Department of Fisheries
Ladong Fisheries College

Kenya
Department of Fisheries†
Fish Africa*†
Kenya Business Development Services
Moi University*†
National Investment Center
Women in Fishing Industry Project (WIFIP)

Lebanon
American University of Beirut

Mali
Direction Nationale de la Pêche†

Mexico
Comite Estatal de Sanidad Acuicola de Sinaloa
Federation of Shrimp Cooperatives
Instituto Sinaloense de Acuacultura
Mariano Matamoros Hatchery
Research Center for Food & Development (CIAD)*
Sinaloa Institute for Aquaculture
Sinaloa State Fisheries Department
State Committee for Aquaculture Sanitation of Sinaloa (CESASIN)
Universidad Autónoma de Tamaulipas*
Universidad Autónoma de Sinaloa–Culiacán*
Universidad Autónoma de Sinaloa–Mazatlán*
Universidad Juárez Autónoma de Tabasco*
Women's Oyster Culture Cooperatives of Puerto Penasco

Nepal
Institute of Agriculture & Animal Science*
Rural Integrated Development Society

Nicaragua
Center for Research of Aquatic Ecosystems-Central American University (CIDEA-UCA)*
Nicaraguan Ministry of the Environment

Philippines
Bureau of Fisheries and Aquatic Resources (BFAR)*
Central Luzon State University*
Department of Agriculture
Genetically Improved Farmed Tilapia (GIFT) Foundation International, Inc
Southeast Asian Fisheries Development Center (SEAFDEC) AQD*

South Africa
Department of Water Affairs & Forestry (DWAF)
University of Stellenbosch**
Water Research Commission (WRC)

Tanzania
Kingorwila National Fish Center
Mbegani Fisheries Development Centre
Ministry of Natural Resources & Tourism, Aquaculture Development Division*
Nyegezi Fisheries Institute
Sokoine University of Agriculture*
Tanzania Fisheries Research Institute
University of Dar-es-Salaam

Thailand
C NN Aquaculture & Supply Company, Bangkok
Network of Aquaculture Centres in Asia-Pacific (NACA)†

Uganda
Blessed Investment Fish Farm**
Gulu University**
Lake Victoria Fisheries Organization (Kenya, Tanzania, Uganda)
Makerere University**
Namuyenge Mixed Farmers Ltd
Source of the Nile (SoN) Fish Farm
Walimi Fish Cooperative Society Ltd
Uganda National Fisheries Resources Research Institute (NaFiRRI)**

Venezuela
BIOTECMAR

Vietnam
Can Tho University*
Dong Nai Fisheries Company
University of Agriculture & Forestry*

APPENDIX 5. ACRONYMS

Program-Related

ACRSP	Aquaculture CRSP
A&F CRSP[29]	Aquaculture & Fisheries CRSP
AquaFish	Aquaculture & Fisheries CRSP
CRSP	Collaborative Research Support Program
HC	Host Country
IGO	Inter-Governmental Organization
ME	Management Entity
MOU	Memorandum of Understanding
MT	Management Team
NCE	No-Cost Extension
NGO	Non-Governmental Organization
PD/A CRSP	Pond Dynamics/Aquaculture CRSP
PI	Principal Investigator
RFA	Request for Assistance
RFP	Request for Proposals

General

FAQ	Frequently Asked Questions
KSh	Kenya Shillings
NB	Nota Bene, note well
PDF	Portable Document Format

Institutions, Organizations, Government Entities & Programs

ACIAR	Australian Centre for International Agricultural Research
AIT	Asian Institute of Technology
ANAF	Aquaculture Network for Africa
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
ATA	American Tilapia Association
AwF	Aquaculture without Frontiers, USA
BAU	Bangladesh Aquacultural University
BFAR	Bureau of Fisheries & Aquatic Resources, Philippines
BIFAD	Board for International Food & Agricultural Development
BIOTECMAR	Cultivos & Biotecnologíca Marina C.A., Venezuela
BOMOSA	Boku, Moi and Sagana Aquaculture project
CESASIN	Comite Estatal de Sanidad Acuicola de Sinaloa (Sinaloa State Committee for Aquaculture Sanitation
CETRA	Centro de Transferencia Tecnológica para la Acuacultura (Center for Aquaculture Technology Transfer), Mexico
CI	Conservation International, Mexico
CIAD	Centro de Investigación de Alimentos y Desarrollo (Research Center for Food & Development), Mexico
CIDEA-UCA	Centro de Investigación de Ecosistemas Acuáticos de la Universidad Centroamericana (Center for Research on Aquatic Ecosystems-Central American University), Nicaragua
CIFAD	Consortium for International Fisheries & Aquaculture Development
CIMMYT	International Wheat & Maize Improvement Center, Mexico
CLAR	Central Laboratory for Aquaculture Research, Egypt

[29] Incorrect abbreviation occasionally used along with AFCRSP; AquaFish CRSP is the USAID-approved abbreviation.

CLSU	Central Luzon State University
COMESA	Common Market for Eastern and Southern Africa
CRC/URI	Coastal Resources Center/University of Rhode Island
CTU	Can Tho University, Vietnam
DASP	Department of Animal Sciences & Production, SUA
DA-BFAR	Department of Agriculture-Bureau of Fisheries & Aquatic Resources, Philippines
DPN	Direction Nationale de la Pêche, Mali
DWAF	Department of Water Affairs and Forestry
EGAT	Bureau for Economic Growth, Agriculture, & Trade (USAID)
EPA	US Environmental Protection Agency
EU	European Union
FAC	Freshwater Aquaculture Center, Central Luzon State University, Philippines
FAO	Food & Agriculture Organization, United Nations
FD	Fisheries Department, Kenya
FDA	US Food & Drug Administration
FDAP	Fisheries Development Action Plan, Cambodia
FiA	Fisheries Administration, Cambodia
FISH	The FISH Project (Fisheries Improved for Sustainable Harvest), Philippines
FIU	Florida International University
GESAMP	Joint Group of Experts in the Scientific Aspects of Marine Environmental Protection, FAO
GIFT	Genetically Improved Farmed Tilapia
GOP	Government of Philippines
GTIS	Guyana Trade & Investment Support Project
IAAS	Institute of Agriculture & Animal Science, Nepal
IARC	International Agricultural Research Center(s)
ICLARM	International Center for Living Aquatic Resources Management (= The WorldFish Center), Malaysia
IDRC	International Development Research Centre, Canada
IEHA	Initiative to End Hunger in Africa
IFREDI	Inland Fisheries Research & Development Institute, Cambodia
IIFET	International Institute for Fisheries, Economics & Trade
ISSC	Interstate Shellfish Sanitation Conference
ISA	Sinaloa Institute for Aquaculture, Mexico
ISTA	International Symposium on Tilapia in Aquaculture
KBDS	Kenya Business Development Services
KNUST	Kwame Nkrumah University of Science & Technology
LSU	Louisiana State University
MARENA	Nicaraguan Ministry of the Environment
MRC	Mekong River Commission
MSU	Michigan State University
NAAG	National Aquaculture Association of Guyana
NACA	Network of Aquaculture Centers in Asia-Pacific, Thailand
NaFiRRI	Uganda National Fisheries Resources Research Institute
NARS	National Agricultural Research System (of Host Countries)
NCSU	North Carolina State University
NEPAD	New Partnership for Africa's Development
NIC	National Investment Center
NOAA	National Oceanographic & Atmospheric Administration (US)
NPRS	National Poverty Reduction Strategy, Cambodia
NSF	National Science Foundation, USA
NSSP	National Shellfish Sanitation Program
OSU	Oregon State University
PACRC	Pacific Aquaculture & Coastal Resources Center/University of Hawai'i at Hilo
PLNSA	Prek Leap National School of Agriculture
RIDS-Nepal	Rural Integrated Development Society-Nepal
SARNISSA	Sustainable Aquaculture Research Network in Sub Saharan Africa
SEAFDEC/ AQD	Southeast Asian Fisheries Development Center/Aquaculture Department, Philippines
SEDPIII	Third Five-Year Socioeconomic Development Plan, Cambodia

SEMARNAT	Secretariat of Natural Resources, Mexico
SoN	Source of the Nile Fish Farm
SOU	Shanghai Ocean University (formerly Shanghai Fisheries University)
SUA	Sokoine University of Agriculture
SUCCESS	Sustainable Coastal Communities & Ecosystems (EGAT/USAID)
TIES	Training, Internships, Education & Scholarships Program (USAID-Mexico)
TNC	The Nature Conservancy
TTU	Texas Tech University, Lubbock
UA	University of Arizona
UAPB	University of Arkansas, Pine Bluff
UAS	Universidad Autónoma de Sinaloa (Autonomous University of Sinaloa)
UAS-C	Universidad Autónoma de Sinaloa–Culiacán
UAS-M	Universidad Autónoma de Sinaloa–Mazatlán
UAT	Universidad Autónoma de Tamaulipas (Autonomous University of Tamaulipas)
UCA	Universidad Centroamericana (Central American University)
UG	University of Georgia
UHH	University of Hawaii at Hilo
UJAT	Universidad Juárez Autónoma de Tabasco (Autonomous University of Juarez, Tabasco)
UJAT-CPSR	Cooperativa Pesquera San Ramón (San Ramón Fisheries Cooperative)
UBAC	Ujung Batee Aquaculture Center
UM	The University of Michigan
UNESP	Universidade Estadual Paulista (São Paulo State University)
URI	University of Rhode Island
US	United States
USG	United States Government
USAID	United States Agency for International Development
USEPA	US Environmental Protection Agency
VT	Virginia Polytechnic Institute & State University
WAS	World Aquaculture Society
WIFIP	Women in Fishing Industry Project (Kenya)
WRC	Water Research Commission
WWF	World Wildlife Fund

Topic Areas

BMA	Production System Design & Best Management Alternatives
FSV	Food Safety & Value-Added Product Development
HHI	Human Health Impacts of Aquaculture
ISD	Indigenous Species Development
MER	Marketing, Economic Risk Assessment & Trade
NE	Mitigating Negative Environmental Impacts
QSD	Quality Seedstock Development
SFT	Sustainable Feed Technology
TAP	Technology Adoption & Policy Development
WIZ	Watershed & Integrated Coastal Zone Management

USAID, Program & Project Terms

AOP	Advanced Oxidation Process
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BSE	Bovine Spongiform Encephalopathy
BW	Brackish Water
cDNA	complementary DNA (Deoxyribonucleic acid)
CFU	Colony Forming Units
CG	Compensatory Growth
DO	Dissolved Oxygen
DTAP	Development Theme Advisory Panel
EC	*E. coli*
EPT	*Ephemeroptera*, *Pleocoptera* & *Trichoptera*
EG	Economic Growth Indicators, USAID

FACT	"F" indicators database, Director of US Foreign Assistance–USAID
FCR	Food (Feed) Conversion Ratio
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GLM	Generalized Linear Model
GMO	Genetically Modified Organism
GnRHa	Gonadotropin Releasing Hormone Analogue
HACCP	Hazard Analysis & Critical Point Control
HIV/AIDS	Human Immuno Virus/Acquired Immune Deficiency Syndrome
HPLC	High Performance Liquid Chromatography
HSD	Hepatosomatic Index
IGF-I	Insulin-like Growth Factor-I
IPM	Integrated Pest Management
IR	Intermediate Results indicators, IEHA program
LAC	Latin America & Caribbean Regions
LC/MS	Liquid Chromatography/Mass Spectrometry
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
LST	Lauryl Sulfate Tryptose
MC	Microcystins
mRNA	messenger RNA (Ribonucleic Acid)
MT	17α-Methyltestosterone
NL	Notochordal
PDI	Pellet Durability Index
PMP	Program Monitoring Plan
PRCA	Participatory Rural Communication Appraisal
RCE	Regional Center of Excellence
RIA	Radioimmunoassay
RRA	Rapid Rural Appraisal
SGR	Specific Growth Rate
SPE	Solid Phase Extraction
SL	Standard Length
SR	Sex Reversed
SS	Salmonella-Shigella
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UV	Ultraviolet
XLD	Xylose Lysine Desoxycholat