AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM

TWENTY-THIRD ANNUAL ADMINISTRATIVE REPORT

1 August 2004 to 31 July 2005

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AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM
Twenty-Third Annual Administrative Report

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Introduction

The Aquaculture Collaborative Research Support Program (ACRSP) represents a collective of 26 US universities and 54 foreign institutions, with over 300 participants working in 24 countries during this reporting period.

The Aquaculture CRSPs mission is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources.

The Aquaculture CRSP is funded by the United States Agency for International Development (USAID) under authority of the Foreign Assistance Act of 1961 (PL 87-195) as amended and by the universities and institutions that participate in the ACRSP. This cohesive program of research is carried out in selected developing countries and the United States by teams of US and host country researchers, administrators, and students. Now operating under its fourth USAID grant since 1982, the ACRSP is guided by the concepts and direction set down in the Continuation Plan 1996, which was awarded funding under USAID Grant No. LAG-G-00-96-90015-00. An overview of ACRSP history and how the program has evolved since its inception is provided in Appendix 1.

This report describes the activities and accomplishments of the ACRSP from 1 August 2004 to 31 July 2005. Activities of this multinational, multi-institutional, and multidisciplinary program are administered by Oregon State University (OSU), which functions as the Management Entity (ME) and has technical, programmatic, and fiscal responsibility for the performance of grant provisions. ME activities at OSU are carried out through a Program Management Office, which is supported in the task of program administration by advisory bodies and reviewers. ME staff and advisory group membership during the reporting period, appears in Appendix 2. To establish the present portfolio of activities, the ME, through a consultative process, set overall themes for aquaculture and aquatic resources research and outreach in developing countries, and conducted regional priority setting processes to engage regional stakeholders in Africa, Asia, and Latin America. Then, through a peer-reviewed competitive process, the ME created a portfolio of focused projects and is managing these projects through their completion.

The projects involved in the ACRSP are diverse and draw upon the great depth and expertise in the university, NGO, governmental, and private sector communities. The overall context for the program is sustainable aquaculture development in coastal and inland areas. Project areas include: Production Technology; Watershed Management; and Human Welfare, Health, and Nutrition. Every ACRSP project currently focuses on institutional strengthening and outreach while at the same time fostering economic growth, food security, and the wise use of natural resources.

The **Amazon Basin Project** involves participants from Peru, Brazil, Colombia, Ecuador, and Bolivia in a systems approach to identifying the best use of scarce aquatic resources. This engages producers, government policy makers, fish sellers, researchers, and many others in a multi-tiered program of marketing analysis, new foods research, nutrition and consumption, and outreach. The **Kenya Project: Watershed Management** includes baseline hydrological and ecological surveys, transboundary water issue dialogs with Uganda, and GIS to evaluate the proper role for aquaculture in watershed planning and development.

Hillary Egna

The **Central America Project** (Honduras, Nicaragua, Dominican Republic, El Salvador, Panama, and Guatemala) works closely with producers and extension services to provide high quality, low-cost inputs to growers. A **Global Project** focused on Best Management Practices is providing state-of-the-art research and training to scientists and policymakers in Brazil, Thailand, and South Africa. The **Southeast Asia Project** (Bangladesh, Vietnam, Thailand, Cambodia, Nepal, and China) integrates complex dimensions of research on environment and biotechnology and examines environmental impacts of non-native species. The **Mexico Project: Human Welfare, Health and Nutrition** focuses on clean water technologies and engages inland and coastal communities in comprehensive multi-institutional research on families, nutrition, and income generation. Many other innovative projects focus on applied research and outreach on aquatic resources management and aquaculture production. These projects and more are described in depth in the succeeding sections of this 23rd Annual Administrative Report.

James Bowman

Carl Schreck

Program Highlights

During this reporting period, ACRSP managed a portfolio of 26 subcontracts with 23 US institutions. The overall annual funding for the program was US$2.15M from USAID with about another US$2M provided by leveraged funding and university matching.

The ACRSP has a long and successful track record in **training and education**. To date, over 630 students have been trained with university degrees—over 330 with advanced graduate degrees—in disciplines related to business, ecology, health, agriculture, and natural resources. Additionally, the ACRSP has offered short-term trainings and topical workshops to over 3,500 people in developing countries. During this reporting period, 26 students completed degrees, with over 75 degrees in progress. Over 700 people received non-degree training through ACRSP auspices in various workshops and outreach offered by Aquaculture CRSP projects described in this Annual Administrative Report.

Hillary Egna

James Bowman

Active Development of New Linkages

NOVEL JOINTLY FUNDED INITIATIVES

Two jointly funded projects engage new communities in the ACRSP enterprise. ACRSP and the Indigenous Environmental Network, through funding from **Heifer International**, have created a novel project to involve Native Americans from the North (US and Canada) and Native Americans from the South (Mexico and Peru) in consultations about the governance of natural resources; linkages between aquaculture, health, and income generation; and aquatic resources management. This pilot activity—named the "Eagle-Condor Exchange Project"—embraces Native American perspectives of the water world by taking a broad cultural brush to water issues facing communities in the North ("eagle") and the South ("condor"). Heifer funding covers costs of the Eagles, and ACRSP funding, through USAID and participating institutions, covers workshops to be held in Peru and Mexico. The ACRSP Management Entity at OSU secured funding for this concept two years ago, and after many conference calls and background work, the project is now set to hold two workshops and exchanges in 2006.

Another innovative project is co-funded by the **US Department of Commerce's NOAA Sea Grant** with a mission of bringing the considerable US aquaculture extension expertise to bear on problems host countries are facing in aquaculture and aquatic resources management. With NOAA's leveraging funds, ACRSP is able to make the leap into extension as a way to bring the positive benefits of ACRSP research to more partners. Unlike many of the mainstream agricultural commodities, in LDCs, the aquaculture sector often does not have adequate extension support. The RFA issued by the ME in December 2004 allowed for broad and diverse participation under the sponsorship of a Sea Grant institution or through subcontracts. In this competitive award process, the winning proposal attracted a diversity of people and institutions. Cornell University partnered with a number of other universities to win the award for work in Mexico. NOAA Sea Grant is jointly funding a related initiative with ACRSP to provide technical assistance by US extension agents to ACRSP host countries. Areas of need identified by

the host countries are varied and include HACCP, seafood safety, and marketing analysis, to name a few. The ME also engaged USDA in discussions about jointly creating and funding another effort to extend international outreach in aquaculture and water resources. Return benefits of these new projects with Sea Grant will include better access to aquaculture technologies developed in host countries, establishment of worldwide networks, and dialog on trade and marketing issues in the aquaculture sector.

Aloyce Kaliba

NEW PARTNERSHIPS AND RENEWED COOPERATION

The ME at OSU began informal discussions with **Mercy Corps International** in Portland, Oregon, USA, to conduct jointly funded aquaculture trainings in China. The ME has since included researchers from the Asian Institute of Technology to help formulate a potential project.

During the past year, ACRSP reached out in support of USAID's new **SUCCESS Project** (Sustainable Communities and Ecosystems). *Aquanews*—ACRSP's flagship publication—highlighted SUCCESS work being undertaken by researchers working for both ACRSP and SUCCESS. ACRSP advertised and supported a trainee to the first SUCCESS training in Tanzania in July 2005: *East African Training Program in Mariculture Extension*. ACRSP connectivity to the SUCCESS Project was further strengthened by the involvement in the new Tsunami project by long-time ACRSP Host Country Principal Investigator, Amrit Bart, who serves as the Tsunami Project Chief of Party. ACRSP Ambassador challenge funds are available to promote synergies between the two USAID programs.

A change in leadership and direction at **WorldFish** (formerly ICLARM) resulted in the President of the World Aquaculture Society and ACRSP Technical Committee member Kevin Fitzsimmons being invited to review WorldFish operations and research. ACRSP Director Hillary Egna was invited by the University of Minnesota to participate in the WorldFish-USAID workshop on invasive species, held in St. Paul, Minnesota, in February 2005. These two activities were strong steps towards revitalizing the foundation for cooperation between ACRSP and WorldFish.

James Bowman

ENHANCING ACRSP CAPACITY AND CONNECTIVITY

Connecting ACRSP host country scientists through the exchange of tilapia technologies began this year, with the ME acting as a consultative body for researchers in Honduras, Kenya, Mexico, the Philippines, and Thailand. The ME facilitated the development of project ideas through a moderated electronic listserv and a survey designed to identify areas of commonality and divergence. Why have certain ACRSP technologies worked in one location but not another? What are some of the most successful ACRSP methods that have benefited producers? These and more questions form the foundation for a lessons learned evaluation of tilapia and native cichlid production in these five host countries. In this HCPI Project, site visits began at the end of this reporting period and will continue through the next reporting cycle.

Last year, the US Department of Commerce through NOAA announced plans for **offshore aquaculture development** in the open ocean (Exclusive Economic Zone). The push for offshore aquaculture is based partially on the perception that the considerable US trade deficit in fish and fishery products could be reduced by competition with other nations who already produce in offshore environments. An emerging topic, offshore aquaculture still presents a relative unknown for the US and LDCs. The ACRSP sponsored two literature reviews—undertaken by the University of Michigan and the Institute for Agriculture and Trade Policy—to examine the potential benefits and pitfalls of the new direction international aquaculture may be taking in the near future.

The Aquaculture CRSP continued developing its ambassador program as a means to foster closer ties with USAID field missions. The Management Entity at Oregon State University established the ACRSP Ambassador program to engage USAID Missions in advanced understanding of the CRSP and the aquatic resources sector, provide qualified on-the-ground professionals to act as resources to the Missions, and help link Mission needs with CRSP capabilities. The first two ambassadors have enjoyed good receptivity by the missions. Nancy Gitonga, ACRSP Kenya Ambassador (and Kenya Department of Fisheries Director) hosted field trips for USAID Mission personnel in Kenya in the summer of 2005. Meanwhile, ACRSP Thailand and South Asia Ambassador (and ACRSP Principal Investigator for Thailand) Amrit Bart connected with various USAID efforts and is now Chief of Party on the Tsunami Project through the University of Rhode Island. Bart and Kevin Fitzsimmons (US Principal Investigator and Technical Committee member) are working on a challenge grant to tie CRSP efforts into the Tsunami project.

SERVICE AND COMMUNITY

The ME at OSU teamed up last year with Kevin Fitzsimmons, President of the **World Aquaculture Society (WAS)**, to offer exciting networking opportunities to ACRSP participants and students. Under this partnership, two separate Honors and Awards Committees were established during the past year to jury student research in competitions for best poster presentations in sustainable aquaculture. In addition, mid-career ACRSP scientists from developing countries competed for WAS awards, which allowed them to present results at an international forum in Indonesia. The ACRSP further supported WAS for the ALCAN prize nomination and other activities throughout the year.

ACRSP **sponsored professional meetings**, including WAS, ISTA (Sixth International Symposium on Tilapia in Aquaculture), and IIFET (International Institute of Fisheries, Economics, and Trade). ACRSP helped support presentations of developing country scientists at these conferences. ACRSP assisted the conveners of ISTA and IIFET in producing conference proceedings, which are available electronically. The impact of ACRSP research was felt at ISTA when over 15 papers were presented on ACRSP research. Technical Committee member Yang Yi presented a plenary lecture on tilapia aquaculture in China, the world's largest producer of aquaculture products. The IIFET conference focused on "What are Responsible Fisheries?" and included sessions on seafood processing, marketing, and consumption issues; medical and ornamental substances from the sea; and international seafood trade issues. In July 2005, the ACRSP ME again entered into agreements with IIFET for co-sponsorship of their next international meeting.

During this reporting period, the ME published Research Reports (Notices of Publication), the program's Work Plan, *Aquanews*, and a number of other reports that can be accessed through the ACRSP website. The ME created posters for presentation at the following **scientific conferences** during this reporting cycle: WAS New Orleans, January 2005; WAS Bali, May 2005; and AKTEA International Conference "Women in fisheries and aquaculture" in Spain, November 2004. Posters developed by the ME were presented by Technical Committee representatives in Indonesia and by Suyapa Meyer (ACRSP Central America Project) in Spain. ME staff participated in broader aquaculture discourse through journal and proposal reviews. ACRSP Director Hillary Egna continued her service to the US National Science Foundation as a Marine Biotechnology panel member. Research Projects Manager Chris Bridger is working with the World Aquaculture Society Industry Relations Committee to develop a book focused on contemporary issues in global aquaculture. Bridger was the Recipient of the Distinguished Early Career Award from the US Aquaculture Society during their Annual Meeting in January 2005 in New Orleans, Louisiana, USA.

CRSP Council activities in which the ME participated included quarterly conference calls, and a steering committee meeting and joint Council-USAID meeting held in Savannah, Georgia, USA, in August 2004. The ACRSP ME played a coordinating role for the preparation of several Council documents and assumed leadership for organizing the Council-USAID and Steering Committee meetings in Portland, Oregon, USA in August 2005. The Council applauded USAID's renewed interest in long-term training, and to this end produced several documents and new projects. ACRSP participated in the review and development of these new activities now being implemented by Michigan State University and the University of California at Davis. The ME at OSU joined in the broader long-term training movement by supporting initiatives to internationalize graduate students' theses.

USAID held several important meetings during this reporting period. The ME attended **USAID meetings** in Washington, D.C., in September 2004 and June 2005. The ME also sponsored former TC co-Chair Kevin Fitzsimmons to attend the USAID stakeholders' meeting in June 2005. New USAID regulations on travel (TraiNet), and on branding and marking were implemented. The ME also responded to *ad hoc* requests for information and reports on training, regional effort, and research outputs.

The ACRSP's **Library Donation Project** continues to be appreciated by host country participants and their institutions. After receiving library donations from OSU faculty and the OSU Valley Library, the ME identifies suitable recipients and sends library collections to them. Recipients are ACRSP host country universities and institutions with accessible libraries. A one-time-only computer-lab improvement was also made possible through the shipment of older model

Kevin Fitzsimmons

computers to Mexico's Universidad Juárez Autónoma de Tabasco (UJAT) this past year. Plans are to continue the library donation project through the final year of the program, as almost all host country libraries need scientific journals and books to enhance their collections.

RENOVATED MANAGEMENT PROCESSES

Advisory structures continued to be updated following the Miller-Rubin recommendations and BIFAD revisions that culminated in several documents in early 2005. This updating process began in the ACRSP two years ago with a phased plan for ensuring transparency through the involvement of external advisory panel members—to manage conflicts of interest—and for savings through elimination of redundancies. The model proposed by Rubin and Miller and discussed by BIFAD builds on the Global Livestock precedent. The ACRSP has moved forward with its own EPAC (External Program Advisory Council) formed entirely of external members.
To handle internal administrative issues at US universities, the ACRSP maintains a group of institutional representatives who are of sufficient stature to resolve issues within their respective subcontracting institutions. These new structures function better than the old and have helped ACRSP develop new linkages, maintain flexibility in the face of changing global priorities, and reduce costs.

Program **website renovation** was undertaken this year, as the extant website was created a decade ago. Advances in software and electronic platforms along with new regulations will make the website faster, more user friendly for the public at large, and more helpful to program participants and donors. Additions to the website over the past few years will be updated as they migrate to the new website, which is expected to be launched next year. Although the ACRSP grant is slated to end in 2006, a fully functional website will provide a useful archive for future researchers, students, and administrators. The ME at OSU has agreed to maintain the website beyond the ACRSP period of performance as a way to encourage creativity and usefulness of the vast amounts of information collected and generated by the ACRSP.

The **timely receipt of funding** from USAID made possible the speediest ever subcontracting process for projects requiring additional allocations. Not only could the highest accountability standards be maintained, but avoidance of multiple contract actions resulted in streamlining and cost savings, not to mention the appreciation of ACRSP partners.

The ME organized the program's first-ever **regional Technical Committee meetings.** The TC decided at the last Annual Program Meeting to experiment with regional meetings as a means to expand host country participation. While that goal was achieved, the costs of having three regional meetings, rather than one annual meeting, made it necessary for the ME to innovate. Working closely with TC members, the ME developed agendas, coordinated logistics, and selected suitable meeting locations in conjunction with regional or global conferences. One regional TC meeting was held during this reporting period while another was planned for September 2005 in South Africa. The Asia Regional Technical Committee Meeting was held in Bali, Indonesia, in May 2005 in conjunction with WAS/Bali, and was made possible through extensive groundwork laid by TC member Yang Yi. Prior to this first TC meeting of the year, the ME conducted elections. An improved, web-based elections process yielded high returns. The complete listing of newly elected TC members appears in Appendix 2. The ME also arranged for external reviewers to be present at regional meetings for interim program evaluations. This new structure allows for more cost-effective evaluations: external reviewers attend the TC meeting, meet with TC members independently, attend ACRSP scientific presentations at the associated conference, and actively participate in the other ACRSP committees.

The ME assisted the TC in initiating dialogues for timely decisions on policies for biodiversity, introduced species, intellectual property, biotechnology, among other topics. The ME prepared policy documentation for all ACRSP participants regarding environmental regulations and compliance. Formal adoption of USAID directives and policies was followed by discussions of stricter standards. Those policy discussions are expected to continue through the year at the two remaining regional Technical Committee meetings.

Proposal review continued similarly to that undertaken for the Eleventh Work Plan. The model used by the National Science Foundation was adapted and used in six external peer review panels involving 19 external referees. Over 15 projects, mostly extensions of existing research, received high marks from reviewers and were ushered in during this reporting period.

Research Highlights

Researchers in Asia characterized basic reproductive parameters of the indigenous carp, *Spinibarbus denticulatus*, and successfully induced spawning. These first steps to develop hatchery technologies are required for aquaculture of this native species.

The OSU/Kenya project team conducted two short courses that trained 38 Kenyan extension agents, six farmers from Kenya, and six hatchery managers from Uganda in hatchery management techniques for the African catfish (*Clarias gariepinus*).

Researchers from Brazil, South Africa, and the US have developed a manual for government officials, nongovernmental organizations, and fish farmers. The manual describes a process for the rational development of aquaculture Best Management Practices. The manual will be published by the Aquaculture CRSP following workshops and field-testing in South Africa and Brazil.

Nancy Gitonga

Philippines Project researchers were successful in isolating and cloning insulin-like growth factor-I in Nile tilapia. Further, hepatic IGF-I mRNA levels were significantly correlated with tilapia growth rate in different feeding regimes and temperature conditions, suggesting that IGF-I mRNA measures could prove useful to assess instantaneous growth rate in Nile tilapia. This research has the potential to lower research costs by providing an immediate assessment of the effects of various parameters on growth without waiting for a full grow-out period to end.

Aquaculture CRSP researchers reported the first results of diet acceptance, fish growth, and diet utilization in surubim (*Pseudoplatystoma* sp.) at early life stages.

Southeast Asia Project investigators have fostered new collaborative linkages with 20 Chinese academic institutions. Three of these institutions have been identified as partner institutions with ongoing collaborative research projects.

The Aquaculture CRSP partnered with the Packard Foundation as part of a Mexico project focused on human health, nutrition, and welfare to conduct a five-day workshop focused on public health, gender equity, and work with the physically challenged. Extension efforts were diversified during this workshop to include bivalve culture, water quality, and shellfish sanitation.

Great research strides were made in developing a formulated diet for the Amazonian black-finned pacu using locally available ingredients. The new diet for pacu is economically viable for small-scale farmers in the Amazon Basin.

Aquaculture CRSP workshops in Kenya and Ghana trained 12 and 85 fish farmers, respectively, in pond recordkeeping and economic analysis. Skills acquired will allow fish farmers to record data that will be useful for securing loans from financial institutions to allow farm expansion.

Research Program Areas & Themes for the Twelfth Work Plan

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

Current Aquaculture CRSP projects focus on one of three program areas:
Production Technology
Watershed Management
Human Welfare, Health, and Nutrition

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

ENVIRONMENTAL IMPACTS ANALYSIS

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

SUSTAINABLE DEVELOPMENT AND FOOD SECURITY

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

PRODUCTION SYSTEM DESIGN AND INTEGRATION

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

INDIGENOUS SPECIES DEVELOPMENT

Domestication of new and indigenous species may contribute positively to the development of local communities as well as protect ecosystems. At the same time, the development of new species for aquaculture must be approached in a responsible manner that diminishes the chance for negative environmental, technical, and social impacts. Efforts that investigate relevant policies and practices is encouraged while exotic species development is not encouraged.

WATER QUALITY AND AVAILABILITY

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

ECONOMIC/RISK ASSESSMENT AND SOCIAL ANALYSIS

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

APPLIED TECHNOLOGY AND EXTENSION METHODOLOGIES

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

SEEDSTOCK DEVELOPMENT AND AVAILABILITY

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

DISEASE, PREDATION PREVENTION, AND FOOD SAFETY

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

FISH NUTRITION AND FEED TECHNOLOGY

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

AQUACULTURE AND HUMAN HEALTH IMPACTS

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

James Bowman

Hillary Egna

Kevan Main

Collaborating Institutions

US AND HOST COUNTRY PARTNERS

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

Lead US Institutions

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

Subcontracting US Institutions

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

Collaborating Institutions

Brooklyn College, New York
Puerto Rico Sea Grant
Texas Sea Grant
Indigenous Environmental Network, Minnesota

Joint Project Participants

Heifer International, Arkansas
Packard Foundation
US Department of Commerce (NOAA National Sea Grant College Program)

Work undertaken in the reporting period comprised the Twelfth Work Plan and continuing investigations from the Eleventh Work Plan. Activities involved researchers in 24 countries:

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

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

Acuarios Leticia, Colombia
Asian Institute of Technology, Thailand
Bangladesh Agricultural University, Bangladesh
Can Tho University, Vietnam
Caritas, Bangladesh
Central Luzon State University, Philippines
Comunidad Indígena Sarayuku, Ecuador
Department of Fisheries Industry, Ministry of Livestock and Fisheries Development, Kenya
Ecocostas, Ecuador
Egerton University, Kenya
Embrapa Environment, Brazil
Escuela Agrícola Panamericana, Zamorano, Honduras
Fisheries and Aquaculture Development Division, Tanzania
Fisheries Department, Ministry of Food and Agriculture, Ghana
Fondo Nacional del Desarrollo Pesquero, Peru
Fundación Arcoiris, Ecuador
FYD International Farm, Philippines
Huazhong Agricultural University, China
Institute of Agriculture and Animal Science, Nepal
Instituto Amazónico de Investigaciones Científicas SINCHI, Colombia

Instituto de Investigaciones IMANI, Colombia
Instituto de Investigaciones de la Amazonia Peruana, Peru
Instituto Nacional de Pesquisas da Amazonia, Brazil
Instituto Technológico Saleciano, Ecuador
Instituto Tecnologico del Mar, Mexico
Kasetsart University, Thailand
Kellogg Foundation, Dominican Republic
La Fundacion Chile
Ministry of Education, Dominican Republican
Moi University, Kenya
National Center for Genetic Engineering and Biotechnology (BIOTEC), Thailand
Nepal Agriculture Research Center
Nong Nam University, Vietnam
Peace Corps, Ecuador
Quisqueya University, Haiti
Research Institute for Aquaculture No. 1, Vietnam
Royal University of Agriculture, Nepal
Sao Paulo State University, Brazil
Sokoine University of Agriculture, Tanzania
Southwest University, China
Stellenbosch University, South Africa
Thailand Department of Fisheries
Universidad Autónoma de Sinaloa, Mexico
Universidad Federal do Amazonia, Brazil
Universidad Juárez Autónoma de Tabasco, Mexico
Universidad Mayor de San Simón, Bolivia
Universidad Nacional de la Amazonia Peruana, Peru
Universidad Nacional de Colombia
Universidad Nacional Mayor de San Marcos, Peru
Universidade Estadual Paulista, Brazil
University of Science and Technology, Ghana
Vincent Foundation, Haiti
Wuhan University, China
Zamorano Alumni Association, Dominican Republic

Training Highlights

One of the Aquaculture CRSP's driving missions is to create a sustainable method that allows anyone with the right resources to conduct aquaculture indefinitely. It is fitting, then, to note that the staff and researchers, the faces behind the effort, are also part of a sustainable framework that calls to the most dedicated students of CRSP training programs, hones their knowledge and develops their skills, and ultimately folds them into the team as Principal Investigators leading their own aquaculture research.

Members of this cycle include a one-time graduate student, Wilfrido Contreras-Sánchez, who became a leader in the Mexico project studying the fate of steroids in tilapia sex alteration and its potential impact on the environment and farmer safety and Yang Yi, a person who began as a Ph.D. student and is now one of the CRSP's longest involved collaborators, studying fertilization and supplemental and alternative feeds at the Asian Institute of Technology in Thailand. Below are brief profiles of some of recent up and coming students. Each student brings a much needed local perspective on aquaculture benefits and barriers in his or her home country, and this shared knowledge allows the program as a whole to better help aquaculture's growth. We are excited to see how they will continue to contribute to the CRSP and to the development of aquaculture in the future.

Carlos Leyva

Carlos Leyva, native to Honduras, started working as an extension agent after graduating from Escuela Agrícola Panamericana (EAP), Zamorano, in 1986. He then went on to receive a B.S. from Kansas State University and began working for a shrimp farm in Choluteca, Honduras, where he received invaluable technical support from Dan Meyer, a CRSP host country Principal Investigator based at EAP. Meyer would ultimately influence Leyva to pursue a graduate degree in aquaculture.

In the fall of 2002, Leyva began working at the University of Arkansas at Pine Bluff. His thesis project, titled "Central American Aquaculture Markets: Optimizing Tilapia Marketing in Honduras," focused on the shortcomings of domestic marketing of tilapia in Honduras. Leyva was responsible for gathering information from small- and medium-scale farmers for use in a model that aimed to optimize marketing efforts in the region. According to Leyva, "Tropical conditions and the country's natural resources are factors that favor aquaculture in Honduras," however Leyva believes that the infrastructure of the Honduran market and middlemen with excessive control over prices make it tough for small farmers. Leyva hopes to shed some light on the constraints to tilapia culture in Honduras.

Emmanuel Vera Cruz

Native to the Philippines, Emmanuel Vera Cruz saw many ways to improve aquaculture in his country, inspiring him to attain a Masters degree from Central Luzon State University (CLSU) in 1991 and pursue his doctorate in Aquaculture from Florida International University (FIU). He hopes to play an important role in remedying some of the problems with aquaculture in the Philippines. The CRSP project he has been involved with includes, "Cost Containment Options for Tilapia Production in Central Luzon, Republic of the Philippines," which uncovered ways to reduce operating costs and increase the profit of tilapia farming.

Another CRSP investigation that Vera Cruz is working on could provide the solution for the best ways to assess growth rate for researchers. With help from his advisor Christopher Brown of FIU and collaborating researcher Russell Borski of North Carolina State University, both CRSP researchers, Vera Cruz hopes to overcome the challenges of assessing the correlation between tissue concentration of IGF-I and growth rate. After graduation, Vera Cruz plans on continuing his research on Nile tilapia at CLSU in the Philippines.

Narayan Pandit

A Nepal native, Narayan P. Pandit was supported by the Aquaculture CRSP under the tutelage of Madhav Shrestha, an Aquaculture CRSP HCPI, for ten months from March 2002. After completing his bachelors degree in agriculture at the Institute of Agriculture and Animal Science in Nepal in 2002, he was inspired by Shrestha to study for his masters degree in aquaculture. This led him to the CRSP-supported work "Women in Aquaculture in Nepal," for his masters degree. In all, 82 small ponds (100 to 200 m^2) were built adjacent to family houses, where women took responsibility for the pond, trained in aquaculture, and were enabled to raise fish in addition to normal household activities and provide a supplemental food source and income. Although there is no aquaculture doctorate program in Nepal, Pandit plans to study towards a Ph.D. in aquaculture with a focus on aquatic resource management, water quality, and biometrics.

Bernardita Campos Campos

In 1998, Bernardita Campos Campos began her research as a University faculty member at Universidad Juárez Autónoma de Tabasco. Through her previous relationships with CRSP PIs, she started a CRSP project: "Studies on Fate of Methyltestosterone and Its Metabolites in Tilapia and on the Use of Phytochemicals as an Alternative Method to Produce a Monosex Population of Tilapia." This study addresses concerns of environmental and human health effects caused by the use of orally administered testosterone to fish.

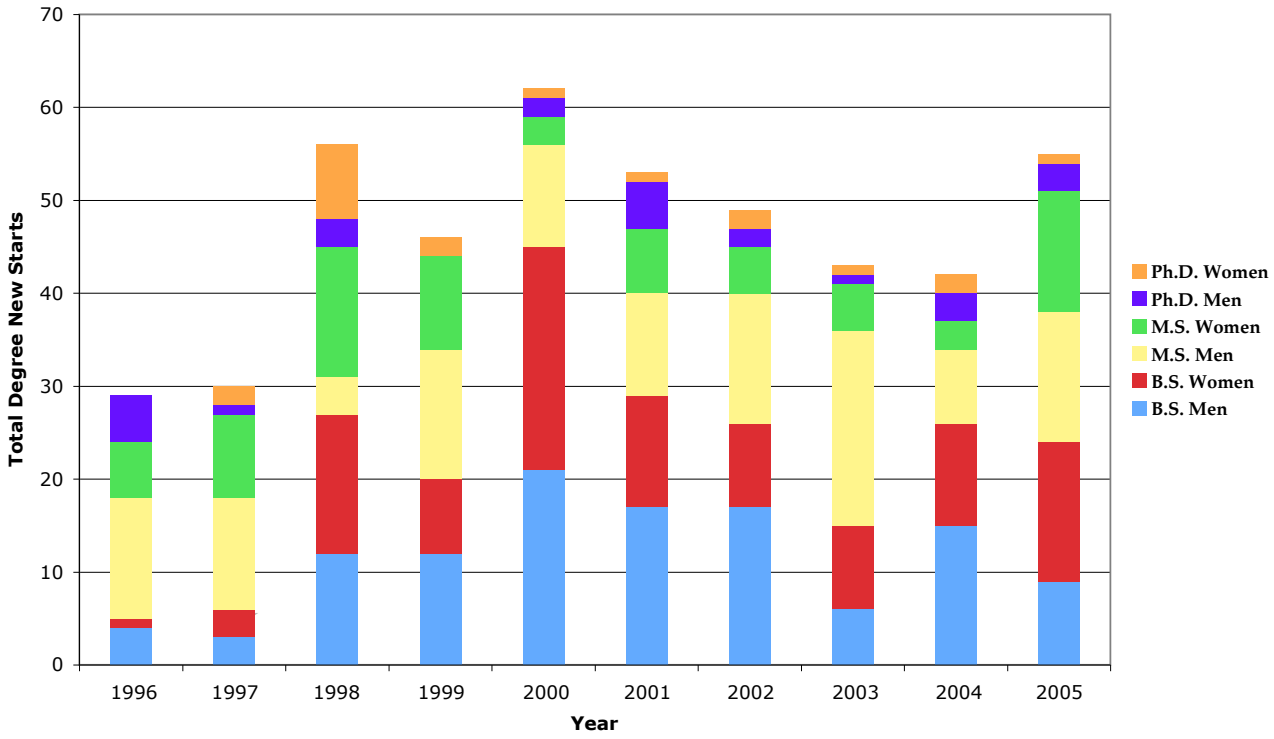
Campos was inspired by Leandra Salvadores of UJAT to stay and pursue a graduate education under CRSP researcher Wilfrido Contreras-Sánchez. The success of her experiments thus far have been encouraging and exciting. In fact, Campos plans to stay in the academic arena, perhaps at UJAT, when she has finished. She also hopes to have the opportunity to study the effects of ultraviolet light on the elimination of methyltestosterone in masculinization systems.

George Osure

Born and raised in Yala, Western Kenya, George Owiti Osure enrolled at Moi University, Kenya, in 1992 and began studying fisheries with CRSP participants Mucai Muchiri, B.C.C. Wangila, and in particular Charles Ngugi. Four years later he graduated with a bachelors degree in Fisheries and began working for the Kenya Department of Fisheries in the Ministry of Livestock and Fisheries Development Division until 2002 when he was offered Aquaculture CRSP funding by Principal Investigator Ron Phelps to study the "Evaluation of reproductive efficiencies, growth performance, and genetic variability of strains of Nile tilapia" at the Department of Fisheries and Allied Aquaculture, Auburn University, Alabama. He was to compare the reproductive efficiencies, growth performance, and microsatellite variability of Egypt, Ivory Coast, Sagana, and Lake Victoria Nile tilapia strains.

Osure successfully defended his thesis in September 2003— receiving the Best M.S. Student Award to boot. On returning to Kenya, Osure will resume working as a fisheries officer at the Kenya Department of Fisheries until he can secure funding for a Ph.D. project. In the future he hopes to become a professor and inspire others like himself.

ACRSP Long Term Training



Jon Rauni

Kenyan Jon Rauni began work with the Aquaculture CRSP in February 2002, and two months later he began working on his masters degree in aquaculture at Moi University. After working with N.K. Kinyajui, Rauni was advised to develop his expertise in aquaculture and apply for a CRSP scholarship through Moi University. When accepted, Rauni dove into a rigorous schedule of balancing course work and thesis research under the supervision of CRSP HCPI Charles C. Ngugi.

After graduation Rauni hopes to continue research and further his education, particularly with respect to *Clarias*, a fish that he has become increasingly fond of because of its widespread distribution throughout Africa, marketability, and potential as a biological control species.

Fred Chu

Fred Chu, a native of Peru, was first approached by Chris Kohler, an Aquaculture CRSP PI at Southern Illinois University at Carbondale (SIUC), while working for Terra Nuova, an Italian nongovernmental organization in the Peruvian Amazon. Kohler extended and Chu accepted an invitation to pursue a Ph.D. at SIUC. After a year improving his English skills, Chu's research studied the use of over 15 native Amazonian plants that are currently being utilized as a source of nutrition for *Colossoma macropomum* and *Piaractus brachypomus* for small-scale aquaculture application.

Chu will be working with many individuals who are active in the CRSP project. He appreciates support from several CRSP researchers as he pursues his Ph.D. Chu identifies Kohler, William Camargo (Coordinator of the CRSP Peru project), and Fernando Alcántara at IIAP as important contributors to his work. In fact, Chu will return to Peru and work at IIAP after he obtains his Ph.D.

This year was marked by the passing of two individuals whose work and vision for a better world benefited us all. ACRSP would not be the same today without their contributions. Dr. James Lannan was instrumental in establishing the Pond Dynamics/Aquaculture CRSP, serving as its first Director until 1987, and Wararat Wudtisin was a promising young researcher from Thailand and ACRSP graduate student at Auburn University. They are missed.

Southeast Asia Project: Production Technology

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

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

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Yao Weizi	Host Country Co-Principal Investigator

Work Plan Research

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

- Integrated cage-cum-pond culture systems with high-valued climbing perch (*Anabas testudineus*) in cages suspended in carp polyculture: Bangladesh/12ATE1a. A progress abstract was submitted for this investigation.
- Integrated cage-cum-pond culture systems with high-valued African catfish (*Clarias gariepinus*) in cages suspended in carp polyculture ponds: Nepal/12ATE1b. A progress abstract was submitted for this investigation.
- Establishment of links with Chinese institutions in collaboration on aquaculture and environmental impacts/12EIA2. A progress abstract was submitted for this investigation.
- Impact of tilapia, *Oreochromis niloticus* introduction on the indigenous species of Bangladesh, Nepal and Cambodia/12EIA3. A progress abstract was submitted for this investigation.
- Assessment of coastal and marine aquaculture development for low trophic level species/12ERA1. A progress abstract was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle system/12PSD1. A progress abstract was submitted for this investigation.
- Optimization of fertilization regimes in fertilized Nile tilapia ponds with supplemental feed/12PSD2. A progress abstract was submitted for this investigation.
- Use of rice straw as a resource for freshwater pond culture/12PSD3. A progress abstract was submitted for this investigation.

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

- Reproductive performance and growth of improved tilapia, *Oreochromis niloticus*/11SDFR3. A final report was submitted for this investigation.
- Controlled reproduction of an important indigenous species, *Spinibarbus denticulatus*, in Southeast Asia/11ISDR2. A final report was submitted for this investigation.

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Integrated Cage-Cum-Pond Culture Systems With High-Valued Climbing Perch (*Anabas testudineus*) in Cages Suspended in Carp Polyculture Ponds: Bangladesh

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

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Abstract

An on-farm trial is being conducted to adapt integrated cage-cum-pond systems to local farm conditions in Bangladesh, to determine appropriate stocking ratio of climbing perch (*Anabas testudineus*) in cages and carps in open water of ponds, to assess growth and production of fishes in both cages and open ponds, and to assess the economic and environmental benefits of this integrated system.

Eighteen farmers' ponds, ranging from 200 to 640 m^2 in surface area, were selected from three villages of Charbangalia, Pagalpara, and Ghoseber of the Haluaghat Upazila, Mymensingh district. Climbing perch and carps were stocked in cages and open water of ponds, respectively, to give caged to open-pond fish ratios of 1:1 and 2:1 as three treatments with four replicates each. On 23 August 2005, fingerlings of silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), Swrpunti (*Puntius sarana*), and common carp (*Cyprinus carpio*) were stocked at approximately one fish m^{-2} with a species ratio of 5:4:4:4:2:1 in open water of all ponds, while climbing perch fingerlings were stocked in one or two 1-m^3 cage suspended in each pond to give cage to open-pond fish ratios of 1:1 and 2:1. There were also four control ponds without a cage (0:1). Control ponds were fertilized fortnightly with cow dung. Commercial pelleted feed (35% crude protein) was given to caged fish twice daily at a rate of 10% body weight per day in the first month and reduced rates in the rest of the culture period. No feed or manure was added into open water of the treatment ponds. The on-farm trial will be terminated in January 2006 after five months of culture.

Integrated Cage-Cum-Pond Culture Systems with High-Valued African Catfish (*Clarias gariepinus*) in Cages Suspended in Carp Polyculture Ponds: Nepal

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

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Abstract

An on-farm trial is being conducted to adapt integrated cage-cum-pond systems to local farm conditions in Nepal, to assess growth and production of fishes in both cages and open ponds, and to assess the economic and environmental benefits of this integrated system.

Eighteen farmers' ponds, ranging from 85 to 130 m^2 in surface area, were selected with six ponds from each of the three sites—namely, Taruwa village of Nawaiparasi district and Gothouli village and Kushahana village of Chitwan district. At each site there were three control ponds without a cage and three treatment ponds with the integrated cage-cum-pond treatment. African catfish (*Clarias gariepinus*) fingerlings of 10–15 g in size were stocked at 100 fish m^{-3} in a 1.5x1.5x1.1-m cage with water volume of 2 m^3 suspended in each treatment pond on 22–24 July 2005. Fingerlings of silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*) were stocked at 1 fish m^{-2} with

a species ratio of 4:2:2:1:1 in open water of both control and treatment ponds on 5 August 2005. The control ponds were fertilized weekly using urea and diammonium phosphate (DAP) at 28 kg N and 7 kg P ha^{-1} $week^{-1}$. Commercial pelleted feed (30% crude protein) was given to caged fish twice daily at a rate of 5% and 3% body weight per day for small size (< 100 g) and large size (> 100 g) African catfish, which was sampled biweekly to adjust daily feed ration. No feed or fertilizer was added into open water of the treatment ponds. The on-farm trial will be terminated in December 2005 after five months of culture.

Establishment of Links With Chinese Institutions in Collaboration on Aquaculture and Environmental Impacts

Twelfth Work Plan, Environmental Impacts Analysis 2 (12EIA2) Abstract

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Abstract

The objectives of this activity are to establish links with Chinese institutions for future CRSP research, identify potential CRSP sites in China and conduct preliminary site evaluation, identify environmental problems caused by aquaculture/fisheries activities, and develop researchable topics.

The linkages between Aquaculture CRSP and twenty Chinese academic institutions have been established through email contacts and visits. A two-day workshop was held on 20–21 May 2005, at the International Conference Center, Huazhong Agricultural University (HAU), Wuhan of Hubei province, China, organized by Aquaculture CRSP, the Asian Institute of Technology, and Huazhong Agricultural University. A full report of this workshop is included in the 23rd Technical Report.

Three Chinese universities, namely, HAU, Wuhan University, and Southwest Agricultural University, have been identified to be partner institutions for this activity. At the three universities, seven M.S. students were selected to conduct research related to environmental impacts of aquaculture in China as their theses. The research topics include: 1) how aquaculture affects water environments in China: past, present and future trends; 2) environmental impacts of aquaculture: a case study in Lake Dong Hu, Wuhan; 3) a new aquaculture wastewater treatment technique: study on a modified biofilm method; 4) current status of pond aquaculture and waste management in China; 5) hydrobiological resources and water-ecological environment assessment in the Guangrun river basin; 6) the community structures of benthos and water quality evaluation of Wangfuzhou reservoir in Hanjiang River; and 7) environmental impacts of cage culture in rivers. The three principal investigators in the partner institutions were supported to attend the World Aquaculture Society Annual Meeting and the Aquaculture CRSP Regional Technical Committee Meeting held in May 2005 at Bali, Indonesia; however, they could not go due to visa problems.

Impact of Nile Tilapia (*Oreochromis niloticus*) Introduction on the Indigenous Species of Bangladesh, Nepal, and Cambodia

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

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Abstract

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

Experiment 1: This experiment is being conducted in nine 100 m^2 earthen ponds at the Field Laboratory of the Fisheries Faculty at Bangladesh Agricultural University in Mymensingh, Bangladesh, to asses the impact of mixed-sex and male mono-sex Nile tilapia on mola (*Amblypharyngodon mola*), chela (*Chela cachius*), and punti (*Puntius sophore*). Fish population structure and recruitment rates are being assessed over time, and the dietary overlap between tilapia and these indigenous species is being evaluated. The experiment commenced on 8 December 2004 and will continue for 20 months. A completely randomized design with three treatments and three replications per treatment is being used. The treatments are (i) mixed-sex tilapia with the three indigenous

fish species; (ii) mono-sex male tilapia with the indigenous species; and (iii) the indigenous species without tilapia (control). Before stocking, all ponds were drained completely to ensure that no other fish were present. The ponds were then filled and limed (250 kg ha^{-1} of $CaCO_3$), manured (1000 kg ha^{-1} of cow dung), and fertilized (100 kg ha^{-1} of urea and 50 kg ha^{-1} of STP) one week prior to stocking. Each species was apportioned equally (25%) within a total stocking rate of 0.56 fish m^{-2} for the two tilapia treatments (i and ii). Each indigenous species was apportioned equally (33%) within a total stocking rate of 0.42 fish m^{-2} for the control (iii). The male to female ratio of indigenous species was 1:1. Nile tilapia were stocked 74 days after the indigenous species were stocked. There was no additional nutrient input to the ponds after the indigenous species were stocked. Individual lengths and weights of a sample of fish were determined during stocking. The initial average weight of mola, chela, punti, and tilapia was 0.68, 0.73, 4.54, and 5.12 g, respectively.

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

Results to date indicate that mola and punti spawned only one time in all treatments during the period of March to May and April to June, respectively. Chela has not spawned. Spawning has occurred in all replications of mixed-sex Nile tilapia.

Experiment 2: This experiment is being conducted in nine 100 m^2 earthen ponds at the Institute of Agriculture and Animal Science in Rampur, Chitwan, Nepal to asses the impact of mixed-sex and male mono-sex Nile tilapia on chandapothi (*Puntius sophore*), darai (*Esomus danricus*), and faketa (*Barilius barna*). The objectives, treatments, experimental design, and procedures of Experiment 2 are the same as in Experiment 1 with the following exceptions. The experiment commenced on 4 June 2005. The ponds were fertilized with 80 kg ha^{-1} of urea and 50 kg ha^{-1} of STP one week prior to stocking. Nile tilapia were stocked 30 days after the indigenous species were stocked. The initial average weight of chandapothi, darai, faketa, and tilapia was 6.30 g, 2.00 g, 3.50 g, and 28.38 g, respectively.

Results to date indicate that chandapothi and darai spawned in all treatments and replications, and faketa spawned only in one replicate of the control. Spawning has occurred in two replications of the mixed-sex Nile tilapia treatment.

Assessment of Coastal and Marine Aquaculture Development for Low Trophic Level Species

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

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Abstract

This report aims to provide the Aquaculture Collaborative Research Support Program (ACRSP) an overview of the literature-to-date regarding use of low trophic level species in nearshore aquaculture development around the world. Additionally, the study analyzes the current literature to assess and prioritize research needs as they relate to culture of low trophic level species in the nearshore. This project was initiated 1 January 2005 and will be completed 30 April 2006.

The first part of our activity will provide a broad summary of the ecological, economic, and sociopolitical concerns or issues repeatedly cited in the literature regarding the development of low trophic level nearshore aquaculture. The second part will detail methodologies used to search the literature and index the collected data in tabular form. The third part of this report will provide detailed analysis of three case studies, each of which involves the use of low trophic level nearshore aquaculture for three distinct purposes: 1) effluent treatment for high intensity production systems; 2) small-scale production of food and income; and 3) enhancement/replacement of wild capture fisheries. The report's conclusion will identify specific research needs and gaps in the literature and propose several strategies by which the ACRSP could address these research needs.

The literature relating to this topic is immense and extremely diverse, and the possibilities for low trophic level systems in the nearshore are innumerable and routinely site specific. Low trophic nearshore aquaculture occurs in a multitude of forms that include monoculture, polyculture, and integrated culture, and the number of species currently utilized in these projects is highly varied. We found research on nearshore low trophic level systems on six of seven continents and scattered throughout several island nations. Moreover, it is clear from the literature that on-the-ground development of new technologies and systems for low trophic level nearshore aquaculture has either preceded or is occurring simultaneously with academic research on these systems.

We draw several conclusions regarding the development of low trophic level aquaculture in the nearshore region. In general, despite the large body of literature, substantial research is needed. The fact that the dynamic nearshore region is so poorly understood necessarily makes aquaculture development there a complex endeavor. If done hurriedly and without understanding of site-specific nearshore processes, aquaculture could contribute to eutrophication and severe

degradation of the region. Moreover, myriad ecological, economic, social, political, and cultural values of nearshore regions necessitate an interdisciplinary approach. We conclude that the development of low trophic level aquaculture in the nearshore should focus on extensive and/or semi-intensive systems to avoid ecological impacts. Thus, rigorous niche market development will be needed to support the variety of systems established. In addition to market development, the aquaculture industry needs to invest in well-researched marketing campaigns for nearshore projects in order to counter its predominantly negative image.

Because we recommend that development of nearshore low trophic aquaculture be based upon a site-specific assessment of social, political, cultural, economic, and ecological factors, we avoid making highly specific recommendations regarding nearshore locations for aquaculture development. However, we will present case studies of successful nearshore low trophic level projects, provide numerous examples of locations in which they appear to be working successfully, and provide a decision-making tree to assist in determining whether a particular nearshore location has desirable qualities for low trophic level aquaculture development.

New Paradigm in Farming of Freshwater Prawn (*Macrobrachium rosenbergii*) with Closed and Recycle Systems
a: Thailand

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

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Abstract

This study included two parts: an experiment on a water recycling system for giant freshwater prawn (*Macrobrachium rosenbergii*); and a survey of prawn farming systems in Thailand. The experiment was conducted in 15 cement tanks (2 x 2.5 x 1 m) at the Asian Institute of Technology, Thailand, during 5 January to 12 May 2004, to develop closed and recycle systems for culture of giant freshwater prawn. Juvenile prawns were cultured in three systems as three treatments, each in triplicate: A) open system with water exchange; B) closed system with aeration; and C) recycle system, in which water from a prawn tank was circulated through a Nile tilapia (*Oreochromis niloticus*) tank to a water mimosa (*Neptunia oleracea*) tank and back to the prawn tank. Survival of prawns, ranging from 40.64% to 88.72%, was highest in the closed system, intermediate in the recycle system, and lowest in the open system ($P < 0.05$). Growth of prawns was not significantly different among all three systems ($P > 0.05$), while gross and net yields of prawn were significantly lower in the open system than in closed and recycle systems ($P < 0.05$). Feed conversion ratio (FCR) in the open system was 2.81, which was significantly higher than in the closed (1.67) and recycle (1.78) systems ($P < 0.05$). Prawn recovered 12.02% N and 7.01% P from feed and fertilizer in the open system and 25.26% N and 13.67% P in the closed system. Prawn, tilapia, and water mimosa together recovered 39.55% N and 25.53% P in the recycle system. Economic analyses showed that there were no significant differences in net returns among the three systems.

The socioeconomic and technical survey of 100 prawn farmers was conducted during 1 May to 31 July 2005 in Thailand. Number of surveys conducted within each province was determined in proportion to the average area (rai), production (kg), and number of grow-out farms using 2003 data supplied by the Department of Fisheries, Bangkok, Thailand. Initial analysis shows that the majority of farms (96%) use monoculture systems. The remaining farmers utilized polyculture systems consisting of prawns and white shrimp (*Penaeus vannemai*). The production system utilized by the majority of farmers includes nursing of prawns at post-larval stage and grow-out (90%); others only practice grow-out. External pollution severely impacts 16% of respondents, moderately impacts 46%, and is of no impact to 38%. Further analysis is in progress.

The experiment demonstrated that the closed and recycle systems may be more environmentally friendly and have good profit potential compared to the open system. The survey will provide extensive information about practices currently used in Thailand to produce giant freshwater prawn. By assessing constraints and problems facing farmers, research can be directed to develop economically and environmentally sound production techniques, as well as evaluate the feasibility of implementing new production systems, such as the recycle system, into current farming practices in Thailand.

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

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

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Abstract

A survey on giant freshwater prawn (*Macrobrachium rosenbergii*) was conducted in Vietnam during March–April 2005. The survey was to assess the current status of giant freshwater prawn farming, including technical, socioeconomic, and environmental aspects in Vietnam. Forty-seven prawn farmers were randomly selected, among which 15 farmers were located in Co Do district of Can Tho province, 15 farmers in Vinh Thanh district of Can Tho province, and 17 farmers in Thoai Son district of An Giang province. The selected farmers were interviewed using a structured checklist and open-ended type of questionnaire. Data entry and analyses are continuing.

New Paradigm in Farming of Freshwater Prawn (*Macrobrachium rosenbergii*) with Closed and Recycle Systems
c: Bangladesh

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

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Abstract

A survey on giant freshwater prawn (*Macrobrachium rosenbergii*) was conducted in Bangladesh during January–June 2005. The survey was to assess the current status of giant freshwater prawn farming including technical, socioeconomic, and environmental aspects in Bangladesh. One hundred prawn farmers were randomly selected, among which ten farmers were located in Mymensingh district, 30 farmers in Noakhali Sadar district, 30 farmers in Bagerhat Sadar district, and 30 farmers in Fakirhat district. Primary data were collected through face-to-face interviews, using a structured checklist and open-ended type of questionnaire, group discussion, and Participatory Rural Appraisal, while the secondary data were gathered from different governmental and nongovernmental sources. Data entry and analyses are continuing.

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

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

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Abstract

An experiment is being conducted in fifteen 200 m^2 earthen ponds at the Asian Institute of Technology, Thailand. The objectives of the study are to assess effects of different phosphorus fertilization regimes on tilapia production and pond water quality, quantify nutrient budgets, and analyze the cost and return for fish with different phosphorus fertil-ization regimes and supplemental feed. Ponds were stocked with sex-reversed male Nile tilapia (*Oreochromis niloticus*) of an average size of 95.5 g at a density of 3 fish m^{-2} on 1 September 2005. Urea and triple superphosphate were applied weekly to all ponds at rates of 28 kg N and 7 kg P ha^{-1} wk^{-1} two weeks prior to fish stocking. Supplemental feeding was provided at 50% satiation level. After stocking and feeding fish, phosphorus fertilization was adjusted for different treatments, while nitrogen fertilization was kept unchanged at 28 kg N ha^{-1} wk^{-1} for all ponds. There were five phosphorus fertilization rates as treatments with three replicates each: 0%, 25%, 50%, 75%, and 100% (control) of 7 kg P ha^{-1} wk^{-1}, giving 0, 1.75, 3.50, 5.25, and 7.00 kg P ha^{-1} wk^{-1}, respectively. The experiment will be terminated when tilapia reach 500 g in size.

Use of Rice Straw as a Resource for Freshwater Pond Culture

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

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Abstract

The objectives of this study are to assess the effects of rice straw on fish production, water quality, plankton, bacterial biofilm, and periphyton; to optimize the loading of rice straw in both Nile tilapia monoculture ponds and carp polyculture ponds; and to compare rice straw and bamboo sticks as substrates in periphyton-based culture systems. This study was comprised of four experiments, conducted in both Bangladesh and Thailand.

Experiment 1 was conducted in 21 outdoor cement tanks of 5 m^2 in surface area at the Asian Institute of Technology during 25 February to 1 April 2005, to investigate physical, chemical, and biological changes of water in the process of the decomposition of rice straw at various loading levels. The experiment used a completely randomized design with seven treatments and three replicates per treatment. The treatments were seven levels of rice straw loading (0; 625; 1,250; 2,500; 5,000; 10,000; and 20,000 kg ha^{-1} on a dry matter basis). Temperature, pH, and dissolved oxygen (DO) were measured daily at dawn, while Secchi Disk visibility was measured daily at 0900 h. Column water samples were taken weekly at 0900–1000 h for the analyses of total alkalinity, total ammonia nitrogen (TAN), nitrite-N, nitrate-N, total Kjeldahl nitrogen (TKN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), total volatile solids (TVS), chlorophyll-*a*, and tannin. Rice straw samples were taken from each tank at the beginning and end of the experiment to quantify periphyton using Sedgwick-Rafter counts and bacteria using total plate counts. Preliminary analyses showed that DO at dawn, pH, water temperature, and Secchi Disk visibility decreased with increasing loading rates of rice straw ($P < 0.05$), while concentrations of total alkalinity, TP, SRP, TKN, TSS, TVS, and chlorophyll-*a* rose with increasing loading rate of rice straw ($P < 0.05$). The analyses of periphyton and bacteria are still going on. The preliminary analyses suggested that the loading rate of 625 kg ha^{-1} could be used in the Experiments 2 and 4 as the base rate.

Experiment 2 will be conducted in eighteen 200 m^2 earthen ponds in a completely randomized design at the Asian Institute of Technology. There were six treatments with three replications each: A) no rice straw mat (control); B) one rice straw mat; C) two rice straw mats; D) three rice straw mats; E) four rice straw mats; and F) rice straw mats covering the slope of dikes. Rice straw mats are prepared by pressing rice straw between bamboo splits. The dimension of rice straw mats is 5 x 1 m. Based on the result of Experiment 1, each mat contains 2.6 kg rice straw (dry weight basis). All ponds were drained completely and limed using agricultural lime at 2,000 kg ha^{-1}. Then the ponds will be filled with water one week later, and fertilized weekly using urea and triple superphosphate at 28 kg N and 7 kg P ha^{-1} $week^{-1}$. Rice straw mats will be suspended vertically in the water column of the treatment ponds according to the design. DO concentrations will be monitored daily at 0600 h in all ponds after placing rice straw mats into treatment ponds. When DO concentrations recover to about 3 mg L^{-1}, sex-reversed Nile tilapia (*Oreochromis niloticus*) fingerlings (about 10 g in size) will be stocked at 2 fish m^{-2}. Then, temperature, pH, and DO will be measured weekly at dawn and late afternoon, while Secchi Disk visibility will be measured weekly at 0900 h. Column water samples will be taken biweekly at 0900–1000 h for the analyses of total alkalinity, TAN, nitrite-N, nitrate-N, TKN, TP, SRP, TSS, TVS, chlorophyll-*a*, and tannin. Rice straw samples will be taken from each pond at the beginning, middle, and end of the experiment to quantify periphyton using Sedgwick-Rafter counts and bacteria using total plate counts. At the beginning and end of the experiment, soil, tilapia, and rice straw will be sampled for the analysis of moisture, total nitrogen, and total phosphorus.

Experiment 3 is being conducted in eighteen 40 m^2 earthen ponds in a completely randomized design at the Bangladesh Agricultural University. A long pond (83 x 8.9 m) was drained completely and partitioned by galvanized iron sheets into 18 small ponds of 40 m^2 each. There were six treatments with three replications each: A) no rice straw mat (control); B) one rice straw mat at the middle; C) two rice straw mats at 3 m apart; D) three rice straw mats at 2.25 m apart; E) four rice straw mats at 1.8 m apart; and F) four rice straw mats covering the slope of dikes. Rice straw was pressed between bamboo splits to make mats. Based on the results of Experiment 1, each mat contained 2.6 kg rice straw (dry weight basis). The dimension of rice straw mats was 2 x 1 m for treatments B through E, and 2.5 x 0.9 m and 2 x 0.8 m for treatment F depending on dike size. All ponds were partially filled with water, treated with rotenone to eradiate wild fish, and drained completely one week later. The ponds were then limed using agricultural lime at 250 kg ha^{-1}, filled with water three days later, and fertilized fortnightly at rates 31 kg urea, 16 kg triple superphosphate, and 1,250 kg cow dung per hectare. Rice straw mats were placed into the treatment ponds according to design. Two bricks were tied at opposite corners of each mat, and the mats were hung from a bamboo pole placed over the side dikes of the ponds by nylon rope for treatments B through E, while rice straw mats were placed over the slope of pond dike and fixed by bamboo stakes. DO concentrations were monitored at 0600 h daily in all ponds starting from 20 August 2005 when the rice straw mats were placed in the treatment ponds. The concentrations of DO in ponds of treatments D, E, and F dropped quickly to zero a few days after placing rice straw mats in ponds. When DO concentrations recovered to about 3 mg L^{-1}, fingerlings (about 25 g in size) of rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), catla (*Catla catla*), common carp (*Cyprinus carpio*), and silver carp (*Hypophthalmichthys molitrix*) will be stocked at one fish m^{-2} with species ratio of 3:2:2:2:1. Then, temperature, pH, and DO will be measured weekly at dawn and late afternoon, while Secchi Disk visibility will be measured weekly at 0900 h. Column water samples will be taken biweekly at 0900–1000 h for the analyses of total alkalinity, TAN, nitrite-N, nitrate-N, TKN, TP, SRP, TSS, TVS, chlorophyll-*a*, and tannin. Rice straw samples will be taken from each pond at the beginning, middle, and end of the experiment to quantify periphyton using Sedgwick-Rafter counts and bacteria using total plate counts. At the beginning and the end of the experiment, soil, carps, and rice straw will be sampled for the analyses of moisture, total nitrogen, and total phosphorus.

Experiment 4 will be done after Experiment 3 is finished to compare the best treatment from Experiment 3 with the developed periphyton-based culture system using bamboo sticks as the substrate. There will be three treatments, each in triplicate: A) no substrate (control); B) the best treatment using rice straw mats as substrate from Experiment 3; and C) periphyton-based culture system using bamboo as substrate.

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

Eleventh Work Plan, Sustainable Development and Food Security 3 (11SDFR3)
Abstract

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Abstract

This study compared the growth, survival, sexual maturation, and various reproductive parameters of four tilapia strains, three of which have been improved through various selective breeding approaches (GIFT, IDRC, and Fishgen-selected) and a local stock (Chitralada) to serve as a non-improved control. The four strains were originally cultured in extensive culture systems with fertilization only. Growth (weight and length) and reproductive parameters (gonadosomatic index, hepatosomatic index, and stages of sexual maturation) were measured on fish sampled every 21 days. Based on staging of gonad development, GIFT were found to become sexually mature marginally later than the other two strains. At nine months of age, broodstock from each strain were stocked in 5 m^2 breeding hapas with 5 males and 15 females per hapa and four replicate hapas per strain. Broodstock were sampled for eggs every week, and data was collected on fecundity and inter-spawning interval (ISI) for the four strains over the 17 months. Seasonal and environmental variances appear to be the major determinants of egg/fry production, with the only

strain difference observed being a lower relative fecundity in GIFT. Across all strains, fecundity per female increased over time while fecundity per unit weight of female remained constant. Spawning frequency and ISIs fluctuated widely between individual fish, and ISIs were even highly variable within individual females, making it very difficult to identify trends. Many females spawned very infrequently, and means of identifying fecund females could have significant impacts upon hatchery efficiency.

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

Eleventh Work Plan, Indigenous Species Development 2 (11ISDR2)
Abstract

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Abstract

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

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

Induced breeding trials indicated that natural induction methods (rain simulation, decreased/increased water depth and flow) did not stimulate mature females to spawn in ponds. A series of locally available hormones (e.g., HCG, LHRHa+Domperidone, CPE), singly or in combinations, was used to induce females to ovulate. Administration of LHRHa, CPE, and HCG were effective in inducing ovulation for *S. denticulatus*. However, LHRHa or CPE induced ovulation more consistently compared to HCG. Fertilization rates and hatch rates were also higher in the LHRHa or CPE than HCG induced groups. Individual females released 4.2– 9.4 x 10^3 eggs when stripped, and egg numbers were correlated with body weight of the female. Simultaneous injection of LHRHa and domperidone was required to achieve high success in induced spawning of *S. denticulatus*. Furthermore, no clear advantages were evident with the other hormone combination strategies.

Philippines Project: Production Technology

Philippines
Subcontract No. RD010A-20 (FIU)

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

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

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Work Plan Research

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

- Insulin-like growth factor-I gene expression as a growth indicator in Nile tilapia/12PSD5. A progress abstract was submitted for this investigation.
- Development of Nile tilapia fillets as an export product for the Philippines/12PSD6. A progress abstract was submitted for this investigation.

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Presentations

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Insulin-like Growth Factor-1 Gene Expression as a Growth Indicator in Nile Tilapia

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

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Abstract

Insulin-like growth factor-I (IGF-I) is a mitogenic polypeptide that is an important regulator of growth in fish. The potential of IGF-I mRNA abun-dance as an instantaneous growth indicator in Nile tilapia (*Oreochromis niloticus*) was evaluated. Hepatic IGF-I cDNA was isolated and cloned and partially cloned. The partial sequence, having 539 base pairs (bp), was found to code for the signal peptide (44 amino acids [aa]), mature protein (68 aa), and a portion of the E domain (19 aa). The deduced 68 aa sequence for mature IGF-I showed 84–90% and 77–80% sequence identity with fish and mammalian counterparts, respectively, confirming the highly conserved sequence homology among species. The B and A domains were even more highly conserved with respect to the deduced amino acid sequence. Based on the mature IGF-I peptide, a sensitive TaqMan real time qRT-PCR assay for *O. niloticus* was developed for measures of hepatic IGF-I mRNA levels. Hepatic IGF-I mRNA levels were found to be significantly correlated with growth rate of fish reared under different feeding regimes and temperature conditions. These findings suggest that hepatic IGF-I plays a key role in controlling growth of *O. niloticus* and indicates that IGF-I mRNA measures could prove useful to assess current growth rate in this species.

Development of Nile Tilapia Fillets as an Export Product for the Philippines

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

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Abstract

To process tilapia into fillet products a vital aspect is to have two stages of culture: one is the rearing of fingerlings and the other is the grow-out stage where the fish have to be grown further to reach an individual weight of about 600–800 grams. An experiment was conducted to evaluate the growth performance of Nile tilapia (*Oreochromis niloticus*) in earthen ponds to reach the preferred size for tilapia fillets. Two stocking densities were used as treatments; these were 1 and 2 pcs m^{-2}. Each treatment was replicated three times. Initial average weight of fish stocks was 85.391 g for Treatment I and 85.052 g for Treatment II. The experiment was done in six 500 m^2 ponds for 120 days. Fish sampling was done once a month to determine the gain in weight of the fish as well as to adjust the amount of feed to be given. The fish were fed with supplemental feeds provided by FEEDMIX Nutrition Specialists three days after stocking at 5%, over time decreasing to 2% of the average body weight of the fish. Pond fertilization was done a week before fish stocking at the rate of 28 kg of N and 5.6 kg of P ha^{-1} $week^{-1}$. Water quality parameters such as dissolved oxygen, water temperature, pH, total alkalinity, total ammonia nitrogen, and Secchi disc visibility were measured once per week. Results showed that Treatment I gave the higher final average weight of 590.168 g and Treatment II resulted in an average weight of 512.994 g. Higher daily weight gain was found in Treatment I with 4.206 g day^{-1} whereas Treatment II had 3.566 g day^{-1}. The mean survival rate was 89.1% for Treatment I and 80.8% for Treatment II. In terms of feed conversion ratio, Treatment I was found lower with 1.6 compared to Treatment II with 1.9. Treatment II gave a higher extrapolated fish yield compared to Treatment I , with mean values of 8,256.4 and 5,250.9 kg ha^{-1}, respectively.

Philippines-Thailand Project: Production Technology

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

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

JAMES BOWMAN

Staff

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Private Sector Collaborators

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

Work Plan Research

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

- Tilapia–shrimp polyculture in Negros Occidental, Philippines/12PSD7. A progress abstract was submitted for this investigation.

Educational Outreach

CRSP researcher and President of the World Aquaculture Society (March 2004–May 2005), Kevin Fitzsimmons had a busy year of chairing conferences, giving special guest lectures, and visiting other nations to discuss their aquaculture systems. In July 2004, Fitzsimmons visited aquaculture research facilities in Korea and met with students, faculty, and research scientists. He also provided a guest lecture at Busan National University on "Advanced technologies applied to aquaculture," and toured tilapia research at Busan University. He then visited WorldFish Center in Penang, Malaysia, in August and provided a seminar on potential collaborations between the ACRSP and WorldFish Center. He also served on the annual review panel for WorldFish Center and visited University Sains Malaysia in Penang where he gave a guest lecture on "Global production of tilapia." In September, Fitzsimmons chaired ISTA 6 with Remedios Bolivar and a session of the Asia-Pacific aquaculture conference in Sydney, Australia. The session's focus was on sustainable inland saline-aquaculture. In January of 2005, Fitzsimmons chaired the US Aquaculture meeting in New Orleans' session on tilapia.

Kevin Fitzsimmons met with aquaculture scientists in Australia in June 2004 to discuss freshwater aquaculture and sustainable farming systems, visiting irrigation-aquaculture projects in the Murray-Darling River basin. Later, in September 2004, Fitzsimmons, Yang Yi, and Amrit Bart visited Myanmar to tour tilapia hatcheries operated by an AIT graduate. The researchers also met with fisheries agency staff at government hatcheries and senior staff at fisheries headquarters. In late October, Fitzsimmons met with European Aquaculture Society officers and attended the EAS annual conference in Barcelona, Spain, and began organizing the ACRSP special session at the WAS 2006 meeting in Florence, Italy. In May of 2005, Fitzsimmons, Bolivar, Yi, and Bart met in Bali, Indonesia, to attend WAS meetings where several presentations were provided.

Fitzsimmons traved to Banda Aceh for Tsunami aquaculture restoration work, meeting with NGOs and government agency staff to discuss more sustainable coastal aquaculture program and met with senior aquaculture officials in Jakarta and Bogor to review aquaculture in Indonesia. He also toured hatchery and production facilities in western Java, meeting with NGOs that support aquaculture and ending destructive harvesting methods (rotenone and dynamite and coral harvest).

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Tilapia-Shrimp Polyculture in Negros Occidental, Philippines

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

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Abstract

Tilapia-shrimp polyculture has rapidly spread to most of the tropical shrimp farming countries in response to environmental and disease problems. There appears to be several benefits to stocking tilapia in conjunction with lower densities of shrimp. By contributing to a more sustainable aquaculture system, rearing tilapia with penaeid shrimp would benefit the entire industry. More specifically, returning abandoned ponds to a productive system would benefit local populations who have lost employment with the shrimp farms. It would also ameliorate the loss of natural resources that provided nursery areas for fisheries harvest.

The primary focus of the experiment is to work with one or two farms in the Philippines that have begun commercial-scale polyculture of tilapia and shrimp. One farm is on Negros and the other is in Mindanao. We will test three stocking plans for a polyculture system by conducting tilapia-shrimp polyculture trials in active ponds at one of these farms. Trials will compare three polyculture systems: sequential with tilapia in supply pond; simultaneous with tilapia in cages in ponds; and simultaneous with tilapia loose in ponds with shrimp. Water quality data will be collected to determine if culture of tilapia in conjunction with penaeid shrimp increases the number of green algae cells per ml of culture water. We will also attempt to determine if the concentrations of yellow and green fluorescing bacteria are significantly different between treatments.

Central Luzon State University has been coordinating with both farms to place a student on-site. The student will determine the exact polyculture system in use through a survey of stocking densities, ages and size at stocking, and size and construction of cages. Our plan is to replicate the stocking densities in the Philippines and Mexico. Stocking of the experiments should occur in November, as well as monitoring of on-going farm-based trials.

Amazon Basin Project: Production Technology

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

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

ROGER HARRIS

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Instituto de Investigaciones de la Amazonía Peruana, Iquitos, Peru (Lead Host Country Institution)

Salvador Tello	Lead Host Country Principal Investigator
Fernando Alcántara	Host Country Co-Principal Investigator
Mariano Rebaza	Host Country Co-Principal Investigator

The Ohio State University, Columbus, Ohio

Konrad Dabrowski	US Principal Investigator
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José Machoa Collaborator
Medardo Tapias Collaborator

Empresa Brasileira de Pesquisa Agropecuári (Embrapa), Brazil
Levy Caraballo Collaborator

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

- Nutrition and nutrient utilization in native Peruvian fishes/12FNF2. A progress abstract was submitted for this investigation.
- Broodstock development of Amazonian fishes/12ISD2. A progress abstract was submitted for this investigation.
- Broodstock development and larval feeding of Amazonian Fishes/12ISD4. A progress abstract was submitted for this investigation.
- Effects of native Peruvian feedstuffs on growth and health of *Colossoma* and *Piaractus*/12FNF1. A progress abstract was submitted for this investigation.
- Amazon aquaculture outreach/12SDF1. A progress abstract was submitted for this investigation.

Educational Outreach
US Principal Investigator Konrad Dabrowski gave two lectures, one entitled "Sex reversal in fish and production of monosex populations" and the other titled "Broodstock development and larval rearing of Amazonian fishes," to undergraduate students at The Ohio State University on 9 February 2005. He then hosted a younger audience of Karrer Middle School students for their Career Mentoring Program on 22 April 2004 in Columbus, Ohio.

US Principal Investigator Rebecca Lochmann and her UAPB nutrition lab put together numerous show and tell and academic presentations to students and the public about pacu. These presentations were expanded to include three days of phone advice given to potential growers in the US on 27–29 April 2005. She also went to Pine Bluff elementary school children and gave multiple show and tell presentations to children.

Lead US Principal Investigator Chris Kohler gave a public seminar in March 2004 in Carbondale, Illinois, entitled "Sustainable small-scale aquaculture in the Amazon Region."

Kohler organized the "4th International Training Course of Prominent Amazonian Aquaculture Species for Students and Professionals," held in the National University, Leticia Campus, Colombia, with the participation of fifty-seven individuals representing Ecuador, Brazil, Colombia, Venezuela, and Peru in July 2004. The "4th International Training Course of Prominent Amazonian Aquaculture Species for Producers" was held at the same time in Leticia, Colombia, with the participation of twenty producers and farmers representing Brazil, Colombia, and Peru. Both were partially funded by ACRSP-USAID.

Kohler organized the "1st International Training Course of Ornamental Amazonian Fish Species" held in Leticia, Colombia, with the participation of eighteen individuals representing Brazil and Colombia in July 2004, funded partially by ACRSP-USAID.

Two extensionists conducted 6 seminars on aquaculture: two seminars at two local schools in Peru; one in Colombia to local farmers; two seminars in Ecuador to local farmers and indigenous groups; and one in Manaus, Brazil, to University students. They are continuing to offer training courses to students and teachers (both natives and settlers) from high schools and vocational schools in Iquitos, Peru, and Leticia, Colombia. The Peruvian extensionist offered extension services for one month in the Ecuadorian Amazon region (San Juan Bosco, Macas, and El Puyo) in February 2005.

Publications
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Nutrition and Nutrient Utilization in Native Peruvian Fishes

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

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Abstract

Native species aquaculture has been expanding in the Amazon region in recent years. *Colossoma macropomum* (Characiformes: Characidae) is the second-largest scaled, freshwater fish in South America. *C. macropomum* (black-finned pacu) is native to the Amazon Basin and possesses many characteristics suitable for aquaculture. Black-finned pacu is in high demand and attains a high price at the marketplace. However, no formulated diets are available specifically for *C. macropomum* culture. Consequently, a wide range of ingredients for locally manufactured formulated diets are used in the countries where this fish is cultured. These diets have variable crude protein (CP) which ranges from 18 to 43% CP, and the supplied ration ranges from one to five percent of the fish wet body weight. Commonly wheat, corn, and rice are some of the main energy sources in these formulated diets. As wheat is not traditionally cultured in the Amazonian region; it has to be imported from distant regions, thus limiting its use for direct human consumption. A growth experiment was conducted to determine the effect of substituting three alternative ingredients for wheat middlings on growth performance and conversion efficiency in Amazonian black-finned pacu (86.9 ± 6.4 g). Fish were fed a control and three practical diets for a 24 wk period and their growth rates and conversion efficiency ratios were determined and compared. Fish were fed at three percent of their wet body biomass divided in two daily rations of one of the four diets: 1) control diet (31.8% CP); 2) cassava diet (27% CP); 3) plantain diet (27.5% CP); and 4) palm peach diet (28.1%). Fish weight and length were measured every two weeks. At the end of 24 weeks, the final mean weights of black pacu in the control, cassava, plantain, and palm peach diets were 538.8, 559.0, 552.7, and 527.4 g, respectively, and these values were not significantly different from each other ($P < 0.05$). Final mean weight gain of black pacu in the control, cassava, plantain, and palm peach diets were 458.2, 476.2, 465.8, and 437.8 g, respectively, and values were also not significantly different ($P > 0.05$). Diets tested did not significantly influence specific growth rate ($P > 0.05$) or feed conversion ratio ($P > 0.05$), however, they did influence protein efficiency ratio ($P < 0.05$). Based on these findings, it was concluded that all of the tested ingredients, cassava, peach palm or plantain meal can replace wheat middling in formulated diets for *C. macropomum* without adversely affecting fish growth performance.

A second experiment was conducted to determine digestibility of the three alternative ingredients tested in the previous experiment with *C. macropomum* in 110 L tanks in a flow-through system at Southern Illinois University at Carbondale. Digestible energy, protein, lipid, and dry matter digestibility coefficients were determined for each feedstuff. The reference diet was similar in composition to those used currently for Characid fishes at Instituto de Investigaciones de la Amazonía Peruana (Peru). Digestibility coefficients were determined by using an indirect method, involving chromic oxide (Cr_2O_3) as a non-digestible marker. The digestibility of crude protein (86.5%), crude fat (90.6%), and energy (62.6%) of pijuayo in *C. macropomum* was far superior to that of yucca and plantain. The digestibility of plantain and yucca by *C. macropomum* were very similar to each other for crude protein (53.9 vs. 48.3%), crude fat (50.9 vs. 57.5%), and energy (23.7 vs. 14.4%). Pijuayo appears to be an excellent ingredient to be employed in formulated diets for *C. macropomum*. Additionally, the abundance of pijuayo in the Amazon Basin makes this fruit economically viable to the small-scale farmers to reduce feed manufacturing cost.

Broodstock Development of Amazonian Fishes

Twelfth Work Plan, Indigenous Species Development 2 (12ISD2)
Abstract

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Abstract

A preliminary study was carried out with 27 *Colossoma macropomum* broodstock between 4 and 11 kg donated by World Aquarium (Saint Louis, Missouri, USA) in two earthen ponds at Southern Illinois University at Carbondale (SIUC). Broodstock were pit-tagged and randomly distributed in three ponds. Water quality was modified to maintain three different environments (three different alkalinities, pH, conductivity, tannic acid content, transparencies, and TDS) emulating the three most common Amazon ecosystems where these fish naturally inhabit to evaluate water quality as a fish reproduction conditioning factor. Blood samples were collected prior to the start of feeding and will be collected once more after spawning. In one month, fish will be induced to spawn by hormonal injections and eggs from individual females incubated separately to monitor percentage of eyed embryos (13 hours after fertilization) and the hatching rate. Blood samples will be taken at the time of hormonal injection and at ovulation from at least four fish of each sex per dietary treatment. Blood plasma, seminal plasma (after centrifugation) and egg samples will be immediately frozen for later analysis at SIUC for hematocrit and steroid hormone analysis. Specific growth rates, food conversion ratios, and condition factors of broodstock will be compared between treatment groups. Survival of larvae at the free swimming stage will be considered as a final indicator of their quality. A duplicate study will be conducted next spring in Colombia, at Acuarios Leticia research station in Leticia, Colombia under the supervision of Universidad Nacional de Colombia and Instituto de Investigaciones de la Amazonía SINCHI.

Amazon Aquaculture Outreach

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

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Abstract

Outreach activities have significantly benefited over 129 producers and their families (256 ponds – 90 ha) in the Peruvian Amazon (Iquitos-Nauta) and 78 producers (23 females, 37 males, and 18 teenagers) and their families in the Colombian Amazon (Leticia), the latter being in its first year of extension activities. Additionally, the two Aquaculture CRSP-funded extensionists have provided aquaculture training to 48 vocational high school students (16 females and 32 males) in the Amazon Basin (Brazil, Colombia, Ecuador, and Peru). One of our extensionists (Pedro Ramirez) from Peru was in an exchange program, initiated in the Eleventh Work Plan, in the Ecuadorian Amazon for one month, training a total of 69 (57 males and 12 females) producers in two basic aquaculture training courses held in El Puyo and Macas. The training courses helped provide technical assistance in aquaculture techniques to local and prospective fish farmers. Fifty-seven individuals representing Ecuador, Brazil, Colombia, Venezuela, and Peru participated in the "4th International Training Course of Prominent Amazonian Aquaculture Species for Students and Professionals," which was held in the National University, Leticia Campus, Colombia, from 21–24 July 2004. Twenty producers and farmers representing Brazil, Colombia, and Peru participated in the "4th International Training Course of Prominent Amazonian Aquaculture Species for Producers," which was held in Leticia, Colombia, from 22–24 July 2004. Eighteen participants representing Brazil and Colombia attended the "1st International Training Course of Ornamental Amazonian Fish Species," which was held in Leticia, Colombia, from 25–27 July 2004. The Amazonian aquaculture website, developed in the Tenth Work Plan, is being maintained. This site is an important tool to communicate the work done by research institutions in the USA, many Amazon basin nations, and elsewhere (over 7,000 hits from 1 August 2004 through 31 July 2005).

Effects of Native Peruvian Feedstuffs on Growth and Health of *Colossoma* and *Piaractus*

Twelfth Work Plan, Fish Nutrition and Feed Technnology 1 (12FNF1)
Abstract

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Abstract

Personnel at the University of Arkansas at Pine Bluff (UAPB) performed health assays on *Colossoma macropomum* used in a digestibility trial at Southern Illinois University at Carbondale. Blood was collected and hematocrit (Hk) and hemoglobin (Hb) were analyzed (Hb cyanide method, Houston, 1990). Mean corpuscular hemoglobin content (MCHC) was calculated based on the formula: MCHC = Hb concentration/Hk. The fish plasma was used for the analysis of alternative complement activity, a measure of the non-specific immune response.

Hemoglobin was not affected by diet, while hematocrit and MCHC were lower in the fish fed the plantain diet than those fed the control diet, but no explanation is obvious. Fish fed the yucca diet had higher complement activity than fish fed the control diet, indicating an immunostimulatory effect of the yucca.

A feeding trial is currently being conducted at UAPB with juvenile *Colossoma macropomum* to determine the effects of diets with cooked or uncooked plantain, pijuayo, and yucca on growth, survival, feed efficiency, and health parameters of gamitana. Six-week data showed no growth or survival differences among treatments. The trial will continue for four more weeks, then the same health parameters measured in the previous trial will be measured.

Broodstock Development of Larval Feeding of Amazonian Fishes

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

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Abstract

Induction of reproduction of the South American catfish (*Pseudoplatystoma surubim* sp.) broodstock raised in our facility at The Ohio State University was attempted on 2–15 March 2005. Fish were initially checked for signs of maturity (production of sperm by gentle pressure of the abdomen in males and oocyte biopsy using catheter in females). Sperm was collected from two males weighing 2,726 and 2,611 g. Sperm concentrations reached 6.88 10^9 spz ml^{-1}, whereas duration of motility in saline solution (0.35%) was very long (up to 13 minutes) in comparison to other freshwater fish species. On 14 March 2005, a female which presented oocytes with peripherical germinal vesicle was injected with two doses of carp pituitary extract (CPE) (0.5 and 5 mg kg^{-1}) at 11-h intervals, whereas the two males that produced sperm and two other potential males were injected with a single dose of CPE (0.5 mg kg^{-1}). The female was observed regularly (2–3 hours) after treatment in accordance with the description given for *P. fasciatum*. Twenty-three hours after the second hormonal injection, a small quantity of eggs (18.7 g) was extracted upon abdominal pressure. Sperm was collected from the two previously identified males and concentrations reached 11.7 and 9.2x10^9 spz ml^{-1}, respectively. Sperm from each individual male (10 ml) was used to fertilize eggs (2 g) either in 10 ml water or saline 0.35% (triplicated treatments). The remaining eggs were inseminated with a mixture of sperm. Microscopic observations did not reveal any progress in embryonic development. Fertilization failed.

On 11 February 2005, we received surubim (*Pseudoplatystoma* sp.) larvae, two days after hatching, from the Aquaculture Center, Sao Paulo State University, Jaboticabal, Brazil (M.C. Portella). Larvae were offered live *Artemia nauplii* during the first week. Then we conducted a feeding experiment and reported for the first time the differences in diet acceptance, fish growth and diet utilization in surubim at early stages of ontogeny (10 mm, total length; experiment 1). In the second experiment with juveniles (25 mm), fish were offered *Artemia nauplii* and overperformed those transitioned to live tubificid worms or two commercial diets both in terms of weight gain as well as survival. Fish offered semi-purified diets based on casein/gelatin or synthetic dipeptides (50% protein), accepted formulated feeds, gained weight, and in the case of peptide-based diet had an excellent survival (85%). Juvenile surubim (initial weight 100.5 + 5.1 mg) grew best when offered the marine larval diet (Aglo Norse), however, severe cannibalism was observed. Results of substantial growth and no cannibalism in fish fed a peptide-based diet are particularly encouraging because this formulation may allow further evaluation of nutrient requirements in this species.

Central America Project: Production Technology

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

Honduras has been an Aquaculture CRSP host country since the program's inception in 1982, excluding a brief interruption from 1987 to 1988 during the crisis created by Hurricane Mitch. In 1999, Aquaculture CRSP research in Honduras moved from Comayagua to a new site at the Escuela Agrícola Panamericana El Zamorano (Zamorano). A Memorandum of Understanding was signed between Zamorano and the University of Georgia (UG) in October 1999, which served as lead institution until 2003. Auburn University (AU) is now the lead US institution. While Honduras serves as the focal point, research and outreach for the Central America Project also occurs in Nicaragua, Dominican Republic, and Guatemala. Ongoing Aquaculture CRSP research in Central America is focused on economics and marketing assessment, subsistence aquaculture for indigenous people, pond design and watershed analyses training, and evaluating tilapia seed supply.

JAMES BOWMAN

Staff

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Adonis Gallindo	Field Assistant
Erasmo Aguilera	Undergraduate Student

University of Georgia, Athens, Georgia

E. William Tollner	US Principal Investigator
Brahm P. Verma	Collaborating Scientist

Work Plan Research

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

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

Publications

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Tollner, E.W., D. Meyer, S. Triminio-Meyer, B. Verma, G. Pilz, and J. Molnar, 2004. Spreadsheet tools for developing surface water supplies for freshwater fish in developing countries. Aquacultural Engineering, 31(2):31–49.

Trejos-Castillo, E., P. Martinez-Mejia, J. Molnar, D. Meyer, S. Triminio-Meyer, E. Tollner, and B. Verma, 2004. Income, food security, and poverty reduction: case studies of functioning clusters of small- and medium-scale producers of tilapia in Honduras. Aquaculture CRSP Information Leaflet No. 1,280. (Spanish language) Auburn: Auburn University, International Center for Aquaculture and Aquatic Environments, Department of Agricultural Economics and Rural Sociology.

Presentations

Triminio-Meyer, S., D.E. Meyer, and J. Molnar, 2004. Productores de alevines de tilapia en Honduras, características, prácticas y necesidades de apoyo. First Latin American workshop for the Tilapia Sector, Puerto Vallarta, Mexico, June 2004.

Triminio-Meyer, S., D.E. Meyer, and J. Molnar, 2005. Evaluation and improvement of tilapia fingerling production and availability in Honduras. WAS Aquaculture America 2005, New Orleans, Louisiana, 17–20 January 2005.

Triminio-Meyer, S., J. Molnar, D. Meyer, W. Tollner, and B.Verma, 2005. Tilapia fingerling production and availability for aquaculture in Honduras. Annual Meeting of the American Association for the Advancement of Science, Washington, DC, 17–18 February 2005.

Thesis

Triminio-Meyer, S., 2005. Tilapia Fingerling Production in Honduras. M.S. Thesis.

Evaluation and Improvement of Tilapia Fingerling Production and Availability in Honduras

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

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Abstract

The lack of an adequate supply of all-male tilapia fingerlings has been identified by fish farmers as a principal constraint to small- and medium-scale fish culture development in Honduras. A survey of tilapia fingerling producers was conducted to evaluate tilapia fingerling production and examine the factors that influence the way farmers produce and distribute fingerlings. Sixteen farmers were identified and interviewed during the period from September 2003 to July 2004. Seed production is concentrated in the valley areas of Olancho, Comayagua, and Cortez, Honduras. Fingerling sex reversal with hormone-treated feed was practiced by 14 of the 16 farmers. Seven fingerling farms are family-owned, four are private companies, one is a cooperative, one is operated by a nonprofit organization, another run by a university, and two are government stations. From each of the farms, and in the manner that would be used by a typical producer, a minimum of 1,000 fingerlings were purchased and transported to the aquaculture station at Zamorano for evaluation (count, uniformity of size, and uniformity of color). A subsample of 250 fingerlings purchased from each farm was reared to a size when sex identification was possible. The sex of each adult fish was determined by visual examination of the genital papilla to ascertain the percent of males in each subsample. In aggregate, the sample produces approximately 15.3 million fingerlings per year.

Most (75%) of the fingerling producers interviewed also raise tilapia, produce other aquaculture species, and have other farm enterprises. Fingerling farmers have at least 4–6 years of formal education and fingerling production experience with an average of 6.7 years and a range of 0–25. This study considered three indicators of fingerling quality (uniformity of color, size, and male gender). The results show that there is higher variability for color and gender than for size among the fingerling batches evaluated. This variability suggests that the quality of fingerling delivered to tilapia farmers is not consistent. Most of the fingerling batches evaluated fall under the 90% level of uniformity of size, color, and gender. Only two independent variables had a significant relationship with fingerling quality. Farmer experience growing tilapia is positively related to fingerling quality production, but production training in itself was not related to fingerling quality, as producing seed is a specialized and skilled activity. High variability in sex reversal occurs in part because most farmers do not use standard methods of grading their fry and fingerlings by size, thus introducing inconsistency in hormone dosage and length of treatment. This is an area where training can accomplish improvement in the outcomes of the sex reversal practices as well the size uniformity of fingerling sold. Feeding methods could be one source of low quality. Producers often do not count fry in the sex reversal process, thus the feed they provide is often not well gauged to the number of fish. Some reported that when the demand is high, they sometimes sell fingerlings before the recommended treatment period (28–30 days) is completed. Even though most farmers used the recommended protocol for the preparation of the hormone-treated feed (60 mg MT kg^{-1} of feed), some economize by lowering the dosage or using cheaper alcohol of a different type. Some use outdated hormone (more than four years old). One approach that has proven effective for some fingerling producers is to purchase prepared hormone feed from other farmers or institutions with more experience and access to the hormone source. Improving the level of practice among fingerling producers is a key step to improving quality and productivity in the industry.

Understanding the Agricultural Knowledge System for The Development of Aquaculture in Nicaragua: Economics, Institutions, and Markets

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

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Abstract

The Agricultural Knowledge and Information System for Development (AKISD) is an analytical tool that integrates all the different stakeholders of a system to create knowledge and technology that suits the needs of producers. An Agricultural Knowledge and Information System links people and institutions to promote mutual learning and generate, share, and utilize agriculture-related technology, knowledge, and information. The implementation of this analytical tool requires the holistic analysis of the production system or activity under study and not the isolated analysis of individual producers' units or public and private advocating institutions. For this study, the analysis requires the study of all the different stakeholders on tilapia culture in Nicaragua. The systematic approach is fundamental to combine the different perspectives of stakeholders and disciplines in a holistic process that generates improved technology, policy, markets, and social organization for the increase in productivity of farm-related activities and rural as well as urban development. The study has identified Chinandega and Esteli Departments as areas where clusters of producers and aquaculture infrastructure have developed. Following a training conference in Esteli in November 2005, an increase in the productivity of individual farms affects the level of productivity in the cluster, and clusters affect the level of productivity of other clusters and the overall competitiveness of the Nicaraguan economy. The results of the study should give guidance and direction to the development of the industry and its relation to regional and global markets.

Assessing the Potential for Aquacultural Development to Promote Food Security Among Indigenous People in Guatemala

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

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Abstract

In Guatemala, the total area of freshwater ponds just exceeds 100 ha, which is less than 10% of the total surface dedicated to shrimp production. Some additional 26 ha produce freshwater prawns for domestic consumption. In 1989, FAO reported that five tilapia species (*Orechromis mossambicus, Tilapia rendalli, Oreochromis niloticus, Oreochromis aureus*, and *Oreochromis urolepsis hornorum*) have been introduced into the region and stocked in ponds, large water bodies, and even released into open watersheds. The Peace Corps and governmental technical assistance constructed nearly 600 small ponds in recent decades. Most of the ponds are managed on subsistence and semi-commercial levels, but the coffee crisis and a growing market potential have increased interest in tilapia production. Fish are harvested for home consumption, and surpluses are sold in local markets. Women are responsible for the daily management and feeding of these ponds, while the men are primarily responsible for pond construction and harvest. Two case study areas were chosen where several indigenous communities have sustained involvement in tilapia culture for several years. In Comunidad La Bendicion, Pochuta, Chimaltenango, tilapia cultivation is conducted on a communal land, which has an approximate area of 10,000 square meters, confined by a fence. The compound has a single entrance and a mesh door with padlock. As the ponds tend to be close to dwelling areas, the intent is to protect children and prevent theft. The three ponds (two of 4x4 m and one of 15x8 m) are supplied with water from a spring and from a river. The water arrives by gravity through poliductos (flexibile black plastic pipes), which reduces costs since it is not necessary to pump water. The group purchases fingerlings from the experimental station of Amatitlán; this station is managed by the Universidad de San Carlos de Guatemala where sex-reversed and mixed-sex fingerlings are sold. The fish are sold at an average weight of 450 g; most consumers prefer fish of this weight because there can be an individual fish for each family member. The price for which one sells the tilapia is Q 22 kg^{-1} (Q 7.55 = USD$ 1.00). Previously they were selling the tilapia at Q 17.6 kg^{-1}, but most producers could not cover costs at this price. A parallel study is underway in Suchitepequez. The case studies should generate insights into the strategies for advancing aquaculture among Guatemala's poorest peoples in areas with appropriate soil and water resources.

Pond Design and Watershed Analyses Training

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

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Abstract

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

Mexico Project: Watershed Management

Mexico
Subcontract No. RD009C-01 (OSU)
Subcontract No. RD009E-A (OhSU)
Subcontract No. RD010A-11 (UA)

The Aquaculture CRSP has been active in Mexico since 1997. A Memorandum of Understanding was signed between Oregon State University (OSU) and the Universidad Juárez Autónoma de Tabasco (UJAT) in June 1999. Following a recommendation from the Administrative Management Review in 2002, several Aquaculture CRSP-funded Mexico projects at UJAT – involving Texas Tech University, The Ohio State University, and University of Arizona – were consolidated to form a single umbrella Mexico Project with OSU serving as the lead. Present research within this Mexico Project emphasizes alternative methods of tilapia sex control, indigenous species development, safe handling methods of methyltestosterone, and evaluation of tilapia-shrimp polyculture.

JEFF BURRIGHT

Staff

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Rosaura L. Mendez-Montiel	Undergraduate Student (Mexico; partially CRSP funded)
Ana Y. Torres Marín	Undergraduate Student (Mexico; partially CRSP funded)
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Tamara Young	Temporary Worker (February 2005 through March 2005)

The Ohio State University, Columbus, Ohio

Konrad Dabrowski	US Principal Investigator
Jacques Rinchard	US Co-Principal Investigator
Mary Ann G. Abiado	Research Assistant
Gustavo Rodriguez	Doctoral Graduate Student (Mexico)

University of Arizona, Tucson, Arizona

Kevin Fitzsimmons	US Principal Investigator
Huruy Zerzghi	Graduate Student (Eritrea)
Pablo Gonzalez Alanis	Graduate student
Thianny Trujillo Rodriguez	Graduate student

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

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

Educational Outreach
US Principal Investigator Kevin Fitzsimmons has made several trips to Latin America in order to further tilapia aquaculture. He met with government officials, NGOs, and farmers to discuss forming Brazilian tilapia farmers organization in Brazil in May 2004. He also provided guest lectures at Universidad Juárez Autónoma de Tabasco on polyculture of tilapia and shrimp, meeting with faculty and potential graduate students for MS program at Arizona in Villahermosa, Tabasco, in November 2004, met with faculty at Instituto Technologico y de Estudios Superiores de Monterrey to review aquaculture projects and discuss graduate student projects in Guaymas, Mexico, in April 2005, and finally, he attended a USAID conference along with HCPI Wilfrido Contreras in Guadalajara, Mexico, where he made a presentation on joint research projects with UJAT and the University of Tamaulipas. This is all in addition to his work within the US, where he hosted graduate students from Tabasco and Sonora at the University of Arizona's aquaculture short course and attended the USAID conference in Washington D.C. August 2004. There he met with aquaculture PIs from Mexico and Kenya.

Lead Host Country Principal Investigator Wilfrido Contreras hosted two workshops in Mexico. The first covered safe handling of steroids and clean technologies in aquaculture in Mexico City on 19 February 2004 and the second was on sex reversal in Villahermosa, Tabasco, on 28 April 2004.

Publications
Dabrowski, K. To cover activities of two students from Karrer Middle School during the shadowing program in the Aquaculture Laboratory. News Article. no date given

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Macdonal-Vera, A., N.J. Duncan, W. Contreras-Sanchez, and K. Fitzsimmons, 2004. Effect of stocking density of red hybrid tilapia (*Oreochromis* sp.) on growth and survival of tilapia and shrimp in polyculture. In: R. Bolivar, G. Mair, and K. Fitzsimmons, (Editors), Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, Bureau of Fisheries and Aquatic Resources, pp. 483–484.

Presentations
Dabrowski, K., 2005. Continued studies on the use of phytochemicals as possible sex differentiation affecting agents in tilapia nilotica by dietary administration and immersion treatments. WAS Aquaculture America 2005, New Orleans, Louisiana, 17–20 January 2005.

Fitzsimmons, K., C. King, and D. McIntosh, 2004. Overview of inland-saline aquaculture. Australasian Aquaculture 2004, Sydney, Australia, September, 2004.

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

Twelfth Work Plan, Applied Technology and Extension Methodologies 4 (12ATE4)
Abstract

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Abstract

Developing new techniques for the production of clean aquaculture effluents would be futile unless the information that is generated is transferred to people conducting aquacultural activities. This is especially difficult in Mexico and Central America because information is not readily accessible. Workshops conducted in Mexico under Aquaculture CRSP support have already impacted tilapia culture in Tabasco and Chiapas, and most farmers are growing sex-reversed tilapias. This activity was not conducted until only a few years ago. To complement research for the production of clean sex-inversion techniques, we believe that it is of vital importance to train farmers and extension agents and provide printed materials for the safe handling of steroids in aquacultural facilities. Workshops will be conducted in Central America with the goal of educating extension agents, technicians, students, and farmers on safe and effective sex inversion techniques. These personnel can then train additional growers. A manual in Spanish prepared at Universidad Juárez Autónoma de Tabasco will be used as the primary material at the workshops. The first workshop will be conducted in San Pedro Sula, Honduras, on 13 October 2005. In collaboration with Dan Meyer (Pan-American Agricultural School, Zamorano) we have invited farmers, students, and extension agents to participate in the Honduras workshop. Topics covered will be tilapia fry production, steroid characteristics, steroids in aquaculture, masculinization of fish, safe handling of steroids, use of charcoal filtration systems to eliminate methyltestosterone, and a description of successful operations in Mexico. We are currently establishing a network with farmers and researchers in Guatemala and Costa Rica to implement additional workshops.

Incorporation of the Native Cichlid *Petenia splendida* into Sustainable Aquaculture: Reproduction Systems, Nutrient Requirements and Feeding Strategies

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

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Abstract

Some information has been obtained from wild populations of native species of fish, but little is known about their reproductive performance in captivity. In our laboratory we have studied some reproductive features of tenhuayaca (*Petenia splendida*), and we have found indications that tenhuayaca may be a very good candidate for aquaculture purposes. In Experiment 1, we determined the best sex proportion of adult tenhuayacas for reproduction in captivity. A recirculating system composed of nine 2,000 L plastic tanks was used. Brooders (20–30 cm, total length) were adapted to captivity conditions and placed in three treatments based on sex proportions (1:1, 2:1, and 3:1 F:M). In a triplicated block design, fish were randomly assigned to tanks. Six females were placed in each tank, while the number of males was adjusted according to the experimental design. Final numbers of fish per tank were: 12 for the density of 1:1; nine for the density of 2:1; and eight for the density of 3:1. Reproductive performance (spawning events, fry production, and survival) were evaluated for two months. Results indicated that the number of spawns were very similar for all treatments (28, 29, and 26, respectively). The largest number of fry were obtained in the 2:1 proportion followed by the proportions 3:1 and 1:1 (81,364; 65,778; and 55,035 fry, respectively). However, no significant differences were found between treatments ($P > 0.05$). Survival of fry was very high in all treatments (range 96.9–98.1%). Data from Experiment 2 is currently being analyzed. The experiment on the partial substitution of sardine meal for wheat gluten began on 27 August 2004. A total of 135 mature fish with an average size of 65 g and 19 cm TL were placed into 15-2 m diameter tanks using a completely randomized design (n=9). A sex ratio of 2:1 (females:males) was used. After one month of experimentation, no significant differences in weight or total length have been found between treatments. This experiment ends in November 2005. Other experiments will be conducted between November 2005 and April 2006. A final report will be submitted in June 2006.

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

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

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Abstract

The selective breeding program supported by the Aquaculture CRSP from 2001 to 2003 was initiated using 220 females and 110 males obtained from a batch of fish purchased from Egypt by the state government (Tabasco line). A second line is currently being selected from wild animals. We have identified a stock of wild Nile tilapia in the Usumacinta River that shows several advantageous phenotypic traits, such as a small head, small tail, large body, and uniform color (Wild Tabasco line). For the first year of work, we were able to combine the efforts of the Aquaculture CRSP project and a project supported by the National Council for Science and Technology (CONACyT-Mexico). This action allowed us to work at the Mariano Matamoros Hatchery using 200; 1,000; and 2,000 m^2 ponds and to use fish first selected by Mario Fernández in 2000. Adult fish were stocked in 200 m^2 ponds. From the fry obtained, three selections were made: one at 60 days; a second at 120 days (at this point the fish were separated by sex); and a third at 11 months. We have initiated the selection of organisms from the third generation (F3) of the Tabasco line, the wild line and the control fish (Teapa line). Two-thousand eight-hundred fish were stocked in 200 m^2 ponds using a density of 14 fish m^{-2}. Survival was similar in fish from the Tabasco and the Teapa line; however, fish from the control group had lower survival than the rest (80.5, 70.7, and 61.0%, respectively). Results measured in terms of weight, length, and biomass were very similar between the Tabasco and the wild line; the control was significantly lower than the other lines (12.8, 12.7, and 8.5 g,

respectively). Eight-hundred fish were selected from the first batch and stocked in ponds at a density of 4 fish m^{-2}. After 90 days of growth, fish from the Tabasco line grew faster than the fish from the wild and the control groups (40.1, 32.9, and 31.1 g, respectively). A third selection was conducted in July. Two-hundred females and 66 males were selected as broodstock. Reproductive performance of the three lines is currently being evaluated. A final report will be submitted in June 2006.

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

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

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Abstract

Masculinization of tilapia fry by oral administration of 17α-methyltestosterone (MT) is considered the most successful method employed; however, under certain conditions this technique is sometimes less favorable. Furthermore, significant "leakage" of MT into the pond environment may occur from uneaten or unmetabolized food. This leakage poses a risk of unintended exposure of hatchery workers, as well as fish or other non-target aquatic organisms, to the steroid or its metabolites. We propose the use of intensive systems for masculinizing tilapia fry using MT-impregnated food at a large scale where excess MT is eliminated from the water by means of continuous filtration through UV sterilizers. This study is testing the hypothesis that MT could be eliminated from the water used in intensive sex-inversion systems using UV sterilizers. We are currently running tests in our systems, and experimental runs will be conducted from October 2005 to February 2006. Water samples (20 ml) will be extracted with Sep-Pak cartridges and sent to Oregon State University to determine levels of MT. A final report will be submitted by June 2006.

Elimination of Methyltestosterone from Intensive Masculinization Systems: Use of Solar Irradiation and Bacterial Degradation

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

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Abstract

It is well known that one of the major problems in aquaculture is the elimination of culture wastes from water. The amount and type of residues will depend on the species cultured, the stage of development, and the feeds used. To lower the environmental impacts caused by aquaculture practices, different technologies have been developed to preserve water quality and reduce residue levels during fish culture. These systems are known as recirculation aquaculture systems (RAS) and are widely used because they allow for efficient disposal of wastes in aquaculture. In a previous investigation we developed a RAS to eliminate methyltestosterone (MT) from aquaculture effluents in an intensive system for masculinizing tilapia fry at a large scale. In this system, the excess MT was eliminated from the water and the substrate by means of continuous filtration through activated charcoal filters. Our RAS is composed of a submersible pump, sediment trap, charcoal filter section, mechanical filter section, biological filter section, and a water curtain with sunlight exposure. In this experiment, we were able to demonstrate that MT is eliminated from the water; however, we wanted to determine if bacteria in the biofilter and sunlight played a significant role in eliminating the steroid. The goal of this investigation is to determine if the bacteria present within our RAS are capable of degrading MT. The ultimate goal of our research will be to isolate, characterize, and cultivate the species of bacteria responsible for degradation of steroids. We are currently building the filters needed in our tanks, and experimental runs will be conducted from October 2005 to February 2006. Water samples (20 ml) will be extracted with Sep-Pak cartridges and sent to Oregon State University to determine levels of MT. A final report will be submitted by June 2006.

Testing Three Styles of Tilapia-Shrimp Polyculture in Tabasco, Mexico

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

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Abstract

Tilapia-shrimp polyculture has rapidly spread to most of the tropical shrimp farming countries in response to environmental and disease problems. There appear to be several benefits to stocking tilapia in conjunction with lower densities of shrimp. By contributing to a more sustainable aquaculture system, rearing tilapia with penaeid shrimp would benefit the entire industry. More specifically, returning abandoned ponds to a productive system would benefit local populations who have lost employment with the shrimp farms. It would also ameliorate the loss of natural resources that provided nursery areas for fisheries harvest.

The primary focus of the experiment is to test three stocking plans for a polyculture system by conducting tilapia-shrimp polyculture trials in abandoned shrimp ponds in Tabasco, Mexico. Trials will compare three polyculture systems: sequential with tilapia in supply pond; simultaneous with tilapia in cages in ponds; and simultaneous with tilapia loose in ponds with shrimp. Water quality data will be collected to determine if culture of tilapia in conjunction with penaeid shrimp increases the number of green algae cells per ml of culture water. We will also attempt to determine if the concentrations of yellow and green fluorescing bacteria are significantly different between treatments.

In July 2005, one of the students from Tabasco, Mexico (Rafael Garcia) came to attend the Shrimp Pathology short course at the University of Arizona. We are also working on Rafael's admission to the University of Arizona for January 2006.

The tilapia-shrimp experiments will be conducted from November 2005 to May 2006 at the "Centro Piscícola Puerto Ceiba" in Paríso, Tabasco, Mexico. Refurbishment of the ponds has begun, and stocking should take place in November.

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

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

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Abstract

Species of "robalo," or snook, constitute one of the most important commercial fisheries along Mexico's coast in the Gulf of Mexico. The common snook has perhaps received the most attention and fishing pressure on the southwestern side of the Gulf, but spawning grounds for common snook have been reported as far north as the lower Laguna Madre and its associated estuaries in Texas. In Mexico, there is a trend for diminishing catch volumes for common snook, a situation that has led to concerns for the regional snook fisheries and calls for improved management practices. In Texas, there have been no reported commercial snook landings since 1961. The development of an aquaculture industry for common snook in Mexico would therefore benefit the Mexico-Texas populations by providing relief from the fishing pressure on wild stocks.

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

In Mexico, 17 field trips resulted in the collection of 266 individuals. Otoliths from 228 fish were extracted, of which 191

have been processed. Preliminary histological analyses at Texas Tech University indicated that, contrary to expectations, the gonads of some of the young fish collected in Mexico are initially developing directly as females. These observations could have important implications for the present study, but the results need verification by examination of additional samples. Histological analyses are expected to be completed by the end of this year. In addition, a system for fry rearing has been built and we are expecting to complete the spawning and the fry treatment phase by May 2006.

In the US, 32 miles of river were sampled from the mouth of the Rio Grande upstream along the US-Mexico border during January–March 2005. Cast nets, seines, and trawls were used to collect common snook. A total of 32 common snook were collected. Four additional snook were collected using an electroshock boat in August 2005. Gonads and otoliths were extracted and will be processed for analysis by the end of this year. A second field season is planned for January–March 2006. One objective of the US study is to determine the early reproductive development of common snook in Texas. This objective is in support of the Mexico study and will provide information to help generalize the reproductive biology of the Mexico-Texas snook population. An additional objective is to characterize the natural habitat of common snook at its northernmost range. The US study is being supplemented by funds from the US Geological Survey, Texas Tech University, and Texas Parks and Wildlife.

Use of Phytochemicals as a New Method to Sex-Reverse Nile tilapia and Tropical Garfish

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

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Abstract

Longnose gar (*Lepisosteus osseus*) broodstock were obtained with the cooperation of the US Fisheries and Wildlife Service and the Aquatic Ecology Laboratory at The Ohio State University on the Sandusky River, Ohio, in late March 2005. Fish were acclimated in 400 L circular tanks for several weeks. In June 2005, presumptive females (n = 2) and males were identified and separated into groups of one female and 3 males. The remaining males were kept separately. Substrates (plastic plants) were provided in tanks with mixed-sex fish. To induce final maturation, fish were injected with a hormone priming dose and then, eight hours later, with a resolving dose as suggested in the instructions of OVAPRIM® (Syndel International Inc., Vancouver, Canada). Eggs were released from only one female (23 June 2005), and sperm was observed in only two out of 15 males. The ovulating female was then stripped of eggs several times within the next 24 hours (approximately 400 eggs were released). A male garfish was sacrificed, and sperm preparation was obtained from macerated testes to assure insemination. Viable eggs were obtained mostly during the first stripping, and fertilization was negligible in eggs from the following ovulations. In total, 106 larvae hatched after incubation for eight days at 18° C.

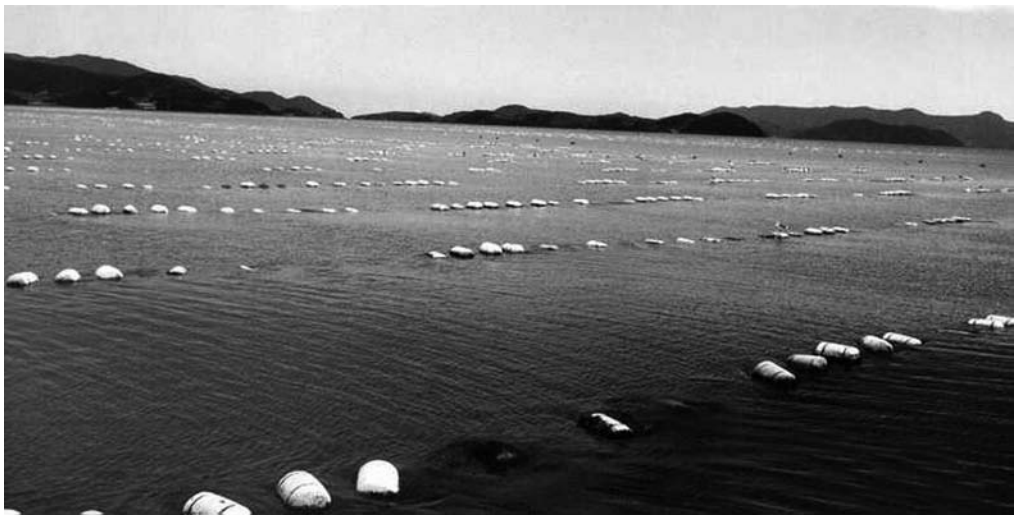
A feeding trial was designed with obtained larvae (initial weight 37.3 mg, length 23.5 mm), where fish were distributed in nine 35 L glass aquaria at the density of 11 fish tank^{-1} (14 July 2005). Control groups were fed with live *Artemia nauplii*. In two other treatments we attempted to provide a formulated, commercial diet (AgloNorse, Ewos, Norway; 59% protein 16% lipids) for two days. As no feeding was observed, all groups were offered live *Artemia nauplii* for the following four days. The second attempt of weaning live food groups onto a commercial diet (AgloNorse) (3 tanks) or the same feed (Aglonorse) with 60 mg kg^{-1} 17α-methyltestosterone (MT) (3 replicates per treatment) was carried out when fish were 37.4 mm total length. Fish were fed ad libitum for 26 days. Several fish were fixed for histological analysis at the time of initiation of feeding with exogenous food and at the completion of MT-treatment. These fish are prepared for histological examination of gonad development and differentiation. We conclude that garfish larvae/juveniles can be effectively adapted to consume dry artificial diets at early life stages, and the hormonal treatment could be included within the first week of exogenous feeding. Upcoming activities will be focused on description of the morphological development of the gonad and differentiation processes in the longnose gar by histological analyses.

The second objective of the project, work on sex differentiation in Nile tilapia, concentrated on identification of parental genotypes associated with sex genes (XX males). The preliminary results of group spawning of fish obtained from the Philippines (40 females and 5 males) (November 2003, PhilFishGen, Nueva Ecija) provided evidence of a high prevalence of female phenotypic gonads (80%). We were able to produce at present 8 groups of progenies from tagged fish. These fish will be evaluated for sex ratio and identified parental stock used for mass larvae production. We expect to be able to produce 600 to 1,500 larvae within six to eight weeks to start feeding trials as described in Study 1 in the Twelfth Work Plan.

Mexico Project: Human Welfare, Health and Nutrition

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

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



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Work Plan Research

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

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

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

- Cross-sectoral and international extension exchange and learning/11AHHR1. A progress abstract was submitted for this investigation.
- Connectivity of water resource status, environmental quality, aquaculture, and human health/11AHHR2. A progress abstract was submitted for this investigation.
- Analysis of critical points in aquaculture production affecting participation and level of benefits to women, youth, and disadvantaged stakeholders/11AHHR3. A progress abstract was submitted for this investigation.
- Food safety and handling: Increasing local consumption of aquaculture products and improving quality/11DPPR1. A progress abstract was submitted for this investigation.

Diversifying and Strengthening Aquaculture Extension Capacity to Develop a Regional Extension Service Model

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

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Abstract

Mexico has a strong capacity for cutting-edge research in many fields, but extension capacity lags behind the needs of industry and the social sector as aquaculture grows and diversification becomes more important. Sinaloa's multi-institutional extension efforts are a recognized vehicle to raise awareness, modify behavior, and transfer technology. Long-term efforts have been made in Sinaloa, Mexico, to establish a corps of extension agents to support the aquaculture sector and to work with other specialists to tackle cross-sectoral problems that affect aquaculture. Extension efforts are directed at implementing best management practices for the major form of aquaculture in the region (shrimp culture) and diversifying the industry through increasing production of freshwater finfish (e.g. tilapia, catfish, small mouth bass) and native species of bivalves and marine fish. Inclusion of neglected stakeholder groups such as women, youth, and the physically disadvantaged is also a goal. The Aquaculture CRSP/Packard Foundation sponsored "Second International Extension and Diversification of Aquaculture Workshop" builds on these efforts and extends them into new areas of learning to include sharing of experiences from other sectors such as public health, agriculture, gender equity efforts, and work with the physically challenged. A five-day workshop was held in Mazatlan, Mexico, on 25–29 July 2005, during which training was provided and sharing of experiences occurred. Smaller breakout sessions provided the opportunity to plan and organize extension efforts and collaborative initiatives. Participants included aquaculture extension agents, researchers, and NGO representatives from five states in Mexico; private industry representatives; and specialists from other nations (Ecuador, US). John Supan and Robert Quintana of the Louisiana Sea Grant College Program also participated and delivered core materials in bivalve culture and sanitation to support diversification efforts as well as two

other investigations (12AHH1 and 12AHH2) concerned with water quality and shellfish sanitation. Extension visits were also made to oyster farms in Nayarit. Course materials from the workshop were compiled and distributed widely for the benefit of extension workers elsewhere. Another outcome of this work was the development of new institutional partnerships and geographical expansion of efforts.

Water Quality Monitoring and Identification of Pollution Sources Leading Towards Classification of Bivalve Growing Waters

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

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Abstract

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

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

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

Outreach and Planning for Implementation of Bivalve Growing Areas Classification and Related Sanitation Action Items

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

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Abstract

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

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

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

Cross-Sectoral and International Extension Exchange and Learning

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

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Abstract

Extension is a recognized vehicle to raise awareness, modify behavior, and transfer technology, but it also represents one of the principal obstacles to developing and improving aquaculture in many parts of the world. Long-term efforts have been made in Sinaloa, Mexico, to establish a corps of extension agents to support the aquaculture sector and to work with other specialists to tackle cross-sectoral problems that affect aquaculture. Extension efforts are directed at implementing best management practices for the major form of aquaculture in the region (shrimp culture) and diversifying the industry through increasing production of freshwater finfish and native species of bivalves and marine fish. Inclusion of neglected stakeholder groups such as women, youth, and the physically disadvantaged is also a goal. The Aquaculture CRSP Cross-Sectoral and International Extension Exchange and Learning Workshop builds on these efforts and extends them into new areas of learning to include sharing of experiences from other sectors such as public health, agriculture, gender equity efforts, and work with the physically challenged. A three-day workshop was held in Mazatlán, Mexico, on 14–16 June 2005 during which training was provided and sharing of experience occurred. Participants included aquaculture extension agents and NGO representatives from Mexico, representatives from other Aquaculture CRSP initiatives (Mexico, Peru, Honduras), and project personnel from other innovative aquaculture extension efforts (UCA/Nicaragua and Ecocostas/Ecuador). An additional two days were spent reviewing the research and progress of the three case studies associated with this project. Course materials from the workshop were compiled and distributed widely for the benefit of extension workers elsewhere. Another outcome of this work was the development of new institutional partnerships and the geographical expansion of efforts. Training materials have also been utilized in Nicaragua, Ecuador, and Tanzania for training under the USAID Sustainable Coastal Communities and Ecosystems initiative.

Connectivity of Water Resource Status, Environmental Quality, Aquaculture, and Human Health

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

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Abstract

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

and analyze findings. The results are being presented in a case study to be published by the Aquaculture CRSP in Spanish and English.

Three geographical sites were selected for consideration. The first is located in the Rio Mocoritos watershed, one of the rivers which flows into the Santa Maria Bay, which is an extensive wetland system (~500 km^2). This watershed exemplifies many watersheds in Sinaloa and other Pacific Mexico states. The upper watershed are widely used for agriculture and are impounded primarily for irrigation and urban use. Aquaculture in the form of small, freshwater ponds and reservoir fisheries are common. Species include tilapia, catfish, small mouth bass, and native species. Most of these operations are structured as fishermen's cooperatives; however, aquaculture is limited by a host of factors. First, water quality in the upper and lower watersheds is affected by the general lack of wastewater and solid waste management. Reservoirs are managed primarily for non-aquaculture purposes, and subsiding water levels often leave ponds and reservoirs without sufficient water to sustain efforts. In the lower reaches of the watershed, urban pollution intensifies. This also affects aquaculture in the brackish water areas, which is primarily shrimp and oyster culture. Sinaloa has a very high rate of cancer and immunological disease, possibly correlated with environmental degradation. Additionally, freshwater and brackish water production is impacted by the apparent spread of Gnathostomiasis, a nematode parasite infecting humans. Aquaculture production is also affected by a lack of fingerlings for all species, poor management techniques, the rustic nature of processing and storage facilities, and the lack of all resources that would be required for producers to market directly and therefore reap greater returns. Oyster producers are impacted by increasing contamination of growing grounds.

Opportunities exist to improve the situation through: fingerling production; small scale hatcheries; watershed management plans; water budgets and management; monitoring and classification of growing grounds; assisting producers with the skills and means to better process, handle, store, and market their products; and greater awareness of the linkages between contamination, economic loss, and human health.

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

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

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Abstract

Preliminary work with the predominant form of aquaculture in Sinaloa, Mexico (shrimp culture) to improve management practices and increase direct benefits to local communities indicated that women and other marginalized stakeholders play a key role in this industry and must be included in participatory, community-based efforts to implement Best Management Practices. Other efforts to increase aquaculture production, particularly in the case of freshwater fish and local species of bivalves, suggested that women would be a primary target group for these efforts given their roles as producers, fishers, and vendors. Additionally, Sinaloa, like many other regions in the world, is dealing with issues associated with urbanization, globalization, and impacts of the growing drug trade. There are large numbers of young, unemployed youth and a high level of physically challenged individuals due to locally high rates of birth defects, HIV/AIDS, cancer, vehicular accidents, and drug-related violence. It is clear that many stakeholders from these groups already participate in aquaculture or wish to do so but confront challenges to entering or increasing their participation in this activity. This work is designed to better understand key obstacles (technical, social, economic) to increased participation and develop simple and immediately applicable strategies to encourage more aquaculture production among these groups. For example, a key deliverable will be a feasibility study and plan to guide the physically disabled in establishing tilapia culture. Research is being carried-out with women's oyster cultivating cooperatives, women working with impoundment tilapia culture, seafood vendors, women fishers and two groups of physically challenged, rural adults who are currently engaged in manufacturing occupations and now wish to cultivate tilapia. The latter operate an NGO called PROJIMO that engages in community-based work to address the needs of the rural handicapped. To date, extensive literature research, field investigations, interviews, site observations and studies have been conducted.

Multidisciplinary teams, including specialists from the University of Sinaloa, University of Rhode Island, University of Hawaii, Hilo, NGOs such as Conservation International, CIAD, and government agencies are responsible for this research. Four workshops have been held to plan the work, define research methodologies, present preliminary results, and analyze findings. A case study outlining the findings of this work will be published by the Aquaculture CRSP in English and Spanish. The women's groups and PROJIMO have also participated in the activity "Cross-Sectoral and International Extension Exchange and Learning" (11AHHR1) to share their extension experience to their respective stakeholder groups and to learn from the aquaculture extension agents.

Opportunities to increase participation of marginalized groups in aquaculture exist if more extension efforts explicitly include women, micro-financing is available, technical training and support is provided, and specialists such as PROJIMO who can facilitate efforts to enable disabled people to engage in aquaculture without discrimination are included.

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

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

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Abstract

Food safety and handling have become major issues for aquaculture in much of the world, including Sinaloa, Mexico, where efforts are underway to sustainably manage and improve benefits from aquaculture. Shrimp culture is the predominant form of aquaculture in the region, and preliminary work has shown that there is a need for small producers, processor employees, and seafood vendors to improve their ability to safely harvest, handle, store, and market shrimp and shrimp products. Many of these workers are women and the rural poor. Additionally, other forms of aquaculture have had their development slowed through the general lack of capacity in this area. Tilapia and other freshwater fish (catfish, small mouth bass) are major aquaculture products, but their full potential cannot be harnessed unless means are found to process and transport the product safely beyond the immediate local market. A major effort is being made to diversify aquaculture away from shrimp toward local species of bivalves in coastal areas. Constraints exist for both local and international marketing of bivalves as water quality deteriorates and standards become more rigorous. Thus, addressing bivalve sanitation issues is a focal point not only for aquaculture development, but for environmental management and public health. The multi-sectoral working group encountered new, previously unrecognized risks, including high levels of gnathosome infection in most bodies of freshwater, which, coupled with the customary and growing habit of eating raw fish products, is poised to become a greater health issue as this parasite can cause severe illness and death. Contaminant levels appear to be increasing in aquatic products as urban, agricultural, and industrial pollution increases unchecked. Previously undetected levels of gastrointestinal illness associated with the consumption of fish and shellfish is beginning to be documented, and rates appear to be high and increasing. Public perception of the safety of aquatic products appears to be diminishing. Given that much of the work focuses on sectors of society most at risk for food-borne illnesses, including the physically disabled, the challenge of finding practical means of ensuring food safety is critical to maintaining aquaculture as a source of healthy and high-quality food. Research is being carried-out with women's oyster cultivating cooperatives, women working with impoundment tilapia culture, seafood vendors, women fishers, and two groups of physically challenged, rural adults who are currently engaged in manufacturing occupations who wish to cultivate tilapia. To date, extensive literature research, field investigations, interviews, site observations, and studies have been conducted. Multidisciplinary teams, including specialists from the University of Sinaloa, University of Rhode Island, University of Hawaii, Hilo, NGOs such as Conservation International, CIAD, and government agencies are responsible for this research. Four workshops have been held to plan the work, define research methodologies, present preliminary results, and analyze findings. A draft of the case study has been produced and is expected to be ready for publication in September 2005.

Kenya Project: Production Technology

Kenya
Subcontract No. RD009A-01 (OSU)

Kenya Project research has been conducted at the Sagana Fish Farm in Central Province since 1996 in collaboration with the Kenya Fisheries Department through a Memorandum of Understanding with Oregon State University (OSU). Additional Memoranda of Understanding have been established with Moi University and companion site institutions in Malawi. Research activities in this reporting period addressed aquaculture development constraints of the African catfish (*Clarias gariepinus*). Experiments are evaluating technologies to increase the survival of fry to the fingerling size for additional grow-out in ponds or for sale as bait to the Lake Victoria long-line fishery. Coupled with this research, the Kenya Project conducted training workshops related to simple techniques for spawning, hatching, and rearing juvenile catfish.

GWYN NEWCOMBE

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Christopher Langdon	Lead US Principal Investigator
James Bowman	US Co-Principal Investigator

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

Charles Ngugi	Lead Host Country Principal Investigator
Victoria Boit	Graduate Student (Kenya; from September 2004)
Stephen Njau	Graduate Student (Kenya; from September 2004)
Mary Makhutu	Undergraduate Student (Kenya; from September 2004)
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Spencer Otieno	Undergraduate Student (Kenya; from September 2004)
Ruth Muhonja	Undergraduate Student (Kenya; from September 2004)

Kenya Fisheries Department, Nairobi, Kenya

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

Work Plan Research

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

- Aquaculture training for Kenyan extension workers, fish farmers, and university students/12ATE3. A progress abstract was submitted for this investigation.
- Studies on strategies for increasing the growth and survival of African catfish (*Clarias gariepinus*) juveniles reared for stocking or for use as bait/12SDA2. A progress abstract was submitted for this investigation.

Theses

Kamau, R.N. 2005. Growth and survival of the African catfish, *Clarias gariepinus*, fry reared in hapas at different stocking densities. MSc. thesis, Moi University.

Nzeve, J. 2005. Growth and survival of African catfish (*Clarias garipinus*) larvae and subsequent juveniles fed *Artemia nauplii*, freshwater rotifers and freeze-dried Cyclops. MSc. thesis, Moi University.

Omwansa, K.D. 2005. Growth and survival of the African catfish, *Clarias gariepinus*, fry reared at different stocking densities in tanks. MSc. thesis, Moi University.

Rauni, J.G. 2005. Survival and growth of African catfish, *Clarias gariepinus*, fry reared in hapas under different shading levels. MSc. thesis, Moi University.

Aquaculture Training for Kenyan Extension Workers, Fish Farmers, and University Students

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

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Abstract

In an effort to stimulate an increase in the fingerling production of African catfish (*Clarias gariepinus*) the OSU/Kenya project (partners include Moi University Department of Fisheries, Kenya Fisheries Department, and OSU Department of Fisheries and Wildlife) is carrying out several training activities at Sagana Fish Farm, Moi University, and on private farms in Kenya. An increased supply of fingerlings will benefit both farmers wishing to produce catfish for the foodfish market and fishermen who use them as bait in the Lake Victoria long-line fishery. In addition, farmers who produce catfish fingerlings should realize increased earnings. The overall plan calls for the training of up to 34 extension workers and six advanced farmers in hatchery management techniques in two short courses conducted at government or university facilities; providing on-farm training in simple techniques for spawning, hatching, and rearing catfish juveniles for up to 12 farmers; providing short-term stipend support for four undergraduate students; and providing full support for two Moi University graduate (M.Sc.) students working on *Clarias* fingerling production problems in 2005 and 2006.

To date, two short courses for extension workers and advanced farmers have been held. The first was conducted at Sagana Fish Farm from 18–29 April 2005, with 14 extension agents and six farmers participating. The second was held at the Moi University Fish Farm from 14–17 August 2005. There were 30 participants in this second course; 19 were extension agents in the Kenya Fisheries Department, while five participants came from the Kenya Marine and Fisheries Research Institute and an additional six were hatchery managers supported by the Government of Uganda. Four undergraduate students in the Fisheries Department at Moi University have received support for short-term aquaculture-related projects during the first half of 2005, and full support is being provided to two M.Sc. students who began their studies in September 2004. The graduate students have completed most of their coursework and are currently engaged in their thesis research. Farmer training sessions will be conducted at one or two selected farms between November 2005 and March 2006.

Studies on Strategies for Increasing the Growth and Survival of African Catfish (*Clarias gariepinus*) Juveniles Reared for Stocking or for Use as Bait

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

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Abstract

This investigation was initiated to look into possible techniques for increasing the survival of fry of the African catfish (*Clarias gariepinus*) reared to fingerling size for stocking in grow-out ponds or for use as bait in the Lake Victoria long-line fishery.

Possible management strategies identified in the project proposal for improving fry survival included varying the duration of the fry rearing phase; offering live, freeze-dried, and/or formulated feeds to hatchery-reared larvae in different sequences (as opposed to offering a single feed throughout the rearing period); and varying the stocking densities of catfish fry to be reared in the hatchery or in ponds.

Two Moi University M.Sc. students have undertaken thesis research focused on two aspects of the fingerling survival problem. One student, Victoria C. Boit, is conducting research on the "Effect of Sequential Feeding and Light Regime on Growth of the African Catfish (*C. gariepinus*) Fry." The other student, Stephen N. Njau, is working on the "Effect of Varying Hatchery Rearing Duration and Stocking Density on Growth and Survival Rates of African Catfish (*C. gariepinus*) Fry." The field and laboratory phases of these research projects will be completed by November 2005, and the students will have their theses ready for examination by their graduate committees by 30 June 2006. The work of these students is being supervised by Charles C. Ngugi (Moi University) and James R. Bowman (Oregon State University).

Africa Project: Production Technology

Kenya, Ghana, Tanzania
Subcontract No. RD010E-E (UAPB)
Subcontract No. RD010E (pending PU)

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

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Work Plan Research

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

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

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

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

Presentations

Kaliba, A., and K. Osewe, 2005. Potential Economic Impacts of Aquaculture Promotion in Tanzania. WAS Aquaculture America 2005, New Orleans, Louisiana, 17–20 2005.

Farmers Training in Tanzania

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

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Abstract

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

The training will be a five-day workshop conducted in collaboration with Mkindo Farmers Training Center. The major topics to be covered are pond construction, pond management, fish health, fish nutrition, economics of production, and marketing. Training instructors will come from the Sokoine University of Agriculture, Kingorwila National Fish Center, Moi University in Kenya, and the University of Arkansas at Pine Bluff, USA. The workshop is scheduled to take place in November 2005. The training activities will be based on training modules, and trainees include women and household members who manage fish ponds.

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

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

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

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Abstract

In much of rural Africa, producing more fish does not necessarily imply profitability of the fish farming business. Record-keeping is an important management tool necessary for business planning and development. If small- and medium-scale fish farming enterprises can be sustained, developed, and be profitable, steps should be taken to teach farmers basic valuation methods for costs and benefits at the farm level as well as principles of keeping records. Small- and medium-scale fish farmers do not receive financial assistance from commercial lending institutions or the government because of the absence of the necessary economic data and information on fish farming. This training is needed to highlight the importance of data for the preparation of business plans that are essential for securing financial assistance from commercial lending institutions.

The training sessions were conducted in Kenya and Ghana. In Kenya, the five-day training session endeavored to train fish farmers in pond record keeping and to view aquaculture as a business enterprise. Twelve small scale fish farmers and hatchery owners participated in the training held from 18–22 July 2005 at Moi University, Chepkoilel Campus, Eldoret, Kenya. The session focused on cost and benefits of constructing good ponds and how to increase fish production through better pond management, pond financial management, and pond

record keeping. Teaching modules developed by resource persons from University of Arkansas at Pine Bluff and Moi University were to be used. Results from this workshop showed that farmers:

- found analyzing production records will point to weaknesses in their operation;
- recognized they are deficient in certain skills (e.g. economic analysis), but with good record keeping, other professionals will be able to adequately assist them; and
- recognized the value of record keeping in terms of gaining potential bank loans.

In Ghana the training involved 85 farmers. The focus of the training was record-keeping and economic analysis, i.e., how to calculate costs and profits. The training was held in Kumasi at the offices of the Ministry of Food and Agriculture from 27–30 June 2005. The training session was conducted in collaboration with the Ashanti region and Brong-Ahafo region farmers associations. Teaching modules developed by resource persons from University of Arkansas at Pine Bluff and Kwame Nkrumah University of Science and Technology, Kumasi, were to be used. Results from this workshop showed that farmers:

- appreciated the importance of record keeping and were able to value home-made inputs;
- were able to identify and list all various farm records; and
- were able to identify constituents of fixed costs, recurrent costs, revenues, and profits.

It is hoped that from this training, fish farmers will begin assembling data and information that would be useful for securing loans from financial institutions, including government lending agencies. The fish farming business will be in a position to obtain the needed financial assistance for investment in the industry.

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

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

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Abstract

With continuing efforts by many NGOs to develop aquaculture in Africa, there is the need to assess present household aquaculture production systems in rural areas and identify target households and natural resource systems with developmental potential for which options can be formulated and their potential impact assessed. An assessment of the smallholder, medium-scale, and community-based ventures will assist potential NGOs to maximize the benefits of development interventions in these countries.

To undertake this assessment, a survey was conducted in each of the nations of Tanzania, Ghana, and Kenya. The survey covered regions in the major fish farming areas. In Tanzania, the survey was performed in the Eastern and Southern zones. In Ghana, the study was conducted in the Brong-Ahafo and Ashanti regions where fish farming is very active. In Kenya, the survey covered the Western and Central regions where fish farmers are concentrated. The survey instrument involved a comprehensive questionnaire for households involved in fish farming or other aquaculture ventures. Both male and female fish farmers were surveyed. The questionnaire was developed after discussions and consultations among the invesigators in the US, Ghana, Kenya, and Tanzania as well as other scientists, extension officers, farmers, and other stakeholders. The survey collected detailed operational, technical, financial, and household data.

Total responses were as follows: Ghana—124; Kenya—138; and Tanzania—148. Analysis of the data is ongoing and will involve a dynamic multi-period adoption model to assess the factors

affecting a decision to engage in fish farming and adoption of different fish production technologies. It is anticipated that the study will provide information on issues such as risks, costs, prices, marketing, gender, finance, and policy as they relate to rural aquaculture enterprises. The assessment will also help to foster linkages between the research institutions, stations, and policy makers as well as provide information that will assist in providing technical assistance to smallholder, medium-scale, and community-based aquaculture ventures.

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

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

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Abstract

Besides contributing to food security and poverty alleviation, aquaculture has been an employment and income-generating activity for many African farmers. Many small-scale farmers have small land holdings in areas of diverse and risk-prone agriculture. Such areas depend solely on natural rainfall for most of the agricultural activities. In some areas, ponds may also provide a focal point for agricultural diversification and increased sustainability by providing a source of water.

To assess the potential economic impact, a survey was conducted in each of the nations of Tanzania, Ghana, and Kenya, covering regions in the major fish farming areas. In Tanzania, the survey was performed in the Eastern and Southern zones. In Ghana, the study was conducted in the Brong-Ahafo and Ashanti regions where fish farming is very active. In Kenya, the survey covered the Western and Central regions where fish farmers are concentrated. The survey instrument involved a comprehensive questionnaire for households involved in fish farming or other aquaculture ventures. Both male and female fish farmers were surveyed. The questionnaire was developed after discussions and consultations among the investigators in the US, Ghana, Kenya, and Tanzania as well as other scientists, extension officers, farmers, and other stakeholders. The survey collected detailed operational, technical, financial, and household data.

Total responses were as follows: Ghana—124; Kenya—138; and Tanzania—148. Analysis of the data is ongoing and will involve a construction of an aggregate input-output square matrix to assess the impact of certain sectors. The input-output matrix is the basis for computable general equilibrium modeling that will be used to calculate the economic multipliers, which are the foundation for estimating economic impact. It is anticipated that the analysis will provide measurable outcomes of aquaculture on rural economic growth, poverty alleviation, and food security. The impact measures will be useful tools for improved decision-making by the respective Host Country governments, development sponsors, and partners. Results from the impact analysis of rural aquaculture development will also be useful to lending institutions and private investors for making sound investment decisions.

Kenya Project: Watershed Management

Kenya
Subcontract No. RD010E-G (UG)

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

WILLIAM TOLLNER

Staff

University of Georgia, Athens, Georgia (Lead US Institution)

E. William Tollner	US Principal Investigator
Frank Onderi Masese	Student (Kenya)
Herbert Ssegane	Graduate Student (Kenya)

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

Mucai Muchiri	Host Country Principal Investigator
Odipo Osano	Host Country Co-Principal Investigator
Geoffrey Karanja	Collaborating scientist
James Kiyiapi	Collaborating scientist
Ruth Kinagwi	Collaborating scientist
H. Farrah	Collaborating scientist

Michigan State University, East Lansing, Michigan

Geoffrey Habron	US Co-Principal Investigator
Heather Pratt	Student (USA)

Department of Environmental Studies, Egerton University, Njoro, Kenya

William Shivoga	Collaborating scientist

Kenya Department of Fisheries, Nairobi, Kenya

Nancy Gitonga	Host Country Co-Principal Investigator

Work Plan Research

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

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

Networking

Tollner has established a relationship with Miheret Endalew Tegegnie, Amhara region Agricultural Research Institute, Bahir Dar, Ethiopia.

Publications

Tollner, E., M. Muchiri, G. Habron, and N. Gitonga, 2005. Hydraulic, water quality and social assessment of the Nzoia Watershed management to meet water quality standards and emerging TMDL. American Society of Agricultural Engineers, February 2005, 701:105.

Presentations

Tollner, E.W., 2005. Hydraulic, water quality, and social assessment of the Nzoia Watershed. TMDL Workshop, Atlanta, Georgia, March 2005.

Tollner, E.W., 2005. Water Resources Management Possibilities. Presented to Water Resources Working Group, Bhar Dar, Ethiopia.

Awards

Tollner, E.W., 2005. Georgia Engineer-of-the-Year. Asabe, Georgia Section. Macon, Georgia.

Building the Capacity of Moi University to Conduct Watershed Assessments

Twelfth Work Plan, Environmental Impacts Analysis 4 (12EIA4) Abstract

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Geoffrey Habron
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Abstract

A major barrier to socioeconomic development in sub-Saharan Africa, including Kenya, is food inadequacy. Some of the more important factors that have led to this status are rapid population growth outstripping food production capacity, post-harvest losses, land degradation that leads to further decline in soil fertility, and climatic changes, particularly periodic droughts

and subsequent flooding. These food shortages, coupled with high poverty rates that diminish people's ability to afford the ever-increasing food prices, have led to related health problems, especially in rural areas. In an effort to meet the required food supplies to feed the growing population, forestlands have been cleared for small-scale agriculture. Inevitably, a major challenge to economic development in Kenya is the sustained increase of food production without compromising the integrity of the environment within which that much needed food is produced. As such, the project seeks to complement other projects that seek to "improve the productivity and sustainability of land use systems in Nzoia, Yala, and Nyando river basins through adoption of an integrated ecosystem management approach" through development of on-farm and off-farm conservation practices and increased local capacity. Desired outcomes include increased biodiversity and reduced erosion.

Such a balance reflects decision-making regarding risk. People must balance the need for meeting food, housing, and health needs with an interest in protecting the environment. Risk approaches require an integration between positivist and constructivist approaches. Risk not only appears as a function of probability to consequence dynamics, but also as a function of risk perception and responses to risk perception.

We envision Moi University as a regional center for the Nzoia basin management. This center will provide a basis for cooperation and stimulation with other projects in Kenya that are ongoing in the Njoro basin, where Egerton University is playing a lead role.

A recent visit was made to begin progress toward each of the project objectives. The major issues discussed included capacity building, budget concerns, and science issues, with progress made on each concern. The GIS lab will be built around the following new equipment: a) Computer running Windows XP; b) GIS software (Arc View); c) Scanner; d) Digitizer; and e) Plotter.

Discussions were held with Moi University administrators regarding placement of the GIS lab on the Moi campus. Moi regards this lab as an integral part of their long range plan to expand offerings in the environmental science area in the next few years. Moi has committed to find space for the computer laboratory and the increasing project library collection.

Land-Use Practices, Policy, and Tenure Regimes in the Nzoia River Basin

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

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Abstract

Perhaps the single most important variable in achieving sustainable watershed management is understanding and underpinning key land use practices that directly or indirectly affect ecological processes and system functioning. The reliance on land for agrarian production in rural Kenya coupled with dependence on land resources for economic livelihood places enormous premium on resources derived from land and as a consequence leads to degradation and hence loss of ecological integrity of the system. A sustainable land management strategy requires not only site-specific intervention but also at the landscape level. A system approach is needed to disentangle critical landscape components and linkages and will more likely lead to overall positive impacts on the watershed. The Nzoia watershed system transcends a broad range of land use systems and practices ranging from small scale holder farmland to large scale mechanized agriculture and cuts across a tenure regime of private ownership to public land (e.g., forest reserves and national parks). The watershed occurs in generally high potential and high population regions of the country, and therefore the influence of land use on the system is extremely important.

Aside from the analysis of land use practices and associated possible environmental effects, another key aspect of this component is to examine the role and influences of prevailing policies and laws as drivers of land use practice—the extent to which the land use systems and practices are guided or influenced by existing laws and policies. An understanding of how much overlap or synergy exists between various land-related policies and legislation and how these might impede sustainable land use management at the site specific level and overall watershed system. How much environmental/land use policy and legislative awareness exists among the rural population within the watershed? What policies or legal provisions exist for mitigating negative environmental impacts of land use practices, e.g., use of pesticides and herbicides? These are some of the critical questions that need to be addressed in this component.

Subsequent discussions are refining the curriculum for an in-country three- to five-day workshop on techniques for applying GIS to watershed assessment. Personnel from the nearby group at Njoro (Egerton University) were present and contributed a valuable perspective to the discussions.

Hydraulic, Water Quality, and Social Assessment of the Nzoia River Basin

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

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Mucai Muchiri
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Eldoret, Kenya

Abstract

The primary goal of the watershed ecology research component will establish the ecological health and potential of aquatic and terrestrial ecosystems to have a potential negative impact on the river system. The health potential of the watershed will be inferred by integrating current and historical conditions at a sampling site of similar, unimpaired reference. This acts as a benchmark against which data from watershed health surveys will be compared to determine the existence of any impairment at the sampled sites. Impairments are defined as deviations from the normal expected natural site conditions. The magnitude of the divergence from the expected site conditions represents the severity of impairment. Developing a benchmark of watershed health potential will be an initial step in setting general watershed rehabilitation goals.

Protocols for monitoring biophysical characteristics of the landscape conditions at sampling sites will be developed throughout the watershed in order to capture the spatial distribution of landscape conditions as a function of biophysical and anthropogenic activities. These protocols will identify key indicator species, which must be identified for each physiographic region. Excellent in-country resources exist for ecological assessment (e.g., http://www.iaia.org/Members/Publications/Guidlines_Principles; and http://www.kws.org/kwstidiploma.htm).

Both rural and urban land use within watersheds invariably affects biodiversity. This includes terrestrial and aquatic biota. Habitats are altered, leading to variation in biotic population structures. In streams the effects come in the form of variation in water quantity and quality. Land use generates both organic and inorganic pollutants that alter the physicochemical quality of the water. Such altered water characteristics in turn influence changes in biological communities. Pollutants entering a river system at identifiable points are often evaluated using physical and chemical measurement techniques. However, in certain situations, particularly in rural agricultural areas, pollutant sources are more diffuse and can make it difficult to take direct measurements. Fish and macroinvertebrate communities are good indicators of ecosystem quality, as the kinds and abundances of animals will vary according to a wide variety of physical habitat differences, such as habitat size, temperature, stream flow or water depth, and pollution. The present surveys will aim at describing: a) the community structure, and b) community processes and interaction for both fish and macroinvertebrates throughout the Nzoia River basin. The cause/impact relationships of land use and biological communities have been used fairly successfully in Europe and the United States to diagnose ecological health of watersheds. This has been done based on identifying a portfolio of impact indicator species.

Plans were made to begin the assessment of hydrological and ecological baselines. The decision was made to focus on two subwatersheds to be identified following a host country PI visit to several subwatersheds. Subwatersheds were selected based on: 1) particular conditions existing at the sites; 2) ease of access for sampling purposes; and, 3) the ease of collection of relevant social data for the Participatory Rural Assessment analysis analyses. The Kapolet and Moiben sub-watersheds were subsequently selected.

Ecological Assessment of Selected Sub-Watersheds of the Nzoia River Basin

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

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Eldoret, Kenya

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Egerton University
Njoro, Kenya

Abstract

Perhaps the single most important variable in achieving sustainable watershed management is understanding and underpinning key land use practices that directly or indirectly affect ecological processes and system functioning. The reliance on land for agrarian production in rural Kenya, coupled with dependence on land resources for economic livelihood, places an enormous premium on resources derived from land, and as a consequence leads to degradation and hence loss of ecological integrity of the system. A sustainable land management strategy requires not only intervention at site-specific locations but also the landscape level. A system approach is needed to disentangle critical landscape components, and linkages and will more likely to lead to overall positive impacts on the watershed. The Nzoia watershed system transcends a broad range of land use systems and practices, ranging from small-

scale holder farmland to large scale mechanized agriculture, and cuts a cross a tenure regime of private ownership to public land (e.g., forest reserves and national parks). The watershed occurs in generally high potential and high population region of the country, and therefore the influence of land use on the system is extremely important.

Aside from the analysis of land use practices and associated possible environmental effects, another key aspect of this component is to examine the role and influences of prevailing policies and laws as drivers of land use practice, i.e., the extent to which the land use systems and practices are guided or influenced by existing laws and policies. Also important is an understanding of how much overlap or synergy exists between various land-related policies and legislation and how these might impede sustainable land use management at the site specific level and overall watershed system. Critical questions that need to be addressed in this component include: How much environmental /land use policy and legislative awareness exists amongst the rural population within the watershed? What policy or legal provision exist for mitigating against negative environmental impacts of land use practices, e.g., use of pesticides and herbicides?

A Michigan State University graduate student, Heather Pratt, studying with Geoff Habron of MSU, is well settled for a two-month stay in Eldoret, Kenya. Two areas within the Kapolet and Moiben subwatersheds have been targeted for Participatory Rural Assessment (PRA) analysis. Three assistants, a driver, and a vehicle to assist with data collection have been engaged.

Determination of Hydrologic Baselines for the Nzoia River Basin

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

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Abstract

The degradation of the Lake Victoria basin has received international attention. The 184,400 km^2 basin drains 14 major rivers with an estimated population of 25 million people. The Kenyan portion of the basin drains 42,000 km^2 with a population of 7.9 million people. The Nzoia watershed comprises 12,000 km^2 of the Lake Victoria basin. Four main processes drive the degradation of the Lake Victoria basin: 1) loss of 89% of forest cover to poor agricultural practices causing erosion and sedimentation; 2) pollution from mines, urban areas, and industry, leading to sedimentation and eutrophication; 3) loss of lake fish species diversity due to introduction of the non-native Nile perch; and 4) poor fisheries management practices. Sedimentation increased fourfold in the last 100 years, with some areas demonstrating losses of 200 horizontal feet each year.

Kenya is on the verge of substantial agricultural development and urbanization, especially in the Nzoia basin. A search of the literature reveals that virtually every agricultural enterprise, from forestry production to container nursery production, has specific Best Management Practices (BMPs) for water quality management with nonpoint source inputs. The US-NRCS has an exhaustive array of BMPs available for agricultural production nonpoint sources. BMPs have recently been published for urban storm water management. Except for specific cases not involving soil tillage (e.g., container nursery in greenhouses), sediment is the most significant pollutant. Sediments are significant in both urban and rural development because a host of chemical constituents adhere to sediment particles. BMPs for urban and rural environments focus primarily on sediment removal and handling. Increased urbanization and increased intensity of agricultural production results in an increased magnitude and frequency of runoff events, reduction of base flow, and increased stream velocities when flowing. These flow changes lead to increased cross-sectional areas, significant down-cutting (unless stream is already heavily armored), increased sediment loads due to bank erosion, urban construction or intensifying agricultural production, modification of streambed to include more fine particles, and subsequent stream modifications being required to reduce flooding risks. Increased urbanization and agricultural development affect water quality as well. Urbanization causes an initial pulse of sediment that subsides as the development stabilizes. Increased agricultural production increases pesticide and sediment loads, which may remain high depending on the degree of soil tillage. The sediment load and consequent increase in fines cause benthic ecology to become much less diverse. Streams generally shift from an external (leaf matter) to an internal (algal organic matter) food chain. The stream community loses diversity and wetlands, springs, and riparian buffers are damaged or lost due to excessive sediment, toxic compounds, or both. The effects on receiving bodies (e.g., Lake Victoria) are felt over longer time frames. After visible refuse and damage to aesthetics, nutrient enrichment and the resulting increase in primary productivity is the most visible sign of development. Lakes act as sinks for sediment-laden materials and take longer to recover from contamination than do streams. Heavy metal absorption, sediment deposition patterns near the outlet, increased algae production in the lake (which indicates possible eutrophication that can in turn lead to fish kills), loss of desirable species, and increased "trash" fish species are documented to occur with development. These documented trends will be pivotal in prioritizing the work on the Nzoia basin. It is not too late to avoid these effects.

The Nzoia basin is in the initial phases of development. Much cultivation in rural areas is conducted by women of the families on soils at the river edge. Environmental legislation on the books provides 30 m buffers; however, the exact point of

measurement of the buffers is legally unclear and thus there is no effective enforced buffer. A buffer design is needed that will preserve some of the existing benefits of being near the river while achieving water quality goals. Environmental quality within and around the Lake Victoria basin, is closely linked to land use practices. Some of the land uses have resulted in serious degradation of ecological integrity and hydrologic processes within the watersheds. This is shown by the loss of biodiversity and habitats as well as altered hydrologic regimes.Consequently, the trend has resulted in declining livelihoods of the inhabitants. These factors have contributed to overall poverty in the region. With this background, there is a need to develop strategies and mechanisms to stabilize and rehabilitate the watersheds in the region. The proposed project will embark on a multidisciplinary approach to develop and demonstrate improved and integrated sustainable management of watershed resources at a watershed scale. The watershed assessment effort and subsequent demonstration projects will be coordinated with the needs of the Kenyan Department of Fisheries in terms of fostering aquacultural enterprises along the river and preserving the Lake Victoria fishery. Overall, the proposed project will complement other efforts to the region to create sustainable, interdisciplinary broad-based watershed rehabilitation models through technical, social, and policy interventions in land use and natural resources management. The fisheries department can provide much helpful reference information to provide an objective standard by which improvements can be measured.

The Nzoia basin contains a variety of geomorphic formations, ranging from pristine fast moving stream, wetlands, lakes, and discharge into Lake Victoria. Selected stations will be characterized for selected indicator species of river health. At least one existing industry (sugar processor or paper mill), an upland wetland, and lakes will be assessed for species composition and diversity.

A watershed water resources assessment is the basis of determining the possibilities of water resource utilization, control, and development. A proper assessment requires the determination of the sources, quantity, and quality of water resources which, in this study, the initial baseline data to assess the conditions in the watershed will be collected. First, an inventory and mapping of the characteristics of the watershed will be undertaken. Next data collection stations will be established at key locations for water quantity and quality measurements.

The US-NRCS developed the Universal Soil Loss Equation (USLE). The USLE predicts soil detachment. Soil delivered to some point below the erosion location may be predicted using a sediment delivery ratio. The US Forest Service published an approach for evaluating sediment delivery ratios through buffer strips. Coupling the NRCS soil loss equation with the Forest Service delivery ratio estimation approach enables the computer modeling of buffer strip scenarios that can prove efficacious for water quality preservation.

A graduate student studying with Bill Tollner, Herbert Ssegane of Uganda, has arrived at Georgia to begin an M.S. degree. He is reviewing the literature with a goal of developing an erosion simulator useful as a demonstration tool for showing the benefits of proper stewardship of stream banks and riparian areas. This tool is envisioned to have benefits relevant to problems in Ethiopia, Kenya, and Uganda.

Marketing and Economic Analysis and Product Diversification Research

Staff

University of Arkansas at Pine Bluff, Pine Bluff, Arkansas (Lead US Institution)
Carole Engle — Lead US Principal Investigator
Ivano Neira — Research Associate

Moi University, Eldoret, Kenya (Lead Host Country Institution)
Mucai Muchiri — Lead Host Country Principal Investigator

Work Plan Research

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

- Regional enterprise budget and business plan development/10MEAR3. The report submitted for this investigation was a final output.

Regional Enterprise Budget and Business Plan Development

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

Carole R. Engle
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Abstract

Efficient management of a tilapia farm can make the difference between profits and losses even in years with unfavorable prices and costs. Farm management involves more than just taking care of the biological processes involved; it includes paying close attention to economic and financial measures of the farm business as well.

This CRSP research has resulted in the development of a manual, titled Tilapia Farm Business Management and Economics, which provides a practical overview of economic and financial indicators and analyses to use to better understand the performance of the tilapia farm business. The manual is designed to assist farm owners and managers in making more informed management decisions on tilapia farms. It presents pro forma financial statements accompanied by instructions for tailoring these statements to specific farm situations. The examples used in the training manual are all based on data obtained from different tilapia farms in Kenya over five years of recent observation. The sample budgets and analyses are based on prices and cost conditions in the country at that time, with some assumptions.

The Aquaculture CRSP has published Tilapia Farm Business Management and Economics to be a supplementary management guide for tilapia farmers, extension officers, commercial producers, and students worldwide, and it may be ordered at no-cost from the ACRSP Management Entity or via the ACRSP website.

Global Project: Watershed Management

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

The complex ecological interactions among nutrients; primary, secondary and heterotrophic productivity; and fish yield are known as pond dynamics. Previous Aquaculture CRSP research in pond dynamics focused on the influence of pond bottom soils on water quality and productivity. In Thailand, Auburn University and the Thailand Department of Fisheries are collaborating to analyze research results and produce Best Management Practices for pond soils. In South Africa and Brazil, workshops will be convened through a partnership between Auburn University, Stellenbosch University (South Africa), Universidade Estadual Paulista (Brazil), and Embrapa Environment (Brazil) to train local stakeholders in appropriate methods to develop Best Management Practices that are suitable for the local aquaculture industry and environment. Outputs from this investigation will include an Aquaculture CRSP manual illustrating the necessary approach to develop Best Management Practices for responsible aquaculture. This manual will be useful for prospective fish farmers in other locations who are interested in developing aquaculture Best Management Practices for their local aquaculture sectors.

BRIGITTE GOETZE

Staff

Auburn University, Auburn Alabama

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

University of Stellenbosch, Stellenbosch, South Africa

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

Kasetsart University, Bangkok, Thailand

Mali Boonyaratpalin	Host Country Principal Investigator

Embrapa Meio Ambiente, Jaguariúna, SP, Brazil

Julio Queiroz	Host Country Principal Investigator

Universidade Estadual Paulista, Jaboticabal, São Paulo, Brazil

Lúcia Sipaúba-Tavares	Host Country Co-Principal Investigator

Work Plan Research

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

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

Educational Outreach

Boyd presented two lectures; the first was three hours, entitled "Principles of water quality management in shrimp culture" and given at two locations of Aqualma Shrimp Farms in Majanga, Madagascar, and the second was two hours called "The shrimp pond ecosystem," and given to Vietnam Ltd. at Shrimp Health Care 2005 in Ho Chi Minh City, Vietnam.

Publications

Silapajarn, K., C.E. Boyd, and O. Silapajarn, 2004. An improved method for determining the fineness value of agricultural limestone for aquaculture. North American Journal of Aquaculture, 66:113–118.

Thunjai, T., C.E. Boyd, and M. Boonyaratpalin, 2004. Bottom soil quality in tilapia ponds of different age in Thailand. Aquaculture Research, 35:698–705.

Wudtisin, W. and C.E. Boyd, 2005. Determination of the phosphorus fertilization rate for bluegill ponds using regression analysis. Aquaculture Research, 36:593–599.

Presentations

Boyd, C.E., 2005. The growing importance of water quality and bottom soil management in shrimp culture. WAS World Aquaculture 2005, Bali, Indonesia, 9–13 May 2005.

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Best Practices for Management of Aquaculture Pond Soils in Thailand

Twelfth Work Plan, Environmental Impacts Analysis 1 (12EIA1) Abstract

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

Mali Boonyaratpalin
Department of Fisheries
Jatujak, Bangkok, Thailand

Abstract

Soils in areas for pond culture of carp, catfish, and freshwater prawn in Thailand often are naturally acidic and low in organic matter. Analyses of soils from pond bottoms revealed that aquaculture resulted in increased organic matter concentrations. Ponds are routinely treated with liming materials, and this has tended to increase soil pH. Bottom soil quality was generally best in freshwater prawn ponds, intermediate in carp ponds, and worst in catfish ponds. This finding was not unexpected, because prawn ponds have the lowest inputs of nutrients and organic matter while catfish ponds have the greatest inputs.

Information obtained—on-site characteristics, pond soil composition, and management procedures—has been analyzed. Data suggested that pond bottom soil deteriorates as a function of increasing pond age, and pond management practices are not adequate to maintain good soil quality. Possible relationships between bottom soil quality and external, negative environmental effects have been identified. Best management practices (BMPs) for pond soils are being developed.

The BMPs will focus on better methods for determining liming rates, applying liming materials to ponds, and improving bottom soil conditions during the fallow period between crops. In addition, BMPs will emphasize the need to use fertilizers, feeds, and organic wastes efficiently to avoid excessive nutrient and organic matter inputs. Techniques for preventing erosion of ponds and discharge canals also will be included in the BMPs.

The BMPs will be translated into the Thai language. The Thailand Department of Fisheries will distribute the BMPs to producers and encourage adoption.

Workshops on Guidelines for Developing Aquaculture Best Management Practices

Twelfth Work Plan, Environmental Impacts Analysis 6 (12EIA6) Abstract

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Lucia Travares
Centro de Aquicultura
Universidade Estadual Paulista
Sao Paulo, Brazil

Abstract

Powerpoint slides and a manuscript have been developed as aids for presenting Aquaculture Best Management Practices (BMP) workshops. The slides are arranged into three sets. The first is entitled "Aquaculture and the Environment." It provides information on the importance of aquaculture, describes aquaculture systems and production practices, and considers possible negative environmental and social impacts of aquaculture. The second set of slides, "Codes of Conduct and Best Management Practices" gives details about the response of the aquaculture industry, international development organizations, governments, and environmental advocacy organizations to concerns over aquaculture and the environment. These responses have been expressed mainly in efforts to encourage producers to apply BMPs designed to avoid negative impacts. The third set of slides describes the process that should be followed in developing aquaculture BMPs. The process should include environmental survey, impact assessment, and development of practices to prevent impacts. Particular attention should be given to involvement of a wide range of stakeholders and a thorough dialogue of the issues surrounding BMPs.

The manuscript "Best Management Practices for Responsible Aquaculture" is intended as a more thorough version of the information presented in the slides. In addition to the slides and manuscript, local environmental experts will be used as resource people and speakers in the workshops to provide country-specific information.

The first BMP workshop will be held at the 7th Biannual Meeting of the Aquaculture Association of Southern Africa in Grahamstown, South Africa (12–16 September 2005). The second workshop will be held in Brazil in March 2006.

Following each workshop, the slides and manuscript will be revised to correct deficiencies found during their use. The manuscript is intended for publication as an Aquaculture

CRSP manual. It also will be translated into Portuguese and published in a Brazilian scientific journal. If it is desired to convene workshops at other locations, the material used for the first two workshops will be available.

Global Project: Human Welfare, Health and Nutrition

Subcontract No. RD010E-F (IATP)

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

Staff

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

Mike Skladany	US Principal Investigator
Ben Belton	Research Assistant

Work Plan Research

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

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

Ex Ante Assessment of Coastal and Marine Aquaculture Development: Charting the Strengths and Weaknesses of Low Trophic Species for Offshore Aquaculture in Developed and Developing Countries

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

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

Abstract

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

Global Project: Production Technology

Subcontract No. RD010A-11 (UA)

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

Staff

University of Arizona, Tucson, Arizona

Kevin Fitzsimmons	US Principal Investigator

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Remedios Bolivar	Host Country Principal Investigator

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico

Wilfrido Contreras-Sánchez	Host Country Principal Investigator
Pablo Martinez	Graduate Student (Mexico)

Work Plan Research

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

- Special sessions, pre-conference travel and poster awards at 2005 and 2006 World Aquaculture conferences and Aquaculture America 2005 and 2006/12ATE9. A progress abstract was submitted for this investigation.
- Aquaculture CRSP sponsorship of the Seventh International Symposium on Tilapia in Aquaculture/ 12ATE10. A progress abstract was submitted for this investigation.

Special Sessions, Pre-Conference and Poster Awards at 2005 and 2006 World Aquaculture Conferences and Aquaculture America 2005 and 2006

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

Kevin Fitzsimmons
University of Arizona
Tucson, Arizona, USA

Abstract

Financial support is critical to the ability of scientists from developing countries to present their findings in an international forum. Host country Aquaculture CRSP scientists benefit from the opportunity to discuss their work amongst themselves, with their US colleagues as well as the broader international community. Students often need financial support to present their research. Students should also be recognized for the tremendous work they put into poster presentations at professional meetings. These are often the first opportunity students have to meet with the wider scientific community and have a chance to discuss their findings with many of the experts.

The Aquaculture CRSP sponsored three student poster awards at the Aquaculture America 2005 meeting in New Orleans. One first place and two runner-up awards were given to those posters judged as the best representatives of the broad research and development theme "to advance sustainable aquaculture." All posters submitted by students were considered and judging was conducted using accepted Aquaculture CRSP guidelines. Specific judging criteria focused on value of the contribution to sustainable aquaculture development, technical quality of the study and level of involvement required, presentation and use of graphics, and overall applicability and benefits of the results. In addition, the Aquaculture America meeting hosted a session that highlighted Aquaculture CRSP research.

A special session for Aquaculture CRSP was organized and held at the World Aquaculture Society (WAS) meeting held in Bali, Indonesia in May 2005. Professional pre-conference awards were also organized and provided based upon abstracts submitted to the WAS meeting. A student poster award program was also organized. Several Aquaculture CRSP scientists served as judges to grade all eligible posters. The grades were actually used for determining both WAS and Aquaculture CRSP student awards. Cash awards for first, second, and third place posters were presented to students at the student social event during the conference. E-memberships to the WAS and copies of the International Symposium on Tilapia in Aquaculture 6 Proceedings were also provided to the winning students.

Similar awards are planned for the Aquaculture Association of Southern Africa conference in September 2005, the US Aquaculture Association meeting in February 2006, and the WAS meeting in May 2006. A special Aquaculture CRSP session has been designated at the WAS meeting in Florence entitled "Sustainable Aquaculture - Linking Tradition with Technology."

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

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

Keven Fitzsimmons
University of Arizona
Tucson, Arizona, USA

Wilfrido M. Contreras-Sánchez
Laboratorio de Acuacultura
Universidad Juárez Autónoma de Tabasco
Villarhermosa, Tabasco, Mexico

Pablo Gonzalez-Alanis
University of Arizona
Tucson, Arizona, USA

Abstract

The International Symposium on Tilapia in Aquaculture (ISTA) meetings traditionally were held every 4 years and are the premier international meeting focused directly on tilapia aquaculture. However, after the Manila, Philippines meeting the demand for more information and number of other locations vying to host additional conferences led us to decide to hold the next ISTA within two years. In the past the ISTA's have provided one of the most important outlets for publication and discussion of the findings of Aquaculture CRSP supported research. Aquaculture CRSP has been a co-sponsor of the last three ISTA's. Aquaculture CRSP institutions in Mexico will be hosting ISTA 7 and we will be especially interested to ensure the success of the conference. Fitzsimmons and Contreras are on the organising committee planning the ISTA 7 symposium, scheduled to convene 6–8 September 2006.

The Aquaculture CRSP will be one of the main sponsors associated with planning the symposium. A graduate student from Universidad Juárez Autónoma de Tabasco will receive support to assist with the conference organisation. Specifically, the student will work with the publication committee working on the proceedings. A website has been created that links back to the Aquaculture CRSP home page. Aquaculture CRSP, WAS and the State of Veracruz will be the publishers of the Proceedings. UJAT will be one of the hosts of the conference and Contreras has an established record of publishing with a local printer who may do the ISTA 7 proceedings. Panorama Acuicola magazine has run one article announcing the conference and we expect to have additional articles in the near future.

Global Project: Joint Initiative

Mexico
Subcontract No. RD010E-H (CU)

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

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

JAMES BOWMAN

Staff

Cornell University (New York Sea Grant) (Lead US Institution)

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

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

Eunice Perez Sanchez	Lead Host Country Principal Investigator

Texas Sea Grant, Houston, Texas

John Jacob	Collaborating Scientist
Ralph Raybum	Collaborating Scientist

Brooklyn College, Brooklyn, New York

Martin Schreibman	Collaborating Scientist

University of Rhode Island, Narragansett, Rhode Island

Barry Costa-Pierce	Collaborating Scientist

Puerto Rico Sea Grant, Mayaguez, Puerto Rico

Ruperto Chapparro	Collaborating Scientist

University of Arizona, Tucson, Arizona

Keven Fitzsimmons	Collaborating Scientist

Instituto Tecnologico del Mar, Veracruz, Mexico

Margarita Cervantes Trujano	Collaborating Scientist

La Fundación Chile, Santiago, Chile

Martin Hevia	Collaborating Scientist

Work Plan Research

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

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

Establishment of the Center for Aquaculture Technology Transfer

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

Abstract

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

Abstract

Dissemination of technical information as part of extension outreach to producers is a critical aspect of sustainable aquaculture development. This project aims to build upon recent technology transfer efforts, including several established ACRSP projects in Mexico and an information network between US and Mexican universities of the Gulf Coast, by establishing a center for aquaculture technology transfer with a narrow focus that will service for all of Mexico. This center, which will be known as the Center for Aquaculture Technology Transfer (CATT), will be patterned after the US Sea Grant Program model. The CATT will be a virtual network of aquaculture research and extension universities and institutions in Mexico and the US that are united through a single mission, a central website, and a director. The overall mission of the CATT will be to enhance the implementation and adaptation of sustainable aquaculture technology and information from research, economic, and regulatory sources to aquaculture production stakeholders. The CATT will also serve as a uniting entity among members to guide research priorities and coordinate joint research funding wherever possible. The CATT will initially focus on one central theme: sustainable aquaculture development. As the program develops, its extension services can be expanded to include additional themes that are important to the country and region. Administration of the CATT, including its organizational structure, its director, and its priority interest areas will be determined by its membership. This project will support the creation and operation of the CATT by hosting an organizational meeting, providing Sea Grant coordination and extension guidance, providing salary support to the CATT director, and providing infrastructure support (e.g., internet/web service, telephone, and office materials).

Development of a Recirculating Aquaculture System Module for Family and Multi-Family Use

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

Mike Timmons
NY Sea Grant Program
Cornell University
Ithaca, New York, USA

Abstract

All aquaculture development is constrained by the availability of suitable water resources. Recirculating aquaculture systems (RAS) represent a sustainable approach to aquaculture production. The primary advantage of recirculating aquaculture is the control of the aquatic environment that enables optimal growth conditions of the target species and limits unwanted diseases that can spread in the open environment. The goal of this project is to develop an RAS as part of sustainable food production at the family/multi-family level for rural areas of Mexico. The RAS to achieve the goals of this investigation will be relatively simple yet robust in design to allow for maximum growth with low risk under likely grow-out conditions. The target species of this investigation is tilapia, which is already a popular fish species in Mexico and for which resources to grow tilapia such as fingerlings and feed are readily available.

The objectives of this project are to identify development opportunities within Mexico for small-scale RAS production; design, test, and technically evaluate a low-cost RAS; and provide recommendations for multiple system implementation. System application research and system design/construction/evaluation will be performed as part of a graduate education program.

First Annual Sustainable Aquaculture Technology Transfer Workshop

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

Dale Baker and Mike Timmons
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Ithaca, New York, USA

Margarita Cervantes-Trujano
The Marine Sciences Faculty
Universidad Autónoma de Baja California, Mexico

Eunice Perez Sanchez
Universidad Juárez Autónoma de Tabasco
Tabasco, Mexico

Abstract

One of the most recent trends in aquaculture production development is the use of recirculating aquaculture systems (RAS). RAS-based aquaculture production is a sustainable form of aquaculture whereby the aquatic environment is all or partially controlled with little or no water exchange with the outside environment. There are many opportunities for RAS production in Mexico. Although considered high-tech and capital intensive compared to extensive pond production techniques, RAS technology is viewed as a must for commercial aquaculture development where strict environmental control is needed at larval and nursery stage production. RAS aquaculture is also applicable for sustainable aquaculture when more conventional forms of aquaculture are not possible, such as in areas with a lack of land resources, poor water (pond) retention, excessive source water contamination, or an inadequate water supply for conventional aquaculture.

This annual workshop will be patterned after the highly successful Cornell University/Freshwater Institute Recirculating Aquaculture Short Course that has been instrumental in educating over 400 aquaculture educators, researchers, and entrepreneurial farmers from around the world on recirculating aquaculture production techniques during the past ten years. The target audience of this workshop will be the researchers and extension personnel of Mexico that are currently involved or intend to be involved in sustainable aquaculture research and production. This workshop will serve to both: a) provide technical knowledge to this audience about RAS techniques; and b) link and transfer information from existing ACRSP research currently performed throughout Mexico. In addition, this technology transfer workshop will also strengthen the research and extension ties among the various research universities and institutions of Mexico and provide an additional link to US resources.

Host Country Principal Investigator Exchange Project

Staff
Asian Institute of Technology, Pathumthani, Thailand
Amrit Bart — Host Country Principal Investigator

Central Luzon State University, Muñoz, Nueva Ecija, Philippines
Remedios Bolivar — Host Country Principal Investigator

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

Kenya Fisheries Department, Nairobi, Kenya
Nancy Gitonga — Host Country Principal Investigator

Escuela Agrícola Panamericana El Zamorano (Zamorano)
Dan Meyer — Host Country Principal Investigator

CRSP Management Entity
James Bowman
Hillary Egna

With the Aquaculture Collaborative Research Support Program's (CRSP) support of relevant research and promotion of sustainable aquaculture around the world, the base of knowledge and institutional capacities of the program's numerous Host Countries have grown considerably. As the Aquaculture CRSP looks toward the future, it becomes increasingly important that its research results and extension methods be shared among workers at locations continents apart. In order to fulfill this prominent need, the Aquaculture CRSP has implemented the Host Country PI Exchange Project as a new way to share the pro-gram's combined discoveries and techniques among its indi-vidual host country research partners.

In mid-2005, Aquaculture CRSP Host Country Principal Investigators (HCPIs) from five countries—including Honduras, Kenya, Mexico, the Philippines, and Thailand—initiated a series of five site-visits and workshops with the primary purpose of exchanging information about tilapia culture technologies. These international exchanges emphasize the discussion of technologies that have been successfully introduced and are currently widely practiced, as well as consideration of those that have not been adopted in some countries.

To date, two of the planned site visits and workshops have been completed. The five HCPIs convened in Thailand from 19–22 July 2005, holding a seminar and touring the facilities of the Asian Institute of Technology on 19 July and visiting fish farms in the area for three days afterward. From Thailand, the group moved to the Philippines on 23 July. A seminar and tour of facilities was held on 25 July at the Freshwater Aquaculture Center, Central Luzon State University, followed by visits to tilapia farming operations around Luzon between 26 and 28 July.

At each site, the host PI organized a seminar to share and compare tilapia culture information through presentations made by the visiting PIs, in which they described current institutional capabilities, research goals, and aquacultural practices in their home countries. The audience for these seminars included research colleagues and staff, local farmers, industry and NGO professionals, and students. The collaborators' aim was to witness how other cultures have developed aquaculture and extended their progress to the public and to compare the results they saw with the outputs of their own efforts back home. The investigators learned the accomplishments of many diverse approaches to aquaculture, as well as the many challenges that they all share. So far this international group has found many instances of Aquaculture CRSP research adoption spread both through research and in the field. They have also observed the success of technologies that other agencies developed through synergies with Aquaculture CRSP affiliates in each host country.

Fish farmers at each site also benefited from the collective knowledge of the HCPIs during the many field and farm visits that were undertaken. The researchers offered expert pond-side advice on reproduction methods, safe-handling of steroids, water-use practices, feeding strategies, and a vari-

ety of pertinent topics to help the individual farmers find greater success in their ventures. Three workshops and site visits remain and are scheduled for October 2005 (Mexico and Honduras) and January 2006 (Kenya).

In preparation for the visits to each other's sites, the PIs conducted an internal survey of tilapia culture technologies that have been adopted and implemented in each of their countries. The survey took the form of a short questionnaire, filled out by the PIs themselves, whose purpose was to gather information suitable for comparing the technologies in use in the countries represented. Information gathered through the questionnaire was then verified through individual interviews with the participants during the site visits. The results of the survey are currently being compiled and will be the topic of a technical report and of a poster to be presented at Aquaculture America 2006 in Las Vegas.

Deliverables from this project will include not only the above-mentioned report and poster, but also a "best practices," or "best technologies," report, gleaned from the presentations and observations made in each country, a compendium of the materials presented and/or handed out during each workshop, and follow-up ("echo") seminars presented by each PI to colleagues, fish farmers, government and NGO officials, and other interested parties upon return to his or her home country.

Although the Host Country PI Exchange Project will complete within a specific, limited period of time, the movement that it has sparked will continue. This project will end when the collaborators have finished visiting one another's institutions and the final discussions, reports, and presentations have been made, but the participants will have fostered relationships that will open new doors to the flow of information. It is hoped that this exchange will encourage them to continue to work together in the future. As host country institutions build independent international networks, this lasting effect of the Aquaculture CRSP will ensure that the worldwide concern over food security and aquaculture will find support from a truly global community.

The Eagle of the North and the Condor of the South Aquaculture Exchange Project

Joint Initiative: Aquaculture CRSP and Heifer International (US, Canada, Mexico, Peru)

Heifer International (Paul Smith)
Indigenous Environmental Network (Tom Goldtooth)

ACRSP Management Office (Hillary Egna, James Bowman)
Bemidji State University, Bemidji, Minnesota (Mike Skladany)
IIAP, Peru (Fred Chu)
UJAT, Mexico (Wilfrido Contreras)

> *"All Indigenous Peoples and cultures communicate with the water world. Water life has supported Indigenous Peoples for all time. Many Indigenous People recognize the turtle, whale, or salmon as their crest, totem, or clan. Fish, shellfish and other aquatic life remain an integral part of Indigenous Peoples life-way and culture.*
>
> *Today the water life is threatened. The many reasons include industrial development, urban expansion, and instances of uninformed, non-sustainable agriculture. Aquaculture offers promise for expanding upon Indigenous Peoples' health and sustainability of the water world. Properly developed, aquaculture enhances core cultural objectives such as biodiversity, sustainability, food security, and community wellness."*
>
> -Eagle/Condor project proposal

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

The Aquaculture CRSP has partnered with Heifer International in a project that spans four countries—the United States, Canada, Mexico, and Peru—to identify challenges to watershed management and human health. An active partnership will formulate strategies that address and eliminate constraints to aquaculture development specifically in the context of Indigenous Peoples.

While Indigenous People have practiced aquaculture for thousands of years, the modern science of aquaculture is relatively recent. Tribal governments have initiated approximately 50 active aquaculture projects for Indigenous Peoples that primarily focus on economic development through the creation of jobs while also supporting aquatic rearing practices that incorporate traditional cultural values. The potential for further integration of aquaculture into Indigenous culture can directly address biodiversity, sustainability, food security, and community wellness, but further exploration of these issues has not yet been pursued to any great degree in the North or the South. Currently, Indigenous aquaculturists work in relative isolation from each other and other non-Indigenous aquaculture-oriented organizations.

This collaborative work is intended to serve as a future link to other Indigenous and non-Indigenous organizations that work with aquaculture. Specifically, the Eagle/Condor project intends to create an opportunity for Indigenous representatives of tribal governmental projects, universities, organizations, and community-based groups to participate in a training exchange program in aquaculture. It is hoped that this fusion reinforces Indigenous Knowledge and the shared "cosmovision" of Indigenous Peoples.

The Eagle of the North and the Condor of the South aquaculture exchange program are important for a number of reasons, including:

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

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

Management Office
Hillary S. Egna
Christopher J. Bridger

National Sea Grant College Program Extension Office
James D. Murray

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

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

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

Following the Host Country needs assessment and review of applications, appropriate matchmaking will be conducted to ensure that needs are addressed through effective extension services. This initiative will result in meaningful benefits to both organizations. For the Aquaculture CRSP, technical assistance needs identified by Host Country PIs are addressed. For its part, Sea Grant will build capacity through increased international experience and awareness, and US producers will benefit from the reverse flow of knowledge back to the US from overseas producers.

Appendix 1. Aquaculture CRSP Historical Overview

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

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

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

Aloyce Kaliba

The third grant phase (submitted for funding to USAID as the 1990-1995 Continuation Plan) represented new directions for research. Moving away from the sole study of biological phenomena, several new projects funded at this time included economics research, gender studies, on-farm studies, and technology transfer. The 1993-94 reporting period was a tumultuous year for the Aquaculture CRSP. Civil war in Rwanda challenged the resolve of Aquaculture CRSP researchers as many of their Rwandan colleagues lost their lives to violence. Despite adversity, the Aquaculture CRSP helped with evacuation while continuing its research activities elsewhere.

Hillary Egna

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

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

The Continuation Plan 1996-2001 represented significant evolution of the program. Proposed research emphasized an approach to aquaculture development that addressed environmental effects and social and economic aspects, as well as production optimization. This fourth grant ushered in a new era of oversight, as the Aquaculture CRSP modified its original advisory structure to increase representation among participating institutions and provide an effective mechanism for new institutions to be represented on the Board of Directors and Technical Committee and introduced systemic confidential peer-review for proposals and publications. These changes resulted in improved experimental design and a greater relevance of Aquaculture CRSP activities to the needs of their host countries. Research oversight was further accomplished through the design of impact indicators, developed jointly by the principal investigators and the Program Management Office (PMO) and based upon the results framework of the Aquaculture CRSP Continuation Plan 1996-2001. These quantifiable characteristics of research activities were applied to all project subcontracts issued under the new grant and were collected by the PMO at the end of each investigation. USAID supported repeated extension of the Continuation Plan 1996-2001 past its original end date, and the Aquaculture CRSP acts within this most recent grant to this day.

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

Hillary Egna

Jeff Burright

The initial extension of the Continuation Plan 1996-2001 was allocated to fulfill all objectives originally proposed as part of the five-year grant but could not be addressed owing to annual budget cuts over the grant period. Projects funded within the Eleventh and Twelfth Work Plans focus on one of three program areas – Production Technology, Watershed Management, and Human Welfare, Health, and Nutrition. The Aquaculture CRSP peer-review process was further enhanced at this time through adoption of peer-review panels modeled after the National Science Foundation acclaimed process. Research and activities are presently ongoing in 24 countries and scheduled to end by 31 July 2006.

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

APPENDIX 2. PROGRAM PARTICIPANTS

PROGRAM MANAGEMENT OFFICE STAFF

Oregon State University, Corvallis, Oregon

Hillary Egna	Director
Danielle Clair	Associate Director of Operations
Joan Westfall	Office/Financial Manager
Chris Bridger	Research Projects Manager (from December 2004)
Katy Lloyd	Research Assistant

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

Washington, DC

Harry Rea	Cognizant Technical Officer

ADVISORY BODIES

External Program Advisory Council

Christine Crawford, Chair	University of Tasmania, Hobart, Australia
Jason Clay	World Wildlife Fund
Revathi Balakrishnan	FAO, Bangkok
Marcia Macomber	CGIAR Water for Food Challenge Program

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	Oregon State University

Institutional Representatives

Patricia R. Alvarez	Florida International University
Roy Arnold	Oregon State University (interim)
Linda L. Brainard	Cornell University
Lawrence A. Davis	University of Arkansas at Pine Bluff
Peter J. Gerard	University of Michigan
Barbara A. Goswick	University of Arkansas at Pine Bluff
Colin Kaltenbach	University of Arizona
Ricki McMillan	Insitute for Agriculture and Trade Policy
Anne J.M. Moffat	Ohio State University
C. Michael Moriarty	Auburn University
Gordhan L. Patel	University of Georgia
Lee Anne T. Peters	University of Arizona
Prudence M. Rice	Southern Illinois University at Carbondale
Rose Tseng	University of Hawaii

2004–2005 Technical Committee* Members

Co-Chairs

Chris Brown	FIU
Jim Diana	UM

Material and Methods Subcommittee		*Research Area of Expertise*
Claude Boyd	AU	Production optimization
Suyapa Meyer	Zamorano	Social and economic aspects
Yang Yi	AIT	Environmental effects

Technical Progress Subcommittee

Joe Molnar	AU	Social and economic aspects
Bill Tollner	UG	Environmental effects
Maria Haws	UH	Production optimization

Work Plan and Budget Subcommittee

Dan Meyer	Zamorano	Production optimization
Nancy Gitonga	Kenya DOF	Social and economic aspects
Wilfrido Contreras-Sánchez	UJAT	Environmental effects

External At-Large Members

Damon Seawright	US tilapia producer

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	OSU
Steve Sempier	OSU

2005–2006 Technical Committee* Members

Co-Chairs

Jim Diana	UM
Claude Boyd	AU

Material and Methods Subcommittee		*Research Area of Expertise*
Suyapa Meyer	Zamorano	Social and economic aspects
Yang Yi	AIT	Environmental effects
Kevin Fitzsimmons	UA	Production optimization

Technical Progress Subcommittee		
Bill Tollner	UG	Environmental effects
Maria Haws	UH	Production optimization
Kwamena Quagrainie	UAPB	Social and economic aspects

Work Plan and Budget Subcommittee		
Nancy Gitonga	Kenya DOF	Social and economic aspects
Wilfrido Contreras-Sánchez	UJAT	Environmental effects
Remedios Bolivar	CLSU	Production optimization

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	OSU
Chris Bridger	OSU

2004–2005 Honors and Awards Committee Members

Amrit Bart	AIT
Remedios Bolivar	CLSU
Chris Bridger	OSU
Christine Crawford	U Tasmania
Jim Diana	UM
Kevin Fitzsimmons	UA
Susan Kohler	SIUC
Steve Sempier	Miss. State
Yang Yi	AIT

*Technical Committee co-chairs and members serve two- and three-year terms, respectively. Newly elected Technical Committee members were announced at the May 2005 Asia Regional TC Meeting, Bali, Indonesia.

AQUACULTURE CRSP MEMORANDA OF UNDERSTANDING

Memoranda of understanding, representing formal ties between US and Host Country institutions, have been established between:

- Auburn University and Moi University, Kenya
- Auburn University and Stellenbosch University, South Africa
- Florida International University and the Freshwater Aquaculture Center, Central Luzon State University, the Philippines
- Oregon State University and Moi University, Kenya
- Oregon State University and the Department of Fisheries, Ministry of Livestock and Fisheries Development, Kenya
- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico
- Southern Illinois University at Carbondale and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonía Peruana, Peru
- The University of Michigan and the Asian Institute of Technology, Thailand
- University of Georgia and Escuela Agrícola Panamericana, Zamorano, Honduras
- The University of Hawaii at Manoa and the Freshwater Aquaculture Center, Central Luzon State University, the Philippines
- The University of Hawaii at Hilo and Universidad Autónoma de Sinoloa, Mexico

APPENDIX 3. FINANCIAL SUMMARY

This section summarizes the expenditures of USAID, non-federal, and host country funds for CRSP research activities and program management. This unaudited information is intended to provide an overview of CRSP program budgets and matching support for the period 1 August 2003 to 31 July 2004. Official financial reports are submitted to USAID via the Management Entity's Research Accounting Office.

Cost sharing contributions from the US institutions and contributions from host countries are presented in the table on the following page. Not all sites reported host country contributions, and those that did may not have fully accounted for in-kind contributions, typically including water, electricity, fish stock, labor, and supplies.

			August 1, 2004 to July 31, 2005			
Subcontract Number	Project Leader	Region and Institution	USAID Since 8/96	Cost Share[2] Since 8/96	Total US Funds	Host Country Contributions3
Research						
RD009A-01	Bowman[6]	Kenya: OSU	1,099,098	79,096	1,178,194	240,000
RD009B-01	Bolte	Global: OSU	313,524	85,835	399,359	
	Heikes[4]	*Global: UAPB*	7,900	4,148	12,048	
RD009C-01	Schreck[6]	Mexico: OSU	999,818	147,310	1,147,128	285,250
	Patino[4]	*Mexico: Texas Tech*	28,107	9,273	37,380	
RD009L-01	Heifer et al[6]	Global: OSU	495,947	98,052	593,999	25,000
RD009M-01	Shriver	Global: IIFET	14,150	4,920	19,070	
RD009P-01	HCPI	Global:OSU	197,902	19,866	217,768	50,000
RD009Q-01	Johnston	Global:IIFET	20,000	3,209	23,209	
RD010E-01	Engle	Global: UAPB	436,910	105,869	542,779	42,000
RD010E-02	Shelton	Africa: UO	117,280	31,194	148,474	
RD010E-03	Piedrahita	Global: UCD	78,101	26,611	104,712	
RD010E-04	Diana[6]	Southeast Asia: UM	2,052,106	208,259	2,260,365	265,300
	Rakocy [4]	*Southeast Asia : UVI*	9,889	0	9,889	
RD010E-05	Ward	Honduras: UT	19,767	4,066	23,833	
RD010E-06	Green	Honduras: AU	502,056	78,435	580,491	140,484
RD010E-07	Boyd[6]	Global: AU	502,271	115,579	617,850	31,000
RD010E-08	Lim	Kenya: AU	520,679	120,018	640,697	
RD010E-09/C	Phelps	GlobałKenya: AU	175,352	42,171	217,523	
RD010E-10	Molnar	Global: AU	68,293	14,489	82,782	
RD010E-11	Fitzsimmons[6]	Global: UA	442,205	76,673	518,878	376,320
RD010E-12	Kohler[6]	Peru: SIUC	990,019	324,058	1,314,077	301,050
	Dabrowski[4]	*Peru: OhSu*	13,000	11,963	24,963	
RD010E-13	Lochmann	Peru/Kenya: UAPB	146,305	46,956	193,261	
RD010E-14	Lovshin	Guatemala: AU	67,168	16,792	83,960	
RD010E-15	Brown	Philippines: UH	100,061	25,015	125,076	
RD010E-16 [6]	Tollner	Kenya/Honduras: UGA	476,268	73,575	549,843	29,225
RD010E-17	Molnar[6]	Honduras: AU	395,263	68,839	464,102	
RD010E-18	Hatch	Honduras: AU	55,266	13,816	69,082	
RD010E-19	Boyd	Honduras: AU	45,947	11,487	57,434	
RD010E-20	Brown[6]	Philippines: FIU	536,264	137,481	673,745	129,000
	Borski[4]	*Philippines: NCSU*	8,737	2,929	11,666	
RD010E-A	Dabrowski[6]	MexicøPeru: OhSU	289,838	93,416	383,254	68,350
RD010E-B	Batterson	Thailand: MSU	57,020	14,274	71,294	
RD010E-D [6]	Haws[6]	MexicøLAC: UH	220,000	24,039	244,039	245000
RD010E-E	Quagrainie[6]	Africa:UAPB	129,134	28,409	157,543	
RD010E-F	Skladany	Global:IATP	17,687	4,422	22,109	
RD010E-G	Tollner[6]	Kenya: UGA (and MSU)	213,801	27,794	241,595	25850
RD010E-H	Baker	Mexico: Cornell	75,265	15,053	90,318	26000
Special Activities					0	
RD008B/C	TC, EAP, IR[6]	Global:advisory, review	731,710	182,928	914,638	
International Extensior	TBA with NOAA	Bangladesh, S Africa: UCD, TBD	120,000	30,000	150,000	24000
Côte d'Ivoire Report	Kaplan	Côte d'Ivoire: Hofstra University	4,000	1,000	5,000	
Impact Assessment Rej	TBA	Global: TBA	147,164	32,199	179,363	
Research Support					0	
RD009G-01	Central Database Management	Global: OSU	279,714	73,083	352,797	
RD009E-01	Education Development	Global: OSU	244,970	61,242	306,212	
RD009K-01	Information Management & Networking	Global: OSU	2,511,132	627,783	3,138,915	
Subcontract Administration		Indirect on Subs up to 25,000	201,500	0	201,500	
Research Subtotal			16,178,588	3,223,626	19,402,214	2,303,829
					0	
MANAGEMENT					0	
					0	
Program Management					0	
Operations and Admir	8A/M	OSU Management	4,044,635	n/a	4,044,635	
					0	
Total			20,223,223	3,223,626	23,446,849	2,303,829

1. Reflects funding received and committed under all USAID allocations through 7/31/05; 2. Cost share figures reflect subcontract commitments; 3. Host country contributions are voluntary; 4. Subcontract off aof previous subcontract; 5. Cost sharing is not required for management operations; 6. Amounts are estimates, as subcontracts are under development as of the date of this report.

APPENDIX 4. PUBLICATIONS

Regional Research

CENTRAL AMERICA

Honduras

ASIAN INSTITUTE OF TECHNOLOGY

Publication

Munsiri, P. and B.F. Hajek, 1996. Texture and chemical composition of soils from shrimp ponds near Choluteca, Honduras. Aquaculture International, 4:154–168.

AUBURN UNIVERSITY

Theses

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

Martinez-Mejia, P. Case study of commercial tilapia production in Olancho, Honduras. M.S. thesis, Auburn University, Auburn, Alabama, USA.

Trejos-Castillo, E. Income, food security, and poverty reduction: case studies of small-scale aquaculture producers in Santa Barbara, Honduras. M.S. thesis, Auburn University, Auburn, Alabama.

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Alvarenga, H.R. and B.W. Green, 1986. Growth and production of all male Tilapia nilotica and all male hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) in ponds. Rev. Latinoamericana de Acuicultura, 29:6–10. (in Spanish)

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Boyd, C.E. and D.R. Teichert-Coddington, 1994. Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds. Journal of the World Aquaculture Society, 25(3):210–213.

Boyd, C.E. and D.R. Teichert-Coddington, 1995. Dry matter, ash, and elemental composition of pond-cultured *Penaeus vannamei* and *P. stylirostris*. Journal of the World Aquaculture Society, 26(1):88–92.

Boyd, C.E. and M.C. Haws, 1999. Good management practices (GMPs) to reduce environmental impacts and improve efficiency of shrimp aquaculture in Latin America. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, at San Pedro Sula, Honduras, pp. 9–33.

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Green, B.W., 1995. Polyculture of tilapia with marine shrimp. Actas del Primer Simposio Centroamericano sobre cultivo de tilapia, pp. 117–125.

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The Ohio State University

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Appendix 5. Linkages

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

Acuarios Leticia, Colombia
Alabama Catfish Producers Association, Montgomery, Alabama
Alpha Aquaculture, Kenya
American Association for the Advancement of Science (AAAS), Washington, DC
American Association of State Colleges and Universities International Higher Education Linkages Project (IHELP), Washington, DC
American Fisheries Society, Bethesda, Maryland
American Tilapia Association, Arlington, Virginia
Aqua Technics, Carlsborg, Washington
Aquacorporacion, International, Honduras
Aquaculture for Local Community Development Programme (ALCOM), Harare, Zimbabwe
Arid and Semi-Arid Lands (ASAL) Project, Government of Kenya, Laikipia, Kenya
Asian Development Bank, Tarahara, Nepal
Asociación Nacional de Acuicultores de Honduras (ANDAH), Tegucigalpa, Honduras
Association for International Agriculture and Rural Development (AIARD), Washington, DC
Australian Center for International Agricultural Research (ACIAR), Nelson Bay, Australia
Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh
Bangladesh Rural Advancement Committee (BRAC), Bangladesh
Bean/Cowpea CRSP, East Lansing, Michigan
Board for International Food and Agricultural Development (BIFAD) Washington, DC
Brackish Water Shrimp Culture Station, Ranot, Thailand
Broadening Access and Strengthening Input Market Systems (BASIS) CRSP, Madison, Wisconsin
Brooklyn College, New York
Brunell Engineering Works, Kenya
Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi
Bureau of Fisheries and Aquatic Resources (BFAR), Manila, Philippines
Can Tho University, Vietnam
Canadian International Development Agency (CIDA), Hull, Quebec, Canada
Caritas, Bangladesh and Iquitos, Peru
Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt
Centro de Adiestamiento de la Agricultura Sostenible (CEASO), Honduras
Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia
Chiang Mai Rehabilitation Center, Thailand
Chulalongkorn University, Bangkok, Thailand
Clackamas County Extension Office, Oregon City, Oregon
Clemson University, Clemson, South Carolina
Coastal Resources Center, Narragansett, Rhode Island
Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (CODDEFFAGOLF), Tegucigalpa, Honduras
Commonwealth Agricultural Bureau International,
Comunidad Indígena Sarayuku, Ecuador
Consejo Nacional de Ciencia y Technologia (CONACYT), Mexico
Consejo Nacional del Ambiente (CONAM), Lima, Peru
Consortium for International Earth Science Information Network (CIESIN), Washington, DC
Consultative Group on International Agricultural Research (CGIAR), Washington, DC
Cooperative for Relief and Assistance Everywhere (CARE), Bangladesh, Honduras, Peru, and Atlanta, Georgia
Cornell University, Ithaca, New York
CP Group, Thailand
CSIRO Livestock Industries Chiswick Pastoral Research Laboratory, Armidale, Australia
Danish International Development Agency (DANIDA), Copenhagen, Denmark
Dar es Saalam University, Dar es Saalam, Tanzania
Department for International Development (DFID) Fish Genetics Research Programme, Swansea, Wales, United Kingdom
Department of Agriculture, Yunnan Province, China
Department of Aquaculture, Nepal
Department of Fisheries, Phnom Penh, Cambodia
Department of Fisheries, Udorn Thani, Thailand
Department of Livestock and Fisheries, Savannakhet, Laos
Derby Holding Company, Kenya
Development for the Municipality of Centro, Tabasco, Mexico
Ecocostas, Ecuador
Egerton University, Njoro, Kenya
Ejido Rio Playa, Comalcalco, Tabasco, Mexico
El Carao Fish Culture Station, Comayagua, Honduras
Embrapa Environment, Brazil
Empresa Brasileira de Pesquisa Agropecuária (Embrapa) Environmental Laboratory, Campinas, Brazil
Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), Brazil
Empresa Nacional de Energia Electrica, Tegucigalpa, Honduras
Escuela Agrícola Panamericana, Zamorano, Honduras
Escuela de Agricultura de la Region Tropical Humeda (EARTH), San José, Costa Rica
Escuela Superior Politécnica del Litoral (ESPOL)/Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM), Guayaquil, Ecuador
European Foundation for the Improvement of Living and Working Conditions, Dublin, Ireland
European Inland Fisheries Advisory Commission (EIFAC), Rome, Italy
Farm-Level Applied Research Methods for East and Southern Africa (FARMESA), Swedish International Development Cooperation Agency (SIDA), Stockholm, Sweden

Fe y Alegria, Lima, Peru
Federación de Agroexportadores de Honduras (FPX), San Pedro Sula, Honduras
Fideicomisos Institutos en Relación con la Agricultura (FIRA), Morelia, Michoacán, Mexico
Fisheries and Aquaculture Development Division, Tanzania
Fisheries Department, Ministry of Food and Agriculture, Ghana
Fisheries Industry Technology Center/University of Alaska Kodiak & University of Alaska Fairbanks Sea Grant Marine Advisory Program
Fisheries Society of Africa (FISA), Nairobi, Kenya
Fondo Nacional de Desarrollo Pesquero (FONDEPES), Lima, Peru
Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Foreign Agricultural Service, Research and Scientific Exchange Division
Forum for Organic Resource Management (FORMAT), Nairobi, Kenya
Foundation Chile, Santiago, Chile
FYD International Farm, Philippines
General Directorate of Fisheries and Aquaculture (DIGEPESCA), Tegucigalpa and San Pedro Sula, Honduras
Genetically Improved Farmed Tilapia Program (GIFT), Muñoz, Nueva Ecija, Philippines
German Development Service, Kenya
Global Aquaculture Alliance, St. Louis, Missouri
Global Livestock CRSP, Davis, California
Global Village, Honduras
Henry Spira/GRACE Project on Industrial Production, School of Hygiene and Public Health, Johns Hopkins University
Hofstra University, Hempstead, New York
Huazhong Agricultural University, China
Inland Water Resources and Aquaculture Service (FIRI), Rome, Italy
Institut Pertanian Bogor (IPB), Bogor, Indonesia
Institute for Agriculture and Trade Policy, Minneapolis, Minnesota
Institute for the Regional Ecodevelopment of the Amazon, Ecuador
Institute of Agricultural and Food Information, Prague, Czech Republic
Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Rampur Campus, Chitwan, Nepal
Institution for Research in Food and Development, Hermosillo, Sonora, Mexico
Instituto Amazónico de Investigaciones Científicas SINCHI, Colombia
Instituto Colombiano de Desarrollo Rural INCODER, Bogota, Colombia
Instituto de Investigaciones IMANI, Colombia
Instituto del Mar del Perú (IMARPE), Callao, Peru
Instituto Nacional de Pesquisas da Amazonia, Brazil
Instituto Politécnico Nacional, Mexico City, Mexico
Instituto Technológico Saleciano, Ecuador
Instituto Tecnologico del Mar, Veracruz, Mexico
Integrated Pest Management CRSP, Blacksburg, Virginia
Inter-African Committee on Oceanography, Sea and Inland Fisheries
International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya
International Development Research Centre (IDRC), Ottawa, Canada
International Service for National Agricultural Research (ISNAR), Honduras
International Sorghum and Millet (INTSORMIL) CRSP, Lincoln, Nebraska
Japan International Cooperation Agency (JICA), Japan
Kasetsart University, Thailand
Katholieke Universiteit Leuven (KUL), Belgium
Kellogg Foundation, Dominican Republic
Kenya Fisheries Department, Kenya
Kenya Marine and Fisheries Research Institute
Kenya Medical Research Institute (KEMRI), Nairobi, Kenya
Kenyatta University, Nairobi, Kenya
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
La Fundacion Chile
Lake Basin Development Authority, Kenya
Lake Victoria Environmental Management Programme, Kenya
Land Tenure Center, Madison, Wisconsin
Louisiana State University, Baton Rouge, Louisiana
Magarini Aquafarmers, Malindi, Kenya
Malawi National Aquaculture Center, Malawi
Marine Farms ASA, Norway
Mekong River Commission, Phnom Penh, Cambodia
Mesta de Bombon Maca Producers Association, Peru
Microcredit Summit Campaign, Washington, DC
Ministry of Agricultural Development, Panama
Ministry of Agriculture, Animal Husbandry, and Fisheries, Entebbe, Uganda
Ministry of Education, Dominican Republican
Ministry of Environment and Natural Resources, Tegucigalpa, Honduras
Ministry of Fisheries, Iquitos, Peru
Ministry of Tourism, Natural Resources, and Environment, Fisheries Division, Dar es Salaam, Tanzania
Mount Kenya Fish Farmers Association, Central Province, Kenya
National Agricultural Library, Washington, DC
National Agricultural Research Council, Nepal
National Agriculture University (NAU), La Molina, Peru
National Aquaculture Centre, Zomba, Malawi
National Center for Genetic Engineering and Biotechnology (BIOTEC), Thailand
National Council for Science and Technology, Mexico
National Inland Fisheries Institute (NIFI), Bangkok, Thailand
National Museums of Kenya, Nairobi, Kenya
National Research Initiative, Thailand
National Shrimp Culture Advisory Group, Tegucigalpa, Honduras
National Technical Information Services (NTIS), Springfield, Virginia
Nepal Agricultural Research Council, Lalitpur, Nepal
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok, Thailand
Nong Nam University, Vietnam
Noorul Islam College of Engineering, Tamil Nadu, India
North Carolina State University, Raleigh, North Carolina
North Central Regional Aquaculture Center (NCRAC), East Lansing, Michigan

Nuestros Pequeños Hermanos (NPH), Honduras
Oceanic Institute, Waimanalo, Hawaii
Oceanol, Centro, Tabasco, Mexico
Ohio State University Research Foundation (OSURF), Columbus, Ohio
Oregon Sea Grant, Corvallis, Oregon
Organization of African Unity, Addis Ababa, Ethiopia
Patani Fisheries College, Patani, Thailand
Peace Corps, Ecuador
Peanut CRSP, Griffin, Georgia
Population and Fish Genetics Group
Programa Cooperativo de Investigacion y Transferencia de Tecnologia Agropecuaria para los Tropicos (PROCITROPICS), Peru
Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (PRADEPESCA), Panama
Project Globale, Honduras
Project Rural Reconstruction, Santa Barbara, Honduras
PROMIPAC, Nicaragua and El Salvador
PROSEAL, Iquitos, Peru
PROSHIKA, Dhaka, Bangladesh
Quisqueya University, Haiti
Red de Desarrollo Sostenible Honduras (RDS-HN), Honduras
Regional Center of Education and Qualification for Sustainable Development (CREDES), Mazatlan, Mexico
Research Institute for Aquaculture No. 1, Dinh Bang, Tu Son, Bac Ninh, Vietnam
Roche Aquaculture Research Centre Asia Pacific, Bangkok, Thailand
Royal Institute of Technology, Stockholm, Sweden
Royal University of Agriculture, Nepal
Rural Reconstruction Program (PRR), Santa Barbara, Honduras
Sagana Women's Group, Sagana, Kenya
Sarasawathi Foundation, Thailand
Science and Math Investigative Learning Experiences Program (SMILE), Oregon State University
Secretaria de Agricultura e Abastecimento do Estado de Sao Paolo, Brazil
Secretaría de Agricultura y Ganadería, Honduras
Sichuan Provincial Fisheries Association, Ziyang, Sichuan Province, People's Republic of China
Sinaloa State Committee for Aquaculture Sanitation (CESASIN)
Sisaket College of Agriculture and Technology, Thailand
Socio-Economic Development Centre (SEDEC), Binh Thuan Province, Vietnam
Soil Management CRSP, Honolulu, Hawaii
Sokoine University of Agriculture, Tanzania
Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines
Southeast Asian Outreach (SAO) Cambodia Aquaculture at Low Expenditure (SCALE) Project, Cambodia
Southern African Development Community (SADC), Harare, Zimbabwe
Southwest University, China
Special Program for African Agricultural Research (SPAAR), Washington, DC
Sustainable Agricultural Centre for Research and Development in Africa (SACRED-Africa), Bungoma, Kenya
Sustainable Agriculture and Natural Resources Management (SANREM) CRSP, Watkinsville, Georgia
Taiwanese Mission, Honduras
Technical Integration Asia Network, Yangon, Myanmar
Terra Nuova, Lima, Peru
Texas A&M University, College Station, Texas
Texas Sea Grant, Houston, Texas
Texas Tech University, Lubbock, Texas
Thai Lux, Thailand
Thailand Department of Fisheries
Training and Occupation for Disabled Association, Poi Pet, Cambodia
Uganda Wetlands and Resource Conservation Association (UWRCA), Uganda
United Aqua Farms, Bangladesh
United States Department of Agriculture (USDA), Washington, DC
United States Fish and Wildlife Service (USFWS), Washington, DC
United States Food and Drug Administration (FDA), Washington, DC
Universidad Autónoma Metropolitana, Mexico City, Mexico
Universidad de Santiago de Compostela, Santiago, Spain
Universidad Federal do Amazonia, Brazil
Universidad Mayor de San Simón, Bolivia
Universidad Nacional Agraria La Molina, Lima, Peru
Universidad Nacional de Colombia
Universidad Nacional Federico Villareal, Lima, Peru
Universidad Nacional Mayor de San Marcos, Lima, Peru
Universidad Técnica de Machala, Machala, Ecuador
Universidade de São Paulo, Brazil
Universidade Estadual Paulista, Brazil
Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
Universität Hohenheim, Stuttgart, Germany
Université Nationale du Rwanda, Butare, Rwanda
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam
University of California, Davis
University of Cantho, Vietnam
University of Delaware
University of Fisheries, Nhatrang, Vietnam
University of Nairobi, Kenya
University of Oklahoma
University of Puerto Rico, Mayaguez, Puerto Rico
University of Rhode Island, Kingston, Rhode Island
University of Science and Technology, Ghana
University of Stirling, United Kingdom
University of Texas at Austin
University of the North, Pietersburg, South Africa
University of the Philippines in the Visayas, Iloilo, Philippines
University of the Virgin Islands, St. Thomas, USVI
University of Wales, Swansea, UK
University of Washington, Seattle, Washington
University of Wisconsin-Madison, Madison, Wisconsin
Vincent Foundation, Haiti
Virginia Polytechnic Institute, Blacksburg, Virginia
Wageningen University, The Netherlands
West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire
Western Regional Aquaculture Consortium (WRAC), Seattle, Washington
Wetlands Conservation Program, Mazatlan, Mexico

Winrock International, Lima, Peru
World Aquaculture Society (WAS), Baton Rouge, Louisiana
World Bank, Washington, DC
World Conservation Union (IUCN), Nairobi, Kenya
World Fish Center (ICLARM), Penang, Malaysia
World Neighbors, Honduras
World Wildlife Fund, Washington, DC
WorldFish (ICLARM)
Wuhan University, China
Zamorano Alumni Association, Dominican Republic

APPENDIX 6. ACRONYMS

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

US	United States
USAID	United States Agency for International Development
USVI	University of the Virgin Islands, St. Thomas
UT	University of Texas
UV	Ultraviolet
VSS	Volatile suspended solids
WAS	World Aquaculture Society
WIDeST	Web-Based Information Delivery System for Tilapia