



Final Report of the Aquaculture Collaborative Research Support Program: 1996 to 2008 Volume 1

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Final Report: 1996 to 2008
Volume 1

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TABLE OF CONTENTS for VOLUME 1

PREFACE	ii
EXECUTIVE SUMMARY	iii
I. INTRODUCTION	1
II. ACCOMPLISHMENTS: PROGRAM ACTIVITIES SUMMARY	3
III. RESEARCH PROJECTS.....	7
<i>RESEARCH.....</i>	<i>7</i>
<i>EDUCATION AND TRAINING</i>	<i>13</i>
<i>ENGAGING STAKEHOLDERS AND END-USERS</i>	<i>15</i>
<i>RESOURCE CONSERVATION</i>	<i>18</i>
<i>WORKING WITH PARTNERS.....</i>	<i>19</i>
IV. RESEARCH SUPPORT: PROGRAM-WIDE ACTIVITIES	23
<i>PARTNERED PROJECTS</i>	<i>23</i>
<i>DATABASES</i>	<i>29</i>
<i>CONFERENCES SUPPORTED AND ATTENDED.....</i>	<i>30</i>
V. CAPACITY BUILDING.....	32
<i>DEGREE AND NON-DEGREE TRAINING SUMMARY</i>	<i>32</i>
<i>LONG-TERM TRAINING</i>	<i>33</i>
<i>SHORT-TERM TRAINING</i>	<i>38</i>
<i>STUDENT PROFILES</i>	<i>39</i>
<i>LEGACY BUILDING.....</i>	<i>58</i>
<i>INSTITUTIONAL STRENGTHENING</i>	<i>58</i>
<i>INSTITUTIONAL STRENGTHENING IN KENYA</i>	<i>59</i>
VI. PROGRAM DESCRIPTION	62
<i>AQUACULTURE CRSP HISTORICAL OVERVIEW.....</i>	<i>62</i>
<i>LOCATIONS</i>	<i>64</i>
<i>PROGRAM MANAGEMENT</i>	<i>66</i>
<i>OVERALL DESCRIPTION OF ACTIVITIES.....</i>	<i>67</i>
VII. LESSONS LEARNED	68
VIII. FINANCIAL SUMMARY	72



PREFACE

This report cannot encompass the entirety of the Aquaculture CRSP's activities and accomplishments since its inception, nor indeed since the approval of the PD/A CRSP Continuation Plan 1996 and subsequent funding of the Eighth Work Plan in 1996 that extended the life of the program. The full extent of the Aquaculture CRSP's research and accomplishments can be found in our Annual Technical and Administrative Reports. Here we do not intend to supplant these, but focus instead on highlights, achievements and features of the program since 1996, in accordance with the Standard Provisions accompanying the Grant Document.



EXECUTIVE SUMMARY

The Aquaculture CRSP (formerly the Pond Dynamics/ Aquaculture CRSP) has undergone significant changes since its inception under Title XII. Its original purpose was to conduct a global experiment that would result in a complex model of variables that influence production of pond aquaculture systems.

The CRSP conducted the Global Experiment for more than ten years. Researchers studied pond ecosystems including physical, chemical, and biological processes. By conducting a series of standardized experiments at each site, the PD/ A CRSP has created the kind of baseline data commonly found in other agricultural disciplines, but which has been lacking for so long in aquaculture. The data from the Global Experiment have been compiled into the world's largest database on tropical aquaculture. PD/ A CRSP researchers harness the statistical power of this database to develop simulation models and guidelines for more efficient aquaculture production. One such software product to come out of this research is the POND© Decision Support System.

Upon successful completion of this work, the PD/ A CRSP (as it was then known) submitted a proposal to continue research in this area and perhaps more importantly, conduct research to develop practical applications of the model.

In the final funded year of Aquaculture CRSP, more than 683 students had been trained with university degrees – over half with advanced graduate degrees – in disciplines related to business, ecology, health, agriculture, and natural resources. Aquaculture CRSP offered short-term trainings and topical workshops to over 4500 people in developing countries. Aquaculture CRSP managed a portfolio of 26 direct subcontracts with US universities and had extended subcontracting relationships with another 19 US institutions, involving 24 countries. The overall annual funding for the program averaged around US\$2.15M from USAID with about \$1M per year in leveraged funding and from university matching contributions.

Some technologies developed by Aquaculture CRSP include: Decision Support Software; World's largest database on ground-truthed pond variables; Pond construction techniques allowing improved use of up to 13 million ha of land in SE Asia; novel feeding technologies to reduce costs by about \$400/hectare, translating into a 17% increase in the net value of the crop.

Responsible watershed management is paramount for improved human nutrition and welfare, secure economic development, and ecosystem health. The Aquaculture CRSP has been concerned with aquatic resources management from an ecosystem perspective. Several investigations were intimately associated with aquatic resource management in the Nzoia and Njoro Watersheds in Kenya. Other Aquaculture CRSP projects indirectly addressed watershed management through the appropriate use of technologies, such as safe handling and recovery of steroids in aquaculture, design of recirculating aquaculture systems, and development of aquaculture methods for native species production.

Non-native species introductions into otherwise delicate ecosystems are counter to the criteria of sustainable development and the 1999 US Executive Order on Invasive Species. The Aquaculture CRSP does not tolerate exotic species introduction in its activities. Numerous Aquaculture CRSP investigations addressed biodiversity concerns by determining the effects of non-native species on native aquatic populations while other investigations focused on

developing cultivation methods for native species that have locally accepted markets. Examples of native species research include black pacu (*Colossoma macropomum*) and red pacu (*Piaractus brachipomus*) in the Amazon Basin; Amazon and Parana Rivers catfishes (*Pseudoplatystoma* sp.); indigenous carp (*Spinibarbus denticulatus*) in Southeast Asia; native cichlid (*Petenia splendida*), tropical garfish (*Atractosteus tropicus*), and common snook (*Centropomus undecimalis*) in Mexico; and the African catfish (*Clarias gariepinus*) and indigenous original strains of Nile tilapia (*Oreochromis niloticus*) in Kenya.

The Aquaculture CRSP historically has focused on aquaculture production optimization. Farm optimization research allows farmers to become better stewards of the environment while accruing greater profits from their efforts to further alleviate poverty in local communities.

In Thailand, acidic soils can hinder effective management of fish ponds. The CRSPs interdisciplinary research team determined that different pond construction techniques would make a difference. Diking instead of digging ponds will make 13 million hectares of acid-sulfate soils more useful for aquaculture. US institutions investigate topics of general utility to Aquaculture CRSP researchers and the international aquaculture community. Studies of pond soil and water interactions are one example of applied research that can be used by researchers and pond managers worldwide.

Through Aquaculture CRSP research, farmers in the Philippines use an innovative delayed feeding strategy that results in substantial monetary savings by decreasing the quantity of wasted feed. In Latin America, research on the safe use of steroids to produce all-female tilapia stocks has greatly increased farm production through increased growth and food conversion ratios, and reduced negative environmental impacts associated with commonly used technologies.

In Rwanda, inorganic fertilizers were too expensive for most farmers to use in their ponds and organic fertilizers were often in short supply. Aquaculture CRSP researchers developed a system to compost indigenous green grass right in the pond. The result? Greater pond productivity and fish growth than with more expensive fertilizer treatments.

In Honduras, the demand for tilapia fingerlings far exceeded the supply. When the Aquaculture CRSP fertilization and breeding protocols were adopted, fingerling production tripled without the expensive supplements previously needed.

Optimal pond soil management and fertilization strategies have created a pond environment that minimizes fish mortality, decreases environmental impacts, and increases farm-scale economic returns in Thailand and around the globe. Many Aquaculture CRSP technologies developed through research overseas are also applied to domestic pond aquaculture farms in the Southern US states through the reverse flow of information via researchers, students, and publications from the Aquaculture CRSP.

All the work detailed in the Eighth through Twelfth Work Plans is complete. Out of hundreds of investigations, all but one or two are either "Successfully Completed" or "Successfully Completed With Modification." (See Appendix 1.)

The further continuation of the program was supported to its end by USAID, through a series of continuation grants. The final two unfunded years allowed for the graceful exit from host countries, and for sustaining linkages to be established. In 2006, Oregon State University won a competitive for a new CRSP in Aquaculture and Fisheries (AquaFish CRSP), based on a Request for Proposals from USAID. This award will allow continued benefits from the infrastructure, relationships, and goodwill that were established by the Aquaculture CRSP.



I. INTRODUCTION

The Aquaculture Collaborative Research Support Program (CRSP) is one of nine CRSPs in operation. It is one of a family of agricultural research programs partially funded by the United States Agency for International Development. It is a partner of USAID's Economic Growth, Agriculture, and Trade (EGAT) Bureau's Office of Agriculture, and for a short time also part of the Office of Natural Resources Management and USAID's Water Team. The Aquaculture CRSP's cohesive program of research is carried out in selected developing countries and in the United States by teams of US and host country researchers, faculty, and students.

In 1975, the United States Congress passed an amendment to the Foreign Assistance Act of 1961 known as "Title XII -- Famine Prevention and Freedom from Hunger." The mandate of Title XII is to "... improve the participation of the agriculturally related universities in the United States' governmental efforts internationally to increase world food production and provide support to the application of science to solving food and nutrition problems." This legislation aims to provide mutual research benefits to both the United States and host countries. Under Title XII, the CRSP concept was created by the U.S. Agency for International Development (USAID) and the Board for International Food and Agriculture Development (BIFAD). The program is intended as a long-term mechanism to focus capabilities of U.S. Land Grant Universities to carry out the Title XII mandate. In its September 1997 strategy statement, USAID recognizes the importance of strengthening the agricultural sector to build a firm base for economic growth.

The CRSPs are communities of U.S. Land Grant Universities working with host country National Agricultural Research Systems (NARS), International Agricultural Research Centers (IARCs), U.S. agribusiness, private voluntary organizations (PVOs), host country colleges and universities, private agencies, USAID/Washington and USAID Missions, and other U.S. federal agencies such as USDA. The CRSPs help build sustainable capacities of NARS of host countries so that they can solve problems of agricultural production and utilization. The collaborative research of scientists in these programs benefits U.S. agriculture, as well as agriculture in these countries. Research conducted by these programs helps farmers improve their incomes and alleviate hunger without depleting the natural resource base on which they depend for food, fuel, fiber, and shelter. Collaborative Research Support Programs work with international agricultural research centers, private industry, and non-governmental organizations in the US and abroad. Collaborative Research Support Program research strengthens host country institutions and provides training opportunities for host country scientists.

Aquaculture, the cultivation of aquatic plants and animals, is an ancient art and an emerging science. Global demand for fish has soared in the past decade, while stocks of wild fish have dwindled. In many countries, fish is the single most important source of animal protein. In the 21st century, aquaculture promises to be the primary means of increasing fish production.

In 2004 a USAID SPARE Panel reiterated the context in which this CRSP has long operated. "Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and invaluable providers of employment, cash income, and foreign exchange. Fisheries products are the world's most widely traded foods, with commerce dominated by the developing countries. Fisheries products are the primary protein sources for some 950 million people worldwide, and are an important part of the diet of many more. In comparison to other sectors of the world food economy, however, the fisheries and aquaculture

sectors are poorly planned, inadequately funded, and neglected by all levels of government. This neglect occurs in a paradoxical situation: fishing is the largest extractive use of wildlife in the world; and aquaculture is the most rapidly growing sector of the global agricultural economy. ... The lack of US engagement in international fisheries and aquaculture not only compromises America's financial position: an important part of our Nation's food security is at risk; and our domestic fisheries and aquaculture industries are rapidly losing their competitive position."

The Aquaculture CRSP's focus has been to improve the efficiency and sustainability of aquaculture systems. The Aquaculture CRSP's mission is to "enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources."

Aquaculture CRSP projects are diverse and draw upon a great depth of expertise in the US university, NGO, governmental, and private sector communities. The Aquaculture CRSP has brought together the resources of US institutions and host countries and to increase the efficiency of pond culture systems and to disseminate successful aquaculture strategies.

All Aquaculture CRSP projects have focused on institutional strengthening and outreach while at the same time fostering economic growth, food security, and the wise use of natural resources.

Now completing operations under its fourth USAID grant since 1982, the Aquaculture CRSP has been guided by the concepts and direction set down in the Continuation Plan 1996, which is funded under USAID Grant No. LAG-G-00-96-90015-00, and which forms the basis of this Final Report.

In 2006, the Aquaculture CRSP applied for, and received a no-cost extension to complete work begun under the previously funded program. The purpose of the no-cost extension was:

- To allow students in degree programs to finish their degrees , and
- To facilitate a smooth transition between the Aquaculture CRSP and the new Aquaculture & Fisheries CRSP.

This report includes extension activities (1 July 2007 through 30 September 2008) for closing out project and program objectives. Additional no-cost extensions focused on: Rehabilitation of field sites after the Kenya political strife and the Mexico floods, which directly affected our researchers and students; archiving information, visual images, data; establishing an on-line searchable database for CRSP publications; sponsoring conferences and workshops; producing manuals; completing critical research and exit plans and management activities supporting research.

This report is not intended to supplant information in the Annual Reports. Rather, we highlight key achievements and data from those reports that emphasize how the Aquaculture CRSP has fulfilled, if not exceeded, the original plans for this CRSP.

We cover the items required in the standard provisions for grant reporting including:

- (a) A summarization of the program's accomplishments
- (b) An overall description of the activities under the program during the period of this grant
- (c) Comments and recommendations regarding unfinished work and/or program/continuation and direction
- (d) A fiscal report that describes how the Grant (and any matching) funds were used.



II. ACCOMPLISHMENTS: PROGRAM ACTIVITIES SUMMARY

Since the Eighth Work Plan was funded in 1996, the Aquaculture CRSP has continued to build its legacy of improving lives with scientific research, outreach, and education in all aspects of pond aquaculture.

Our projects focused on developing appropriate technology to directly impact aquaculture farmers in 24 countries in Africa, South America, and Asia. The Aquaculture CRSP has helped farmers, extension agents, and other stakeholders increase productivity, adopt appropriate technologies, and enhance farm-to-market efficiencies, thereby boosting profitability and, ultimately, quality of life for many thousands of low-income people. Our outreach often involved training of personnel who would then disseminate relevant information through a range of methods.

Aquaculture CRSP has emphasized the need to fund cutting-edge research that would develop appropriate technologies. Thus our outreach complemented basic research, closing the loop. Funded research related to every aspect of pond aquaculture. Our prior experience had indicated many opportunities for eliminating a wide range of ineffective or inefficient practices by providing alternatives. Our science-based investigations covered most aspects of the pond life cycle:

1. Site identification, construction and preparation.
2. Organism biology, feeding, disease and predator control.
3. Water quality management.
4. Harvest and post-harvest practices.

This cohesive research led to significant productivity gains through all aspects of aquacultural practices. In many of our host country sites, multiple approaches were implemented, leading to substantial and sustainable improvements in aquaculture productivity for local farmers.

However, to benefit from the science, individual farmers needed to understand the benefits of adopting new methods. To optimize technology transfer, complementary investigations evaluated aspects of the socio-political and economic context of aquaculture production:

1. Education and training of outreach personnel and local farmers.
2. Evaluation of the role of key end-user groups (notably women) in aquaculture production and marketing.
3. Understanding the role of traditional and recommended practices in conserving natural resources such as water quality.
4. The necessity to work with local organizations and other institutional partners to maximize program impact.

We also understood the need to leverage our resources on a broader scale, and therefore engaged in a number of activities that stretched across our program. For example, we disseminated publications related to our research and other aspects of the aquaculture industry, through print and electronic media. We also provided database support for research and development of aquaculture practices, including an expert system (decision support system). Another way of disseminating acquired knowledge was to support and attend conferences that were consistent with our aim to communicate with aquaculture practitioners around the world.

Through these various approaches, the Aquaculture CRSP provided a diverse yet unified platform from which to improve lives of local people in host countries. By supporting capacity building of host countries, we leveraged resources in a way that exemplifies the goals and mission of USAID.

We illustrate with brief examples from three host countries in which we built relationships with locals and reinforced capacity: Kenya, Honduras and the Philippines.

The Aquaculture CRSP Kenya Project exemplifies the accomplishments of the Aquaculture CRSP. In this project, we focused on:

- Research and technology dissemination
- Rural and agricultural finance
- Land and Water Management
- Agricultural resource policy

Our on-farm trials provided sound reasons for farmers to adopt Aquaculture CRSP technology and practices related to farm management, feeding and fertilization strategies, record keeping, and harvest methods. Marketing and economics activities assisted with rural and agricultural finance concerns such as getting credit for starting or expanding a fish farm operation.

Another Aquaculture CRSP project with the Kenya Department of Fisheries and Moi University is a watershed management study of land-use policies and practices, hydrological and water quality characteristics, and ecological parameters of the Nzoia River Basin. The project provided much of the means for Moi University to become a regional leader in watershed assessment and management. Moi University now has the ability to serve as a resource to government departments in Kenya and other countries dependent upon the Lake Victoria watershed.

From their work in Kenya, researchers produced a business management training manual, “Tilapia Farm Business & Economics” published by Aquaculture CRSP. The manual was based on the Kenya model, but the approach can be used anywhere. Since publication in March 2006 more than one hundred copies of this manual have been requested for private farm use, workshop curricula, NGOs, and government extensionists. Another manual produced in 2008, “A New Guide to Fish Farming in Kenya,” promises to become a popular reference for Africa in general, and a French translation is underway.

In the Aquaculture CRSP Honduras Project we emphasized sector productivity through enhancing:

- Research and technology dissemination
- Market and trade capacity

In 1997 the commercial fish farming industry began exporting tilapia fillets to North American markets. Aquaculture CRSP research and training in Honduras focused on locally generated experimental data to develop and disseminate information to manage tilapia farm operations. As a result, Honduras is now a hub of extension training for Central America, with CRSP researchers holding workshops in Nicaragua, Ecuador, the Dominican Republic, and Honduras. Market studies in Honduras resulted in increased government support for the tilapia farming industry coupled with considerable expansion of the tilapia aquaculture sector. Production of tilapia and other cichlids in Honduras has increased from 120 metric tons in 1990 to 11,722 mt in 2003.

In the Aquaculture CRSP Philippines Project we likewise emphasized sector productivity:

- Research and technology dissemination

- Market and trade capacity
- Rural and agricultural finance

To meet the needs of growing tilapia markets in the Philippines, farm operators increased efficiency by adopting Aquaculture CRSP recommendations. Research on supplemental feed demonstrated that production with delayed feeding methods compares favorably with *ad libitum* feeding. Delayed feeding strategies developed by the CRSP showed farmers how to reduce total feed costs by \$400 per hectare. This gain translated to a 17% increase in the net value of the crop. Aquaculture CRSP research in the Philippines is helping to increase tilapia fillet size, hence strengthen the industry and raise profits by meeting the needs of the international export market. As farmers adopt a cost efficient feed practice and the industry looks at global opportunities, the Aquaculture CRSP has helped the Philippines position itself to diversify its economy by adding tilapia to its export products.

In addition to projects with national impact, Aquaculture CRSP's track record includes improving individual lives. The various Host Country project, have consistently leveraged Aquaculture CRSP support to provide unique opportunities to Host Country researchers and students (see Student Success Stories). These projects have also reached beyond academia and institutions to benefit struggling farmers and low-income enterprises.

For example, in Kenya, William Kiama switched from horticulture to aquaculture. From two small ponds, he expanded to seven, and by implementing an Aquaculture CRSP-developed business model, he was poised to become one of the country's leading ornamental fish producers.

From Aquaculture CRSP training in Honduras, Ponciano Cruz acquired technical knowledge and practical experience related to optimizing tilapia culture. He served as an extension officer, providing advice to 200 to 300 farmers yearly.

Many of our programs were specific to host countries. Others were cross-cutting, impacting several research initiatives. For example, in the Global Experiment, CRSP's researchers conducted a series of standardized experiments at each host country site, creating baseline data commonly found in other agricultural disciplines, but long absent in aquaculture. The data from the Global Experiment have been compiled into the world's largest database on tropical aquaculture. US institutions investigate topics of general relevance to CRSP researchers and the international aquaculture community. Our studies of pond soil and water interactions comprise an extensive body of applied research that continues to be used by researchers and pond managers worldwide.

Since the conclusion of the Global Experiment, local needs have driven the research agenda. Shortly before this grant began, in Rwanda, CRSP researchers developed a system to compost indigenous grass in the pond. The new method provided higher pond productivity and fish growth than possible with more expensive fertilizer treatments. Many of those techniques were conveyed to Kenya, helping to jumpstart aquaculture.

In Honduras, CRSP researchers recommended fertilization and breeding protocols that tripled fingerling production without expensive supplements.

In Thailand, the CRSP research team determined that different pond construction techniques would make a difference to acidic soils, which can hinder management of fish ponds. By diking instead of digging ponds, 13 million hectares of acid-sulfate soils will be more suited for aquaculture.

In Bangladesh, CRSP researchers realized that production and ROI could be boosted if extension agents were consistent in recommending the best fertilization regimes. Several regimes were evaluated and, once the best one had been determined, the researchers cultivated collaborations to ensure this regime was consistently recommended by different extension agencies.

Putting local and national impacts into perspective, another aspect of the CRSP approach is to organize research agendas around opportunities for collaborative projects.



III. RESEARCH PROJECTS

Aquaculture CRSP research projects have been characterized by strong collaborations between US institutions and those in Host Countries. We have supported a range of investigative projects to support five main areas to meet the Aquaculture CRSP mission and that of USAID. Specifically, these include

- Technology development, whether de novo methods or techniques or appropriate technological transfer within the framework of economic opportunity.
- Education and training, including career track scientists from graduate level onwards as well as extension work to educate and train practicing farmers.
- Engaging end user groups, for example to ensure gender equity in reaping the benefits of aquaculture production.
- Resource conservation, including use of indigenous or low-food chain species, minimal input fertilization regimes, and effluent and water quality evaluation.
- Working with partners, such as building inter-institutional connections between countries as well as facilitating networking among aquaculture researchers and farmers.

RESEARCH

In seeking proposals, we imposed rigorous conditions to ensure the highest quality research. The RFP process involved intensive work by the ME for avoiding conflicts of interest, fair reviews, and well written instructions and materials. Proposals were selected that showed promise of generating new information and were innovative, feasible, and demonstrated technical merit as assessed via rigorous external peer review. After some modifications, the peer-review process settled on the framework in place for NSF proposal reviews. Except for some tumultuous years when funding was delayed or reduced by USAID, most activities were funded on a two-year cycle.

Investigations provide a transparent means for evaluating different types of work under the CRSP, be it quantitative, empirical, biologically-based, qualitative, policy-based, or informal. Each investigation was clearly identified as an experiment, study, or activity, based on the following definitions:

- **Experiment:** addresses a testable hypothesis. An experiment implies collection of new data by controlled manipulation and observation.
- **Study:** may or may not be less technical or rigorous than an experiment and may state a hypothesis if appropriate. Studies include surveys, focus groups, database examinations, most modeling work, and collection of technical data that do not involve controlled manipulation
- **Activity:** requires staff time and possibly materials but does not generate new information like an experiment or a study. Conference organization, training sessions, workshops, outreach, and transformation and dissemination.

We also required that proposals included at least one experiment or study and outreach activities such as training, formal education, extension, and conference organizing to supplement the scientific research being proposed. Each funded investigation after the Ninth

Workplan identified intended beneficiaries, stakeholders, and end-users, and provided metrics.

The Continuation Plan 1996 was based on a strong conceptual foundation that built upon the achievements of the earlier-funded work (Figure 1). Moreover, the Continuation Plan expanded the CRSP's scope beyond the global experiment to meet more fully the original Title XII mandate and realize the vision of the legislation.

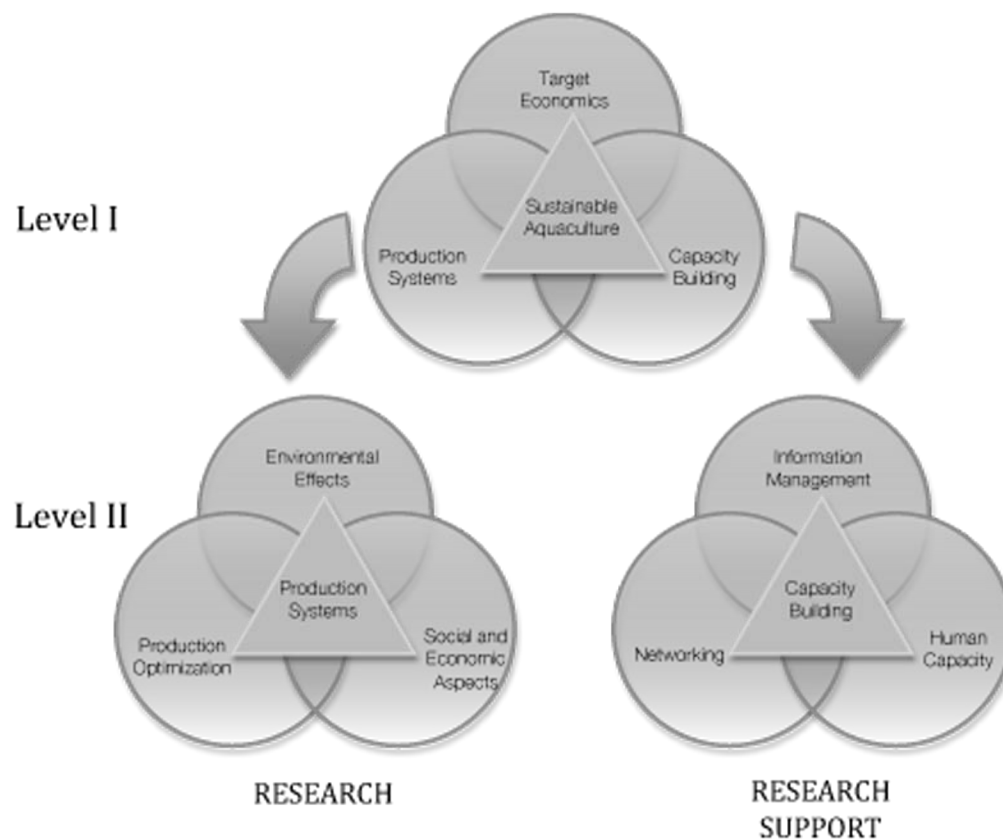


Figure 1. Conceptual framework for the PD/A CRSP as presented in the PD/A CRSP Continuation Plan 1996-2001.

The basis of the Aquaculture CRSP was built on strong themes that have provided the program focus and direction to support sustainable aquaculture research since 1996. The themes were in turn built around two building blocks: research in production systems and capacity building through research support activities (Level I in Figure 1). Production systems research concentrated on specific themes in the areas of production optimization, social and economic aspects, and environmental effects. Research support activities included information management, networking and human capacity development (Level II).

To guide our research program, the Aquaculture CRSP developed RFPs with themes within the program's overall context: sustainable aquaculture development and aquatic resource management in coastal and inland areas. Examples of themes for which we have solicited and funded proposals include:

- **Environmental Impacts Analysis**— Aquaculture's rapid growth has increased concern about environmental impacts. A primary goal of Aquaculture CRSP's research is to determine the scope and how to reduce the effects, for example, of poor management practices and industrial aquaculture.
- **Sustainable Development & Food Security**— Aquaculture is increasing in importance as a source 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 & Integration**— Aquaculture is an agricultural sector with specific input demands. Systems should be designed to improve efficiency and/or integrate aquaculture inputs and outputs with other agricultural and non-agricultural production systems.
- **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 & Availability**— Aquaculture development that makes wise use of natural resources is at the core of the CRSP. Gaining a better understanding of water and aquaculture is a matter of great interest to the Aquaculture CRSP. 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 & Social Analysis**— Aquaculture is a rapidly growing industry; its risks and impacts on society need to be assessed. Significant issues in this arena include cost, price, and risk relationships; domestic market and distribution needs and trends; the relationships between aquaculture and women/underrepresented groups; and the availability of financial resources for small farmers.
- **Applied Technology & 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 & 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, & 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 & Feed Technology**— Ways and methods of increasing the range of available ingredients and improving the technology available to manufacture and deliver feeds is an important theme. Better information about 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 & Human Health Impacts**— Aquaculture can be a crucial source of proteins and micronutrients for improved human health, growth, and development. Conversely, human health can be negatively impacted by aquaculture if it serves as a direct or indirect vector for human diseases. There is also interest in better understanding the interconnectedness of such human health crises as AIDS/HIV and aquaculture production.

Appendix 3 (Volume 2) lists the themes applicable to each Work Plan.

Technology Development

Aquaculture is the fastest growing agricultural sector, and demand for its products continues to exceed production. Particularly in host countries, new and appropriate technologies are needed to enhance productivity, optimize return on investment (ROI) and to mitigate environmental impacts. Aquaculture CRSP achieved a number of significant successes in developing such technologies.

- Collaboration between the Asian Institute of Technology (AIT) and Nepal's Institute of Agriculture and Animal Science (IAAS) resulted in development of fertilization regimes using inexpensive local grass, avoiding use of expensive, and potentially polluting, artificial fertilizers. (See Success Story Box)
- In Nepal, scientists developed protocols for polyculture of carp with other fish species, ensuring optimal use of ponds to maximize harvest yields.
- In Thailand, researchers characterized soil conditions that optimize pond cultivation of catfish, freshwater prawn, carp, and tilapia. These data provided the basis for publication of best practices for optimizing the chemistry of soils on pond bottoms throughout the pond life cycle.
- Research in Thailand conducted as a joint project of Michigan State University and AIT evaluated the ability of clay-like materials to provide more efficient sequestration of nutrients from fertilizer, to stabilize water chemistry in ponds, and to purify pond water effluent for recycled use.
- Development of an algal bioassay test kit for determining pond fertilization requirements. The kit provides simple and specific fertilization recommendations, and is now being used at Asian universities, government agencies, NGOs, and private farms.
- In Mexico, a joint project between Ohio State University and UJAT investigated use of phytochemicals to minimize the cost of producing monosex populations (necessary to maximize yields). Another aim was to prevent the undesirable biological and environmental effects associated with high dosages and prolonged use of the widely used artificial sex reversal hormone, methyltestosterone.

Technologies were disseminated through many means, but one means that CRSP is particularly known for is its scientifically-based and practical manuals. The ME edited, designed, and published many of these manuals, but some were produced solely by the projects. Manuals will continue to be distributed through on-line downloads, and in rare cases, by paper copies available through Host Country researchers and the ME. Appendix 4 (Volume 2) contains a complete listing of these manuals. Examples of featured titles include:

- *Acuacultura Manual de Prácticas*

- *A Manual of Fertilization and Supplemental Feeding Strategies for Small-Scale Nile Tilapia Culture in Ponds*
- *A New Guide to Fish Farming in Kenya*
- *Aquaculture Pond Bottom Soil Quality Management*
- *Best Management Practices for Responsible Aquaculture* (English & Thai versions)
- *Farmers Training in Tanzania* (in Swahili)
- *Field Testing Least-Intensive Aquaculture Techniques on Small-Scale Farms in Thailand*
- *Pond Fertilization: Ecological Approach and Practical Applications*
- *Producción de Tilapia en Fincas Integradas.*
- *Reproducción y Cria de Alevines de Tilapia: Manual Práctico* (Spanish, English, & French versions)
- *Salud, Ambiente y Acuicultura En La Costa Pacifica De Mexico*
- *Sistema De Recirculacion Modular Para Uso Familiar/Multi-Familiar*
- *Reproducción y Cria de Alevines de Tilapia: Manual Práctico* (in Spanish, English & French versions)
- *Tilapia Farm Business Management & Economics: A Training Manual*

A textbook on pond aquaculture (*Dynamics of Pond Aquaculture*) was published by CRC Press in 1997, and has been a unique source of information for researchers and students in the field of aquaculture. That book generated enough interest for publishers to contact the CRSP about writing another book on aquaculture. Researchers in the CRSP wrote well over 300 peer-reviewed articles. Over 25 peer-reviewed publications per year at our funding level since 1996 is considered a high return on investment in the scientific community, not to mention additional returns from high numbers of students and stakeholders receiving quality training.

Some technology development occurred in concert with the web, and provided web-based expert systems for aquaculture and hill slope farming, for example. Two examples include web-based work for Kenya and Honduran watersheds. The *Web-based Information Delivery System for Tilapia*, *WIDeST*, and www.acuacultura.org/ presents information for Spanish and English speakers.

Other technology development successes include achievements ranging from weaning industry off treating tilapia with methyltestosterone to biological improvements in the reproductive capacity of native species such as gar.

Negative environmental impacts from aquaculture operations can affect farm productivity and cause undesired consequences to natural ecosystems through poor effluent management and pollution control. Some examples of CRSP impacts follow:

- ACRSP research in Mexico demonstrated that the masculinizing hormone methyltestosterone (MT) can be eliminated from aquaculture effluents by exposure to solar irradiation or UV sterilizers. Solar irradiation of MT-treated water for a period of two days resulted in approximately 50% elimination of the compound. Intense treatment of the water with a UV sterilizer resulted in 100% elimination of MT over a two-day period. The Aquaculture CRSP was also instrumental in developing protocols for sex-reversal in Nile tilapia aquaculture. However, chemicals used in this procedure were observed in the pond water for up to 8-weeks following treatment. The Aquaculture CRSP responded by pioneering the use of activated charcoal filters incorporated in an intensive recirculating aquaculture system that successfully eliminated excess MT in the application water while maintaining the effectiveness of MT to sex-reverse tilapia for grow-out. Adoption of this novel technology will ensure sustainable industry practices and maintain environmental integrity.
- Results from GIS research in Vietnam have removed planning constraints previously associated with time consuming and costly land assessment on the ground. For example, application of advanced GIS technologies and data sets have demonstrated that over 85% of

the available land in Vietnam is suitable for pond construction. GIS methods have universal relevance and may be applied to other global regions experiencing similar constraints to aquaculture development.

- Aquaculture CRSP techniques are frequently integrated into local Best Management Practices that in turn ensure producers comply with local regulations, act as environmental stewards, and are accepted by environmental NGOs, thereby opening new markets for their products.
- Responsible aquaculture practices attempt to avoid non-native species introduction in order to eliminate possible invasions and possible exposure of parasites and diseases. ACRSP research in Mexico showed that the native longnose gar (*L. osseus*), the North American species, can be used as a surrogate species for tropical gar *Atractosteus tropicus*. Culture of tropical gar are gaining international interest in Central America, particularly in the states of Tabasco and Cancun, Mexico.
- Efficient aquaculture systems require the understanding and control of complex interactions between water quality, fish biology, and health management. Many global aquaculture sectors do not have a complete understanding of pond nutrient use, pond dynamics, species reproductive biology and physiology, and fingerling production strategies. Some examples of CRSP impacts follow:
- Feed and fertilizers research results provide fish farmers tools to increase profitability by decreasing costs while maintaining or increasing fish growth. As an example, delayed feeding trials in the Philippines proved that supplemental feeding may be delayed by 75 days and yield comparable production to ponds having immediate supplemental feeding. Delayed feeding reduced farm management and feed costs by about \$400/hectare, which translated into a 17% increase in the net value of the crop. Farmers in the Philippines immediately adopted this method, and it has since been conveyed to researchers and adopted by farmers in other nations throughout the Aquaculture CRSP network.
- The Aquaculture CRSP has invested substantially in native species development during the grant period as a means to raise locally accepted species and greatly diminish threats to native fish populations by avoiding introduction of exotic species to delicate natural ecosystems. Researchers have collaborated with colleagues in Peru to refine hatchery and grow-out protocols for gamitana *Piaractus brachipomus* and paco *Colossoma macropomum*. These studies have significantly impacted local farmers who can now produce fish at lower costs with a faster growth rate and greater survival.
- Aquaculture CRSP researchers developed the POND® computer program to guide decision-making processes relevant to warmwater pond aquaculture. POND provides educators, extension agents, managers, planners, and researchers with a tool to rapidly analyze aquaculture systems under different management regimes and assist in the development of optimal management strategies. Thousands of users from all major Aquaculture CRSP regions have accessed The POND website and downloaded the software to date.
- Aquaculture CRSP research has focused on the characterization of pond bottom soils to ensure the implementation of appropriate pond management plans that optimize fish grow-out while reducing the potential for deleterious environmental impacts. This research culminated in a 41-page manual covering all aspects of pond soil management, from initial construction to ongoing care of soils in mature pond systems. The manual is one of the most popular Aquaculture CRSP publications, with wide dissemination to farmers and extension specialists throughout the United States and the global pond aquaculture community.

Additional pond bottom research has since concluded that annual application of lime to pond soils is unnecessary, thereby greatly reducing aquaculture production and labor costs.

EDUCATION AND TRAINING

Aquaculture CRSP projects encompass the spectrum of basic and applied research to dissemination of aquaculture information. In particular, we emphasized education as part and parcel of our research work. We also took seriously the mandate to extend our technologies to an appropriate source, and almost every project engaged in outreach through non-degree training. We funded undergraduate and graduate students and offered practical workshops, seminars and lectures on best practices for farmers.

To ensure the training of future generations, the Aquaculture CRSP placed great emphasis on supporting students. There were several ways we did this. First, we favored funding researchers who included graduate and undergraduate students in their proposals. Second, we featured student successes in publications such as *Aquanews*, which were distributed to program participants and other stakeholders. We also employed several students at the ME office at Oregon State University, thus providing opportunities to learn general administrative skills that would help us meet our goals.

Besides supporting student research directly, the Aquaculture CRSP looked to motivate and inspire students. By honoring research accomplishments, the Aquaculture CRSP is speaking on behalf of its distinguished researchers to reward and encourage exemplary students who will become the next generation of scientists. For example, in conjunction with the 2004 World Aquaculture Society meeting, the Aquaculture CRSP sponsored a series of awards, including six student pre-conference awards, and one first place and two second place Student Poster Awards.

We also supported travel for students to attend conferences. In many cases, we provided these students their first opportunity to participate in the vital scientific activity of presenting research results. For some, it was the first time they had traveled internationally. Such training under the auspices of the CRSP has created a cadre of well-rounded aquaculture researchers who are able to conduct world-class research at a global level. Just as importantly, these scientists learned how to report their accomplishments to the wider scientific community.

As part of our mandate to our PIs, we supported and encouraged them to expose students to aquaculture research. Many presentations reported during the funding period mention students among their audiences. This outreach to the next generation leverages our organization's knowledge equity, by ensuring that students are inspired to take up aquaculture research or careers related to aquaculture.

Events that included university students among the participants, also tended to include government fishery officers, researchers, university teachers. These students were exposed not just to informative and useful research but also to scientific discourse, which is an essential part of any scientist's training.

We have even included high school students as part of this outreach, to the point where, for example, Kevin Fitzsimmons (a former chair of the Aquaculture CRSP's Technical Committee) presented a paper to Aquaculture America '99 (Tampa, Florida), entitled "*High school students and aquaculture projects.*" Our outreach program for aquaculture producers in the Peruvian Amazon included 52 high school students from Instituto Superior Pedagógico Público de Loreto, and another 44 high schoolers from the Instituto Superior Tecnológico Pedro A. Del Aguila Hidalgo. In another example from our Amazon Outreach program, two CRSP-funded

extensionists provided aquaculture training to 777 vocational, high school, and university students in the Amazon Basin.

Since 1996, the Aquaculture CRSP has trained over 4500 farmers, non-governmental organization workers, government extension agents, and university representatives through short-term, informal training sessions. These workshops are closely linked with Aquaculture to local stakeholders for potential on-farm adoption. Workshop topics vary greatly and include pond construction and management, clean water technologies, farm business plan development, and best management practice development, to name a few.

Multi-Lingual Workshops Enhance Pond Design in Central America

*by Ernest W. Tollner (University of Georgia)♦Joseph Molnar & Patricio Paz (Auburn University)♦
Dan & Suyapa Meyer (Escuela Agrícola Panamericana University)*

Efforts to enhance aquaculture productivity in Central America have focused on developing and providing courses that teach optimal design of aquaculture ponds. These courses are becoming so popular that a number of universities are providing at no cost computer lab facilities for teaching the courses.

Lectures during the courses were given in English, being simultaneously translated and supplemented with handouts in Spanish—a method that met with considerable success. To further supplement the lectures, workshop participants were given a CD in both English and Spanish that contained all handouts and pond design models. Another effective approach was to coordinate activities of Escuela Agrícola Panamericana University alumni chapters in Honduras and Panama who helped with workshop scheduling and organization.

Workshop audiences have included a mix of faculty members, students and consulting architects and engineers. The president of the Panamanian chapter of the American Institute of Architects recently attended a workshop in Panama.

The course features a field practicum that provides excellent teaching points. Workshop participants are presented best practices by being shown examples of a water delivery canal system, well-constructed pond side slopes, and appropriate soil sealing techniques. Conversely, they also learn from pond design mistakes such as poorly constructed spillways, failure of the main catchment reservoir dam failure, and the consequences of poor soil sealing techniques.

In order to establish infrastructure and an independent research and production base, Aquaculture CRSP programs emphasized education of Host Country personnel. We undertook two main approaches:

student support and farmer outreach.

We supported students who were on track to graduate with scientific or technical expertise in aquaculture. We also undertook a solid program of training in fish production, sampling techniques, computer use, economics, and marketing. The number of farmers, scientists, and agency personnel worldwide who have received CRSP training now exceeds 2,400. These personnel represent over 10 countries.

In many instances this support was integrated with funding for other research, such as technological development, thus optimizing the return on funding. Our farmer outreach training had the express purpose of directly improving farmers' knowledge about aquaculture best practices. As a complex enterprise, aquaculture cannot be "taught" in one or two courses. Therefore, we identified specific needs in host countries and tailored outreach and training to meet these needs. In particular, we focused on "training the trainer" to foster host country independence from ongoing need for training expertise.

For example, for the past 10 years Ponciano Cruz has advised fish farmers throughout Honduras. Courses and training on tilapia culture at Escuela Agrícola Panamericana, Zamorano sponsored by the Aquaculture CRSP prepared and motivated him to specialize in fish culture extension. In turn, Mr. Cruz has organized and conducted more than 20 training events with beginner and advanced fish farmers. His classes include topics such as pond construction, stocking and harvesting fish, water quality, and processing and marketing of tilapia locally. Much of the information presented during classes was derived from Aquaculture CRSP research and extension publications sponsored by the Aquaculture CRSP.

SUCCESS STORY

Nepal's Institute of Agriculture and Animal Sciences Builds Capacity for Aquaculture

by Madhav K. Shrestha(IAAS), Yang Yi (AIT) & James S. Diana (University of Michigan)*

The Institute of Agriculture and Animal Science (IAAS) in central Nepal is the only institution in the country that provides postgraduate training in agriculture and animal sciences. In 1999, the Aquaculture Department started its master's program with only one student. Back then, IAAS had limited laboratory and field facilities, restricting its capacity to graduate additional students. Due to the funding of various projects by the Aquaculture CRSP, we have since graduated about 90 additional master students, around 15 per year.

Aquaculture CRSP extended its regional sites from Southeast Asia to South Asia, enabling IAAS to partner with the Aquaculture CRSP in 2001. The partnership was facilitated through the Asian Institute of Technology (AIT), a regional institution.

Since 2001, IAAS has completed four research projects:

- (1) combining two species, (called polyculture) grass carp and Nile tilapia in pond aquaculture with a readily available, inexpensive local grass to provide supplemental feeding, avoiding use of expensive and potentially polluting artificial fertilizers
- (2) trials of sahar fish and carp species in an integrated "cage-cum-pond" environment, conducted at the IAAS research station
- (3) similarly integrated trials of catfish and carp, in research station and farm environments
- (4) investigating the impact of introducing tilapia on indigenous Nepalese fish species.

Through the support of the Aquaculture CRSP, such research projects helped to establish a fully-equipped

aquaculture laboratory. Fish culture facilities were also built to accommodate the experiments, including conversion of six concrete ponds to 18 smaller tanks and construction of 29 earthen ponds and connecting drainage canals.

In terms of infrastructure, the research facility was fenced with barbed wire and concrete poles, and provided an electric supply.

Aquaculture CSRP travel grants to Dr. Shrestha K. Madhav (as Host Country PI, Department Head and IAAS Director of Research) enabled him to participate in national and international seminars, conferences, and workshops. Following these visits Dr. Madhav conveyed his knowledge to Aquaculture Department faculty.

In addition to travel grants, Aquaculture CRSP has helped fund thesis research of masters students. Dr. Shrestha himself was partially supported by Aquaculture CRSP for his masters and doctoral studies. Aquaculture CRSP contributed to another students completing his MSc program in 1999, whereas another who completed her MSc in 1997 is now in the third year of her Ph.D.

In this way, Aquaculture CRSP support has been leveraged to provide unique opportunities to Host Country researchers and students. Thus, Aquaculture CRSP has been instrumental to the success of the Aquaculture Department at IAAS. Aquaculture CRSP has helped the Department build capacity for research, establishing research facilities, and ultimately in to provide quality education at IAAS. Such support is crucial to IAAS and ultimately benefits the Nepalese people, environment and economy.

**now at Shanghai Ocean University*

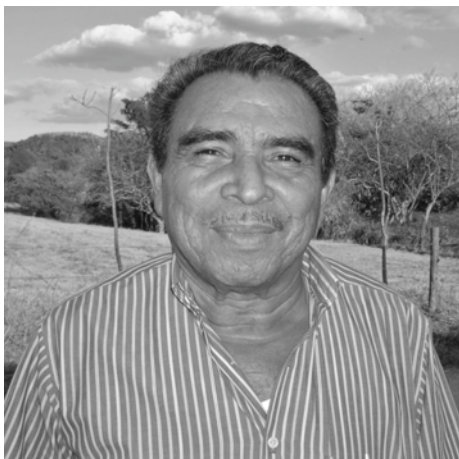
ENGAGING STAKEHOLDERS AND END-USERS

Economic inequity has long been recognized as a driver of poverty. In particular, progress has been made in other spheres of economic activity when gender parity has been achieved—that is, ensuring that men and women have equal access to economic opportunities. Aquaculture CRSP has focused on introducing this approach to aquaculture. For example, a number of our projects have outreach and education programs for women's groups, such as Escuela Agrícola Panamericana in Honduras and at Sagana, Kenya. Several early publications testify to Aquaculture CRSPs pioneering efforts to improve the role of women in aquaculture, particularly in Rwanda.

Success Story

◆
Ponciano Cruz

Training the trainer: fish culture extension in Honduras



Rather than an exhaustive account of the Honduras Aquaculture CRSP project, we focus here on the impact of Aquaculture CRSP support on one individual, Ponciano Cruz. Mr. Cruz was born in Sabana Grande in southern Honduras. His education is in technical agriculture. He has worked as an extension agent for the Honduran Institute of Professional Formation (INFOP) for 26 years. For the past 10 years his extension work with INFOP has focused on tilapia culture.

During this time Mr. Cruz has provided technical assistance to fish farmers throughout Honduras. He participated in several important training events on tilapia culture and reproduction and rearing of tilapia fry and fingerlings. These courses, sponsored by the Aquaculture CRSP and offered by Zamorano [Escuela Agrícola Panamericana], have adequately prepared and motivated him to specialize in fish culture extension at INFOP.

He has organized and conducted more than 20 training events with beginner and advanced fish farmers during the past several years in many parts of Honduras. These classes include topics such as pond construction,

stocking and harvesting fish, water quality, and processing and marketing of tilapia locally. Much of the information for teaching these events was derived from Aquaculture CRSP research and extension publications sponsored by the Aquaculture CRSP.

He has provided training on tilapia reproduction to many farmers and has helped establish five new fingerling producers in Honduras. The fingerlings these farmers produce are used for stocking their own ponds and/or are sold to other farmers. These local sources of tilapia seed help to resolve the difficult problem that many rural fish farmers face of finding fingerlings for stocking in many parts of Honduras.

He typically provides technical assistance to 200-300 fish farmers each year. He advises these farmers on all aspects of fish farming, including managing the ponds and fertilization.

He was invited by the CRSP to attend the "Workshop on Aquaculture Extension" held in Matzatlan, Mexico in June of 2004. At the workshop, he met extension agents from several Mexican states and neighboring countries. He also made a presentation on aquaculture extension in Honduras.

As Mr. Cruz said in his own words, "I would like to thank the Aquaculture CRSP and the Escuela Agrícola Panamericana for their support and for providing me with the technical knowledge and practical experience related to successful tilapia culture. I have tried to be an ally of the Aquaculture CRSP by disseminating useful knowledge and skills to Honduran farmers to contribute low-cost protein to their diets and added income for rural families."

Status update: Mr. Cruz retired from his extension position and is now working as a private technical consultant for tilapia farms in Honduras.

Success Story



Narayan P. Pandit Engaging Key End-User Groups

Nepal is a name that conjures up images of snow-covered peaks and tough mountaineers. But Nepal native Narayan P. Pandit had a different vision. His aim was to see Nepal's aquaculture realize its potential to become a major contributor to the country's food supply. With the help of the Aquaculture CRSP, he is on his way to making this a reality. For ten months from March 2002, he was supported by the Aquaculture CRSP under the tutelage of Madhav Shrestha, an Aquaculture CRSP Host Country Principal Investigator, also from Nepal.

Growing up in a farmer's family, the seeds of Pandit's interest were sown during his childhood. These formative years inspired his interest in agriculture, so in November 1993 he decided to attend the Institute of Agriculture and Animal Science (IAAS) located near the town of Chitwan in southcentral Nepal. He completed his bachelor's degree in agriculture at IAAS in 2002, and was inspired by Shrestha to study for his master's degree in aquaculture.

Pandit's interest in aquaculture derives from his love of the natural environment and establishing a strong aquaculture sector in Nepal include lack of skilled personnel and

awareness of both the limitations and potential for the industry in his country. Obstacles to appropriate research, inefficient resource management, and an inadequate marketing infrastructure, says Pandit. On the plus side, he recognizes that the country's "vast water resources and diversified geographical conditions" are ideal to culture a wide range of fish species. Marginal swampland and irrigated paddy fields offer particular promise to integrate aquaculture into the Nepalese economy.

Pandit wants to help his country overcome the problems. To this end, his CRSP-supported work was on a master's project: "Women in Aquaculture in Nepal." This was aimed at increasing the involvement of Nepalese women in aquaculture. Specific goals included enabling women to raise fish as well as engage in normal household activities and to provide a supplemental food source and income. In all, 82 small ponds (100 to 200 m²) were built adjacent to family houses, where women took responsibility for the pond and were trained in aquaculture.

Pandit received his MS degree from IAAS in 2004.

RESOURCE CONSERVATION

Much of the world's increasing demand for fish will be met by aquaculture. But aquaculture has an unavoidable environmental impact. In the past, some practices have led to criticism of the industry, creating a need for new approaches to resource conservation and impact mitigation. Aquaculture CRSP has led the way in such research, as the following example illustrates.

In our Thailand project, research data was published as best management practices for optimizing the chemistry of pond soils throughout the pond life cycle. By implementing these BMPs, farmers lessen negative environmental impacts caused by suspended solids in pond effluents and off-site disposal of pond sediment.

RESOURCE CONSERVATION SUCCESS STORY



Creating Connections: Research and Workshops in Brazil and Thailand

by Claude Boyd (Auburn University)

Significant advances in aquaculture practices are achieved when scientists' research findings are effectively conveyed to farmers in the field. Part of our approach to improving aquaculture outcomes in Brazil and Thailand was to emphasize effective communication of best management practices (BMPs) derived from scientific research to farmers. Tying in with this was a perspective based on limiting the negative impact of aquaculture in environmentally sensitive areas of these countries.

Helping Brazil prevent and mitigate environmental impacts of aquaculture

In Brazil, a two-day workshop, "Development of Best Management Practices for Aquaculture" was held in March 2006 at the State University of São Paulo's Superior School of Agriculture. The forty attendees included technicians, environmental professionals, researchers, university professors, extension agents, government technicians, aquaculture producers, and feed manufacturers.

Discussions covered technical, legal, and conjectural aspects of aquaculture and how these related to the environment. In particular, attendees were concerned with how aquaculture science via BMPs could inform farmers on how to prevent or mitigate aquaculture impacts.

Following the workshop, the Host Country PI, Dr. Julio Queiroz, received numerous requests for BMPs information to improve water and bottom soil quality of aquacultural ponds in São Paulo State and other regions. To meet these requests Dr. Queiroz, has set up stakeholder groups to develop such BMPs for Sao Paulo State.

Following the publicity from the first workshop, Dr. Queiroz found support for a second Aquaculture CRSP BMPs workshop, held at Manaus in May 2007. More than 100 participants [CHECK] attended the workshop.

Dr. Queiroz works for EMBRAPA Environment. This organization has many programs related to improving the environmental performance of agriculture in Brazil. As a direct result of Dr. Queiroz's participation in the Aquaculture CRSP, EMBRAPA's effort now includes an aquaculture environmental impact project.

Students and farmers benefit from aquaculture research in Thailand

In Thailand, Aquaculture CRSP has funded research to acquire important information on soil conditions that optimize pond cultivation of *Clarias* catfish, freshwater prawn, carp, and tilapia. Two students conducted much of the research, which led to their Ph.D. dissertations. Dr. Taworn Thunjai, is now employed in the Department of Fisheries and Dr. Idsariya Wudtisin, is at the Faculty of Fisheries in Kasetsart University. In addition to the dissertations, research data were published as BMPs for optimizing the chemistry of soils on pond bottoms throughout the pond life cycle. By implementing these BMPs, farmers increase pond service life. Moreover, they lessen negative environmental impacts caused by suspended solids in pond effluents and off-site disposal of pond sediment.

To disseminate the findings to university researchers, extension workers, and other professionals an initial workshop was held. To ensure the information was conveyed to fish farmers, two more workshops were held late March and early April 2007. To facilitate their use by farmers, the BMPs were translated into the Thai language.

The BMP manual (English and Thai versions) is available for download from the ACRSP website.

WORKING WITH PARTNERS

Throughout our program, the Aquaculture CRSP has worked with partners to share expertise, engage stakeholders and to obtain matching or supplementary funds. We have developed and maintained links among universities and government ministries, departments of agriculture, and the private sector around the world. Appendix 5 lists several hundred linkages developed over the lifetime of the program.

For example, as a result of partnerships between Cornell University and the UJAT, our Mexico project conceived and inaugurated the Center for Aquaculture Technological Transfer (CETRA; see Working With Partners Success Story). The project integrated scientists and extension workers from three countries: Mexico, Chile and the US, while CETRA's board comprises representatives from academia, government, and private enterprise. Other partnerships have also evolved from CETRA:

- Working with the Instituto Tecnológico del Mar to design a small-scale family farm unit based upon recirculating aquaculture principles.
- Acquiring funding from the Puebla State Government to purchase the recirculating aquaculture package for its rural development program, thereby providing continuing support for CETRA.

Numerous other examples illustrate the Aquaculture CRSP's emphasis on building partnerships and nurturing supportive research networks. Here are a few case studies:

- In Bangladesh, Aquaculture CRSP scientists from AIT and Bangladesh Agricultural University (BAU) worked with three NGOs to determine optimal pond fertilization regimes and the most effective methods of disseminating knowledge about such regimes.
- Organized by US and Mexican scientists from the Aquaculture CRSP, the Seventh International Symposium on Tilapia in Aquaculture (ISTA 7) was held in September 2007 at Veracruz, Mexico, with 971 attendees. Symposium events included:
 - science workshops
 - a trade show
 - technical presentations
 - farm tours
 - a dinner featuring tilapia recipes.
- Hosted by the State Government of Veracruz, the Governor, Fidel Herrera Beltran, gave the opening address. Over two and a half days, science sessions included tilapia reproduction and genetics, pathology, nutrition, production systems, and processing and markets.
- In Ghana, the Aquaculture CRSP facilitated interactions and networking among a variety of pond farming stakeholders. The forum brought together the Ministry of Food and Agriculture, the Department of Fisheries, extension officers, university faculty and scientists, and farmers to establish a common understanding of issues facing fish farmers.
- In Panama, a workshop series involving scientists from the University of Georgia, Auburn University, and Escuela Agrícola Panamericana, Zamorano included in its audience a mix of faculty members, students, and consulting architects and engineers. The president of the Panamanian chapter of the American Institute of Architects recently attended one of these events.
- In Kenya, refurbishment of existing facilities has led to the emergence of two nationally recognized aquaculture research centers: Sagana Aquaculture Center and Moi University Fish Farm. Essential to meeting the challenges were collaborative efforts between two US institutions (Oregon State University, Auburn University) and two Kenyan institutions (Department of Fisheries, Moi University).

SUCCESS STORY**Aquaculture Network for Africa (ANAF)***by Dr. Sloans K. Chimatiro**(excerpted from Aquanews)*

The New Partnership for Africa's Development (NEPAD) recognizes the vital contributions by the African fish sector to food security and income of many millions of Africans, to poverty reduction, and economic development in the continent. It further recognizes the growing opportunities and emerging successes of aquaculture development in the region. Within the framework of the Comprehensive Africa Agriculture Development Program (CAADP), the NEPAD Action Plan for the Development of African Fisheries and Aquaculture, which was endorsed by African Heads of States and Government during the Abuja "NEPAD Fish For All" summit in 2005, provides the framework for channelling investments to safeguard and further increase these benefits.

Critical to achieving the goals of the Action plan is the need for major investments to build capacity in African institutions for planning, research and technology transfer through a strengthened network of training and research facilities around the continent. Therefore, in support of the NEPAD' Pan- African vision, FAO has put in place the Aquaculture Network for Africa (ANAF) as a vehicle with which to create new knowledge-based institutions. The AquaFish CRSP has provided support for and collaborates in the development of the Aquaculture Network for Africa (ANAF). The CRSP provided funds to equip ANAF with computers and provide connectivity among ANAF partners, an element that will be essential to the success of the program.

SUCCESS STORY

Researchers Examine Effects of Live Haul on Tilapia: Return Benefits to US Aquaculture under Title XII

(excerpted from Aquanews)

During typical live-haul of tilapia from farms in Idaho to Oregon, Washington, British Columbia, and California markets, fish undergo loading, transport (often up to 18 hours), and unloading before distribution to markets, which in turn may involve repeating these three steps. Stressors exist in each phase of the live-haul process, generating a physiological response that may negatively impact the health and survival of affected fish, and ultimately the quality of product.

With funding from the Western Regional Aquaculture Center of the US Department of Agriculture (Cooperative State Research, Education and Extension Service), researchers at Oregon State University, the National Marine Fisheries Service, and the University of Idaho, in collaboration with scientific and industrial advisors are investigating the physiological and physical effects that live-haul procedures have on tilapia in the Pacific Northwestern United States.

The four-year project began in 2005 with project leaders outlining objectives centered on identification of current holding and long-haul procedures, in addition to critical steps and factors affecting fish health and survival. Further objectives included the development of computer models predicting water quality and fish response in hauling systems, hauling criteria and protocols designed to optimize fish physiological response and flesh quality, and outreach products designed to inform and assist live-haulers. The research team has currently fulfilled several goals, having identified common loading and transport

practices and associated risks to fish health and survival, with cooperation from transport companies and retailers.

Vibrations, poor water quality, parasites and infectious pathogens, chemicals, and temperature fluctuations are all stressors that may result in negative physiological responses in transported tilapia. Crowding is a large concern during live-haul, when fish are at risk of physically damaging themselves and others as they are netted or contained prior to and during transport processes. Carl Schreck (an Aquaculture CRSP PI) and his team at OSU have conducted experiments examining the physical effects of netting on tilapia at their CRSP-supported fish research facility.

Their hypothesis is that fish are punctured and abraded during netting (exacerbated by concurrent crowding), resulting in physical damage (lost scales and hemorrhaging) and increased susceptibility to disease. Histological analysis appears to confirm punctures in skin and deeper tissues, tears in connective tissue, and edema and bacterial infections within muscle tissue. Aesthetically unpleasing or deceased fish are filleted, although fillets fetch a much lower market price than whole, healthy fish.

Schreck has also worked with members of the project team to demonstrate the ability of a pre-haul Instant Ocean® salt dip to give the fish anti-parasitic and osmotic advantages, delaying mortalities up to two days when compared to control fish.

WORKING WITH PARTNERS SUCCESS STORY

Creating an Outreach Center for Aquaculture Technology Transfer in Mexico

*by Dale Baker & Michael Timmons (Cornell University) &
Dr. Eunice Perez Sanchez (Universidad Juárez Autónoma de Tabasco)*

During the lifetime of the Aquaculture CRSP, program PIs identified a major need for a systematic process to transfer aquaculture technology from lab to farm. Great science is impotent when it goes unused by the people whose lives it is meant to improve.

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

Mexico was selected to pilot the concept of a center for aquaculture technology transfer. As a basis for the center's organization and management, the project PIs used the US Land Grant model coupled with the US Sea Grant extension model.

The project leaders identified three key deliverables:

1. Establish a center for aquaculture technology transfer
2. Conduct a series of workshops on recirculating aquaculture system technology, and
3. Develop a module design appropriate for a small family farm to raise tilapia

All deliverables were met. The Center for Aquaculture Technological Transfer (CETRA) was successfully launched. One of the major achievements in establishing CETRA is that the project integrated scientists and

extension workers from three countries: Mexico, Chile and the US.

The project also resulted in a board for CETRA. The board includes the academic and government communities while three board seats are reserved for private companies. The mix of academic, government, and private sector on the CETRA board is intended to ensure that a realistic balance of activities is undertaken.

The board selected one of the project co-PI's to assume the role of permanent director of CETRA, reporting directly to the Board. The director's responsibility is to implement the vision of the center and to achieve specific milestones defined by the board.

Soon after its inception, CETRA achieved significant milestones. CETRA personnel organized and conducted a series of four workshops in Mexico from December 2006 to September 2007. The inaugural workshop in December 2006 on recirculating aquaculture technologies had 240 people attend for the day. Another three-day workshop in September 2007 was attended by 135 paid registrants. All attendees rated the workshop a success. This workshop was held immediately before the international workshop of tilapia (ISTA 7). The workshop was co-sponsored by Panorama Acuicola (Salvador Meza). Smaller attendances at two of the workshops, around 20 people, allowed more individual attention to the attendees.

Another significant milestone was meeting a third deliverable—developing the design of a small-scale family farm unit based upon recirculating aquaculture principles. This effort was a Master of Science project. Project Leader Margarita Cervantes Trujano, Instituto Tecnológico del Mar, Veracruz supervised the research, conducted by graduate student Ana Gabriela Trasviña-Moreno. For a proof-of-concept field test, the design was implemented on a small farm in Alvarado, Veracruz. Further, the Puebla State Government agreed to purchase the technological package for its rural development program. These funds will be used to partially support the continuation of CETRA.

This program created a foundation for sustained success for aquaculture outreach in Mexico. It concluded with a successful first outreach effort that created an additional family farm unit producing tilapia for self consumption and local markets.



IV. RESEARCH SUPPORT: PROGRAM-WIDE ACTIVITIES

PARTNERED PROJECTS

Partnered projects are at the heart of the Aquaculture CRSP. They are the C of “collaboration” and in many ways, represent the best of the program. Indeed, practically all our projects needed partnerships in one form or another. We cannot cover them all. Here we illustrate a few of our partnerships that benefitted our program and exemplified the goals and vision of the CRSP.

HC PI Exchange Program

With the Aquaculture CRSP’s support of sustainable aquaculture development around the world, the knowledge base and institutional capacities of Host Countries have grown. Thus, it is increasingly important to share research results and extension methods among workers at locations continents apart. To fulfill this need, the Host Country PI Exchange Project shared the program’s combined recommendations among host country researchers.

In mid-2005, Aquaculture CRSP Host Country Principal Investigators (HCPIs) from Honduras, Kenya, Mexico, the Philippines, and Thailand initiated five site visits and workshops. The aim was to exchange information about tilapia. The activities exchanged technologies that are widely practiced, as well as encouraged researchers to consider those that have not been adopted in their countries.

At each site, the host PI organized a seminar to share and compare tilapia culture information. Presentations made by the visiting PIs described current institutional capabilities, research goals, and aquacultural practices in their home countries. The audience included research colleagues and staff, local farmers, industry and NGO professionals, and students. The collaborators’ aim was to learn about aquaculture research and outreach in other countries. They could then compare what they learned with their own efforts back home. The investigators saw the accomplishments of diverse approaches to aquaculture, as well as challenges that they share. The group found many instances of Aquaculture CRSP research spreading to research and to the field. They also observed the success of technologies developed through synergies with Aquaculture CRSP affiliates in host countries.

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

To prepare for the visits, the PIs surveyed themselves to gather information for comparing the technologies in the represented countries. This information was verified through individual interviews with the participants during the site visits.

Deliverables from this project included a “best practices” report, gleaned from the presentations and observations made in each country, a compendium of the materials presented 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 was completed within a specific period of time, the interest it sparked continues. The participants fostered relationships that have opened new

doors, and facilitated information exchange. It is hoped that this exchange will encourage them to continue to work together in the future. As host country institutions build their own international networks, this lasting impact of the Aquaculture CRSP will ensure support from a global community for aquaculture and food security.

International Sea Grant/NOAA

The International Sea Grant/NOAA project matches Aquaculture CRSP Host Country needs for technical assistance with institutional Sea Grant extension services.

The National Sea Grant College Program (NSGCP) comprises a network of 32 university-based programs. The network conducts scientific research, education, training, and extension projects to foster science-based decisions about the use and conservation of US aquatic resources.

The Aquaculture CRSP partnership with the NSGCP couples Sea Grant extension specialists with Aquaculture CRSP Host Country Principal Investigators (PIs) to address international technical assistance needs. The combined efforts of these two programs provides significant synergies.

Technical assistance needs for the Aquaculture CRSP's 24 Host Countries were requested from key collaborators in each country. Technical assistance was needed in categories such as watershed management, environment, new species development, food safety, new systems design or engineering, nutrition, harvesting, outreach, and marketing.

Extension specialists submitted a curriculum vita and completed an online application form developed by the CRSP. Requested information included areas of technical expertise, international work experience, language skills, relationship to Sea Grant, and the desired role in international technical assistance extension. Following the Host Country needs assessment and review of applications, appropriate matchmaking was conducted to ensure that needs were addressed through effective extension services.

This initiative resulted in meaningful benefits. For the Aquaculture CRSP, technical assistance needs identified by Host Country PIs are met. In turn, Sea Grant built 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.

Heifer Project and the Indigenous Environmental Network

This jointly funded project with Heifer International engaged new communities in the Aquaculture CRSP enterprise. Aquaculture CRSP and the Indigenous Environmental Network, through funding from Heifer International, Inc., completed a novel project to involve Native Americans from the North (US and Canada) and Native Americans from the South (Mexico and Peru) in consultations about the governance of natural resources; linkages between aquaculture, health, and income generation; and aquatic resources management. The Aquaculture CRSP Management Entity at OSU secured funding for this concept, and after much background work, the project held the last exchange in Mexico in March 2007. Reports, photos, and participant feedback on the exchange are available from the Aquaculture CRSP website.

Over two years (2005-2007), the Eagle-Condor Exchange Project brought together North American Indian (Eagle) delegates to share information with their Condor counterparts in Peru and Mexico (Condor). These cultural exchanges centered on the water world with an emphasis on aquaculture and interrelated aquatic resource use. Oregon State University involved its Mexico and Peru partners along with their respective US university links, University of Arizona and SIUC. Heifer International involved the Indigenous Environmental Network (IEN), Indigenous Aquaculture Network (IAN), and Heifer's international field offices.

The benefits of these two exchanges exceeded expectations. In particular, the exchanges strengthened traditional knowledge and practices in relation to the water world and aquatic resource use.

Many isolated indigenous groups face encroachment on traditional resources, threatening sustainability of food, livelihoods, and communities. Key issues and common experiences that emerged demonstrated the interrelatedness of fish, fields, and forests.

A strong momentum has emerged among participants and the supporting international organizations. The Indigenous Aquaculture Network continues to develop its vision and approach to revitalizing relations to the water world by applying Indigenous Knowledge and Practice. The Eagle-Condor Exchange brought together these components, emphasizing the need for sustainable economic development combined with traditional cultural practices.

Thus our partnership formulated strategies that address and eliminate constraints to aquaculture development specifically in the context of Indigenous Peoples. This collaborative work is intended to serve as a future link to other indigenous and non-indigenous organizations that work with aquaculture.

Offshore Aquaculture

Several years before the US Department of Commerce through NOAA announced plans for offshore aquaculture development in the open ocean (Exclusive Economic Zone) CRSP realized that the tides were turning. The highlight of NOAA's recent aquaculture efforts culminated in the introduction of the National Offshore Aquaculture Act of 2007. 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 Host Countries. Aquaculture in inland environments is affected by the overall seafood marketplace, and emerging themes need to be understood to allow for adjustments to the CRSP's research agenda. The Aquaculture CRSP 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.

USAID SUCCESS Project

The Aquaculture CRSP reached out to assist USAID's new SUCCESS Project (Sustainable Communities and Ecosystems).

Aquanews—Aquaculture CRSP's flagship publication—highlighted SUCCESS work being undertaken by researchers working for both Aquaculture CRSP and SUCCESS:

- Aquaculture CRSP advertised and supported a trainee to the first SUCCESS training in Tanzania in July 2005: East African Training Program in Mariculture Extension.
- Aquaculture CRSP connectivity to the SUCCESS Project was further strengthened by the involvement in the new Tsunami project by long-time Aquaculture CRSP Host Country Principal Investigator, Amrit Bart, who served as the Tsunami Project Chief of Party.
- Aquaculture CRSP Ambassador challenge funds are available to promote synergies between the two USAID programs.
- SUCCESS researcher Maria Haws is also a CRSP researcher. Maria brings the two USAID programs together by dovetailing her work, mostly recently with Gustavo Rodriquez Chame's investigations in Ecuador.

InterCRSP

InterCRSP natural resource management (NRM) program in West Africa included members of West African agencies and CRSPs in planning workshops in Africa and the US. Joint workshops were held in Niamey, Niger, and Bamako, Mali. The concept for an InterCRSP Program drew on the idea that host countries and CRSP participants alike can benefit by pooling experiences and applicable technologies developed by the CRSPs and elsewhere into a common well.

The role of CRSPs was to provide leadership and technical expertise in setting up additional integrated projects in the region. The Soil Management, Peanut and Sorghum/Millet (INTSORMIL) CRSPs operated an InterCRSP pilot project located near Niamey, Niger, at the site of an earlier project undertaken by Niger's National Institute for Agronomic Research and the Soil Management CRSP.

West African country representatives were enthusiastic about both the pilot project and the InterCRSP NRM concept. Not all CRSPs were involved in each project – rather, the projects included those CRSPs (and the appropriate national counterparts in West Africa) whose expertise was suited to the agro-ecosystem in question. ACRSP participation was primarily at the ME level as the effort was to build interest and partnerships in a region where we did not then have projects.

The CRSP Council appointed the Integrated Pest Management (IPM) CRSP as the lead in organizing this effort on behalf of all CRSPs. The InterCRSP program was funded by USAID independently of the individual CRSPs although some cost-sharing was required.

Together, the InterCRSP CRSPs provide a pool of resources extending to some 39 U.S. universities as well as many NGOs, IARCs, private sector firms, and host country scientists and institutions. As such, the NRM InterCRSP provides a vast source of expertise and experience to draw on to deal with NRM technology development and transfer (TDT) in West Africa.

Library Donation Project

The Aquaculture CRSP actively led a Library Donation Program that 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 provides an inventory list of available books and journals to our Host Country PI institutions.

Recipients are Aquaculture CRSP 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 computers to Mexico's UJAT. Each PI determined the need for individual items that will be held in a publicly accessible library within their home institution. In 2005, the Aquaculture CRSP provided 600 books and journals to PIs in five countries, and our inventory held over 1,700 books and journal issues. In 2006 and 2007, we exceeded the 2005 levels, and have met our goal of 75% donations to reduce inventory. We have donated nearly 99% of the desirable inventory to Aquaculture CRSP Host Countries through the final extension period in 2008, as almost all Host Country libraries need scientific journals and books to enhance their collections.

Ambassador Program

The Aquaculture CRSP initiated a novel Ambassador program in three Host Countries (Kenya, Mexico, and Thailand), in which highly respected host country counterparts serve as a resource for USAID Missions in their respective countries. CRSP Ambassadors hosted field days to communicate the state-of-knowledge and ongoing research activities to inform policy makers. The Ambassador program provided opportunities for Challenge awards through leveraged

Aquaculture CRSP funds up to \$25,000 per project. The first Challenge Award went to University of Arizona for work with Amrit Bart, Chief of Party on the SUCCESS Tsunami Project and Aquaculture CRSP Thailand Ambassador.

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

Publications

Disseminating the results of high impact research has been a CRSP priority during this grant. Our own in-house publications provide a range of services and resources. They provide news and updates on the program's opportunities and accomplishments, summaries of research results, and various titles to help the aquaculture community network and advance.

In addition, Aquaculture CRSP researchers publish the results of their research in established outlets such as academic journals, conference and symposia proceedings, and trade magazines. Since the beginning of the granting period, hundreds of articles have resulted from funded research, representing dozens of separate journals, magazines, and other publications.

A complete list of publications is available in Appendix 4. Here we briefly outline the scope and purpose of the various types of publications produced by the Aquaculture CRSP.

Annual Reports, Work Plans & Research Reports

Annual Reports

During the reporting period Aquaculture CRSP published 11 Annual Administrative Reports. These are published in two volumes: administrative and technical. The Annual Administrative Reports, which are a USAID grant requirement, contain a program overview, research background, staff and fiscal summaries, networking activities, report abstracts, and a publications list. The Annual Technical Reports contain the full text of the reports submitted by investigators who were funded to conduct research within the particular reporting period.

Work Plans

Work Plans outline two-year investigations funded by the Aquaculture CRSP. They include regional (site-specific) and cross-cutting (relevant to several or all sites) research and research support activities.

Research Reports

The CRSP Research series aims to publish all significant research produced by Aquaculture CRSP activities. Two types of publications are listed in the Research Reports series: those published by the CRSP itself and those published in scientific journals and conference proceedings. Research Reports published by the CRSP are available in their entirety electronically and in some cases, in print. Due to copyright restrictions, the CRSP distributes only the abstracts of papers that were published in scientific journals or conference proceedings.

For those papers, we provide a Notice of Publication, which contains an abstract of the paper, publication information, and author addresses. The Notices of Publication are reported quarterly in *Aquanews*.

From 1996, the Aquaculture CRSP handled about 250 *Notices of Publication and Research Reports*, each representing a scientific article or paper resulting from Aquaculture CRSP-supported research. In addition, CRSP had many NOPs translated into Spanish and French. We also published an online compilation of the English and translated abstracts of our peer-reviewed journal articles ("*The Collected Abstracts 1996 to 2008*").

Aquanews

Aquanews is the Aquaculture CRSP's quarterly newsletter. It is distributed to Aquaculture CRSP researchers, students, private business and anyone who has a relationship with the Aquaculture CRSP. First printed as hard copy, this was its primary format, until its full transition to an on-line version in 2007. The circulation of *Aquanews* steadily increased throughout the granting period. Besides in-depth features covering research results and directions, regular columns include student profiles, project highlights, and milestones.

EdOp Net

EdOp Net, is the Aquaculture CRSP's monthly newsletter of aquaculture-related education and employment opportunities. It brings the most unique "hits" to the CRSP website. EdOp Net is mailed to subscribers and sent to recipients via email. It is also available as a PDF on the Aquaculture CRSP website:

The service is linked from other websites as well. Several institutions cite the newsletter as a resource for aquaculture jobs, for example:

- Asian Fisheries Society
- Noé Aquaculture Consultants
- Nha Trang University, Vietnam
- American Fisheries Society
- Aqua Life of Turkey
- Institute for Local Government Administration and Rural Development, Ohio University
- Lista de Empregos em Biologia

Featured Titles and Other Media



Featured Titles are publications that report on CRSP findings and activities but fall outside of other publication series. Many of these titles synthesize years of CRSP research and are published as manuals. These publications report on Aquaculture CRSP findings and activities to provide a broader scope than reports and newsletters. Many of these titles synthesize years of CRSP research. Most titles are available in electronic format and some can be ordered as print copies.

Other publications include those done within the Eagle-Condor Aquaculture Exchange Project "Joint initiative between Aquaculture CRSP and Heifer International." They are downloadable from the website. A multi-authored book entitled, "Dynamics of Pond Aquaculture," was published by CRC Press in 1997. The collection of articles, which

approaches aquaculture production as part of the larger agroecosystem, was edited by CRSP Director Hillary Egna and CRSP Principal Investigator Claude Boyd. Egna also wrote two of the book's 16 chapters. Numerous CRSP researchers contributed to this effort. A sampling of reviews received by the manuscript demonstrates the relevance and timeliness of this new text: "A state-of-the-art study of aquacultural research" and "Theory, practice, the latest techniques,

and human factors—all covered in this complete reference.”

Website

The Aquaculture CRSP updated the website so that it can serve as a repository for reports and information produced by the Aquaculture CRSP. The outcome from this exercise will be a more navigable and appealing system to better serve the international community. Over the past year we launched a searchable online publications database. During this extension we began the continuous process of populating the searchable online publications database through keyword functionality.

Site Descriptions

In order to reach a wider global audience, we finalized the site descriptions handbook. Site descriptions data are important meta-tools for understanding site-specificity of research results from projects operating under the current grant. Enhanced functionality is critical for transmission of information between the present Aquaculture CRSP ME and the new Aquaculture & Fisheries CRSP.

DATABASES

The Aquaculture CRSP Central Database is a centralized data storage and retrieval system for PD/A CRSP research and for other aquaculture research programs with compatible objectives and standardized methodology. The Database contains more than one million observations of pond variables obtained from over one hundred production studies conducted at PD/A CRSP research sites located in the Philippines, Thailand, Indonesia, Egypt, Kenya, Rwanda, Honduras, Panama, and Peru.

The studies contained in the Database pertain to the tropical and sub-tropical production of tilapia, shrimp, and other warm water culture species in solar algae ponds that receive inputs such as plant materials, inorganic and organic fertilizers, and prepared feeds.

Datasets may be searched and retrieved based on geographical location, fish culture methods and species, and desired types of data. Data types available include weather, water quality, pond soil management schedules for water, fertilizers, and fish feeds, and fish production.

Expert System

POND is a computer program developed to guide decision-making processes relevant to warmwater pond aquaculture. POND was written to provide educators, extension agents, managers, planners and researchers with a tool for rapidly analyzing aquaculture systems under different management regimes, and to assist in the development of optimal management strategies.

Pond analysis is accomplished primarily by the use of simulation models combined with an economics package that can be used to generate enterprise budgets for a pond facility. The models are organized hierarchically and proceed from simple ones where fish growth, pond volume, and water temperature are the only state variables, to more complex ones, which describe phytoplankton, zooplankton, bacterial and water quality / sediment dynamics in addition to fish growth, pond volume, and water temperature.

The program can be used to set up pond facilities with different configurations and/or management strategies. Mini-databases are maintained for site, pond, associated fish lots (populations) comprising one or more species, source water, soil, weather and cost characteristics. These databases can be used to describe a “physical” aquaculture facility. Users can also define characteristics of feeds, fertilizers and liming materials.

Once a desired facility has been set up, multiple simulations can be conducted to examine the effects of various pond management scenarios on fish yields and facility-level economics. Pond management scenarios supported include the ability to vary stocking densities and/or species combinations, specify stocking and harvest dates of individual lots, and either specify or allow the model to generate feeding and fertilization schedules, and water balance/flow descriptions through pond facilities. These scenarios can be simulated by the use of either the simple or more complex models. Simple models are expected to be useful for planning/management purposes, and more complex models for short-term management and research applications. A graphics module is available for viewing the results of simulation runs.

Once a simulation is completed, the economics package can be used to generate enterprise budgets on either a per unit area, per unit cost of production or overall facility basis. The budget accounts for fixed, variable, and depreciable costs in addition to income streams that are either user-specified or generated by the model (e.g., fish yields).

Additional features of POND include the ability to customize the software to specific sites and species by the use of a parameter estimation package that compares multiple simulation runs to user-provided fish growth data sets, and arrives at “best-fit” parameters for the models.

CONFERENCES SUPPORTED AND ATTENDED

As a part of its dissemination and outreach activities, the Aquaculture CRSP maintained a strong presence at professional conferences, symposia, meetings and workshops throughout the granting period.

The ME consistently supported top-tier aquaculture meetings such as those of World Aquaculture Society (WAS), International Symposia on Tilapia Aquaculture (ISTA), and the International Institute of Fisheries Economics and Trade (IIFET). Aquaculture CRSP researchers are active participants of several international societies and their respective annual conferences. These meetings provide a venue for research presentations and ensure timely information sharing and reverse flows of information from international research to US aquaculture producers. In addition, students and young professionals are further cultivated during these meetings and are appreciated through Aquaculture CRSP best student poster and pre-conference professional development awards based upon scientific merit and research applicability to sustainable development.

During this time Aquaculture CRSP scientists and students participated in an average of 13 different meetings per year (for Annual Reports 15 through 22). The number of Aquaculture CRSP researchers attending averaged 32 per year, while CRSP participants gave close to a total 400 oral, poster or paper presentations at such meetings—an average of 35 per year.

The range of conference and meeting activities encompasses the entire spectrum of aquaculture science, socioeconomics, and policymaking. For example, we have been regularly represented at the American Association for the Advancement of Science annual meetings—the top scientific conference in the country. Likewise, Aquaculture CRSP has been represented by its PIs at every World Aquaculture Society (WAS) meeting during the granting period. We’ve enjoyed a reputation for cutting-edge science and technology in aquaculture; for example, in 2001, one of our PIs (Chris Brown) represented the CRSP at the USAID Biotechnology in Africa Roundtable held in Washington, DC.

Aquaculture CRSP supported PIs who organized and hosted meetings. Much of this work involved building partnerships with host country and international organizations to facilitate

networks and support for meeting and conference activities. Effective follow-up was key to ensuring a positive impact of such meetings.

For many meetings, Aquaculture CRSP PIs were principal or co-authors on papers published as part of such meetings, and in some cases edited the proceedings. Following is a brief anecdotal account of our participation in one such meeting, the 2006 WAS meeting in Honolulu, Hawaii. The triennial meeting of the WAS is the premier aquaculture technical and trade show held globally. Many Aquaculture CRSP PIs attended. Every third year WAS meets in conjunction with the American Fisheries Society and National Shellfish Association, as well as with over 20 smaller aquaculture organizations. The attendees participate in numerous academic sessions and several business meetings.

Aquaculture CRSP sponsorship at WAS2006 included organizing a special session, Aquaculture CRSP—Global Contributions to Sustainable Aquaculture. We provided the chair and the speakers and also collected all of the presentations for electronic distribution. Travel funds were provided for 11 scientists and students to attend the WAS conference and present their research findings. The session was well attended by CRSP and non-CRSP scientists. At the end of the presentations, two panel discussions were conducted.

Besides external meetings, the annual CRSP meetings serve an invaluable role in reinforcing the organization's network and building a sense of community among scientists, administrators, and stakeholders at host institutions and countries. Attendees share their research results and pursue opportunities that accelerate opportunities for collaborative research. Many students interacted with established researchers, being exposed to new scientific advances, potential mentors and the chance to work on innovative projects. As such, our meetings truly fulfilled the spirit and vision of the CRSP mandate.



V. CAPACITY BUILDING

A salient feature of the CRSP model of long-term training is that the degree training is an integral part of CRSP supported collaborative research projects both in the U.S. and host country universities. The training does not take place in isolation, but is integrated into the overall research, outreach and education program. CRSPs engage in long-term research on a variety of topics, with collaborating researchers from institutions from all over the world. The training occurs under the direct supervision of CRSP researchers in the US and host countries, which ensures that the training activity directly contributes to CRSP and USAID research goals and objectives, as well as to capacity building in partner host countries. Giving students the opportunity to take advantage of project work allows them to be part of cutting edge research while building lasting relationships with researchers in their field from both the U.S. and abroad. It also leads to long-term collaboration between institutions, which is much broader than the scope of the training alone.

Given the collaborative nature of the research, students also have access to U.S. and host country scientists. Many have the opportunity to study and/or conduct field research in varied locations, giving them access to an even more resources. For host country students that may complete their degrees in the U.S., they already have connections with researchers working in their area of expertise in the host country when they return to work. And for students that complete their degrees outside the U.S. they have the opportunity to work with U.S. scientists, and access some of the many resources that U.S. universities have to offer. Being part of a larger ongoing effort affords students a richer and more connected experience than if they were solely participating in a designated training program.

The CRSPs are a cost effective way to increase training because of their high level of success in securing additional funds for this purpose. Another aspect of our approach to training students was our consistent efforts to achieve gender equality. Most aquaculture programs tended to be dominated by men, yet in our final program year, nearly half the students were women. This was a huge change from the early years of CRSP, up through the early-1990s, when less than one-third of the students were women.

DEGREE AND NON-DEGREE TRAINING SUMMARY

The Aquaculture CRSP has taken pride in its long history of providing relevant, top-quality training for its participants, whether they be US or Host Country PIs, support staff at home or overseas, facility managers at research sites, technicians working at those sites, government officials involved in extension work, or students interested in the practice and development of aquaculture. Training has taken many forms, beginning with simple mentoring of co-workers at all levels, unofficial on-the-job training at research sites, collaboration on the planning, conduct, analysis, and reporting of CRSP investigation results, and short- and long-term training programs. Our focus in this summary report is on these short- and long-term training programs that have been conducted by the program.

LONG-TERM TRAINING

CRSP has strived to provide training for students who were interested in aquaculture and would presumably go on to work in the aquaculture field, whether as owners or managers of private farms, officials in government organizations, members of non-government organizations, or faculty in institutions of higher education involved in research and extension. As such, our long-term training efforts focused on teaching general biological and ecological knowledge, scientific principles, and research methodologies, and provided students with early experience in the conduct of experimental work. Long-term training typically took the form of participation in degree programs (BS, MS, or PhD) at higher education institutions, either in the US, a participating Host Country, or in a third country.

Our records indicate that 683 students undertook degree programs with partial or full support from the Aquaculture CRSP, with completion dates beginning as early as 1984. Some students' names appear more than once, indicating that they completed or participated in more than one degree program, e.g., a BS followed by an MS or an MS followed by a PhD. A summary of the number of degree training programs completed each year through 2008 is provided below. In this grant from 1996, 523 students were engaged in degree programs through CRSP. It is interesting to note that the number of women completing degree training programs supported by the CRSP increased dramatically beginning in about 1999, and that the percentage of candidates who were women was consistently greater than 40% during the last three or so years of the program (2006-2008). Only a handful of these long-term (degree) students fell into the category of fully sponsored "participant training," i.e., in the large majority of cases support came not only from the CRSP, but was shared by other organizations and/or by the students themselves.

SUCCESS STORY

◆
Mr. Agwata Ototo

A Short Course Training Success

Of 14 short courses put on by the Moi University Department of Fisheries and Aquatic Sciences between 1999 and 2005, 12 were sponsored by the CRSP. A total of 282 individuals were trained in these 14 courses, of which 228 were men and 54 were women. Although Officers of the Kenya Fisheries Department were generally the primary targets for this series of training courses, which generally trained 20 officers, up to five extra places were always made available for individuals from other agencies or organizations with similar interests, such as KMFRI.

One trainee from KMFRI was Mr. Agwata Ototo, who attended two of our short courses, one in August 2000 and the other in November 2000. Mr. Ototo joined KMFRI in 1990, serving in assignments at the Mombasa, Kegati, Kisumu, and Sangoro stations. He served at the Sangoro Aquaculture Research Station, near Lake Victoria's Winam Gulf, from 1997 through 2001. While there he was involved in the planning and implementation of the Lake Victoria Environmental Management Project (LVEMP), in the Aquaculture Sub-Component of the Fisheries Component.

In August of 2000 Mr. Ototo was selected by KMFRI to attend one of the first aquaculture short courses sponsored by the Aquaculture CRSP, the Kenya Fisheries Department, and the Moi University Department of Fisheries under the Ninth Work Plan. This two-week course, conducted at Moi University's Chepkoiel Campus near Eldoret, focused mainly on the selection of suitable aquaculture pond sites and proper construction of ponds, but also included considerable attention to pond management practices.

Following this training Mr. Ototo returned to Sangoro Aquaculture Research Station, where aquaculture duties were added to his LVEMP responsibilities. One of his first tasks was to demonstrate modern pond design and construction to the station's staff. This was started by designing and building two ponds at the station.

In November of 2000, Mr. Ototo was again selected for participation in a CRSP-sponsored course, this time the more intensive, three-week course covering pond design, construction, and management, fish handling and breeding, and aquaculture business management. This course was conducted at Sagana Fish Farm, Sagana, the Kenya Fisheries Department's primary fish culture facility and the Aquaculture CRSP's prime research site in Africa.

In 2002 Mr. Ototo moved to the Kegati Aquaculture Research Station near Kisii, which was on the verge of being closed down due to non-productivity. Mr. Ototo's task was to convince the KMFRI management that productive aquaculture was feasible at Kegati or otherwise the station was to be done away with. According to Mr. Ototo, "Fortunately I had taken the two CRSP courses and this was a chance for the skills acquired to be shown."

On his arrival at the Kegati station there were 10 ponds, ranging from 72 to 204 m² in size, with a total surface area of 1,313 m². The first task was to construct additional ponds for research and for African catfish (*Clarias gariepinus*) production. This was done in the first two months following his assignment to the station. Other station technicians and auxiliary staff were trained in pond design and construction during the process. Since then 17 ponds have been designed and constructed, four for *Clarias* breeding and 13 as rearing and research ponds. The new ponds range from 91 to 172 m² in size, and the total pond area at the Kegati station is now 2905 m².

Mr. Ototo's efforts have also been felt outside the Kegati station, where he has worked with more than a hundred farmers in seven of the districts around Kisii town. These farmers have been given instruction on pond design and construction, artificial propagation of the African catfish, polyculture of African catfish and Nile tilapia (*Oreochromis niloticus*), some ornamental fisheries, and commercial aspects of aquaculture.

Mr. Ototo cites a number of benefits that have been realized as a result of his participation in the CRSP-sponsored training courses:

- Demonstration of pond design and construction principles to staff at Sangoro and Kegati Aquaculture Research Stations. About 80% of the staff of these stations now understand the principles of pond design and construction
- Artificial propagation of the African catfish at Sangoro station
- Demonstration of the feasibility and value of aquaculture at Kegati station in Kisii, which was kept open as a result of his efforts to increase station capacity and production
- Assistance and training given to a large number of farmers in the Kisii area; topics have included pond design and construction, artificial propagation of African catfish, and help with polyculture of tilapia and catfish

Continued on next page

Success Story: Mr. Agwata Oto (continued)

- Production of fingerlings for distribution to farmers in districts around Kisii Provision of pond management advice to local schools (Kisii area) as well as fish for use as practical specimens in instruction.
- The generation of income at Kegati station through fish production

According to Mr. Ototo:

"It [Kegati station] was the first station to start generating income to the institute and that was only possible from the two trainings I had taken with CRSP . . . After we started doing the ponds, producing fingerlings for farmers, supplying fish to school[s] as practical specimens in the year 2003/2004, this station was talked [about] as the best in KMFRI."

A Farmer Success Story: Mr. Morris Omuhaya

Morris Omuhaya operates 2 ponds, one built in 1996 (200 m²) and one in 1998 (242 m²). The main inputs include fertilizers (DAP and Urea), feeds (dairy meal, pig finisher, omena dust, and lake shrimp), fingerlings (tilapia and *Clarias*), labour (feeding and harvesting) and a water reservoir. Mr. Omuhaya received training by participating in the On-Farm Trials conducted under CRSP sponsorship in 2001-2002. The subsequent benefits to Mr. Omuhaya's operation are best described by Morris himself:

Between 1996-1999, when I had only two ponds, the biggest fish I could produce was 100-150 grams after 12-

14 months. Now I am proud to say that I can produce 300-400 grams of tilapia and a 6-8 kg of *Clarias* fish in 6 months. This came about after being lucky to be selected for on-farm trials of the year 2000/2001. Fish farming is now a business enterprise for me and my family. I can now eat fish (fresh) with my family and the community can now buy fish from me (my farm). Fish farming has now become my major source of income. The frequent visits by these officers (Lecturers from DOF – Moi University) have even made me become a trainer of other fish farmers in this region of Western Kenya"

Morris Robert Omuhaya – Lurambi Division:

The impact of the skills Mr. Omuhaya gained through his participation in the On-Farm Trials is illustrated when we compare the costs, gross value, and net value of crops in his two ponds for 2002 through 2005.

Our data show that the cost of inputs for Pond 1 rose from Kshs 2,249 to 4,900, an increase of 118% while that of Pond 2 increased by 122% because of increased inputs. During the same period, sales from Pond 1 (mostly stocked with tilapia) rose from Kshs 15,276 to 21,000, an increase of 37.5%, while that of pond two (Stocked with 600 tilapia and 100 *Clarias*) rose from Kshs 9,190 to Kshs 19,690, an increase of 114%. Net values for the two ponds increased by KShs 3074 and KShs 7605, respectively, between 2002 and 2004, equivalent to increases of 23.6 and 111%. The bottom line shows that the overall net value in 2004 was 130% greater than that in 2002.

Numbers of students completing degree programs with Aquaculture CRSP support through 2008.

Year	Men	Women	Data not Collected	Total	% Women
1984	4	0	0	4	0.0
1985	10	6	0	16	37.5
1986	8	5	0	13	38.5
1987	9	8	0	17	47.1
1988	5	1	0	6	16.7
1989	14	2	0	16	12.5
1990	12	6	2	20	33.3*
1991	9	1	0	10	10.0
1992	8	5	0	13	38.5
1993	8	1	0	9	11.1
1994	8	3	0	11	27.3
1995	16	9	0	25	36.0
1996	9	3	0	12	25.0
1997	5	6	1	12	54.5*
1998	19	8	0	27	29.6
1999	24	19	0	43	44.2
2000	23	11	0	34	32.4
2001	33	21	0	54	38.9
2002	12	3	0	15	20.0
2003	3	0	0	3	0.0
2004	50	26	0	76	34.2
2005	29	18	0	47	38.3
2006	19	18	1	37	50.0*
2007	19	17	0	36	47.2
2008	16	13	0	29	44.8
Unknown	56	39	3	98	41.1
Total/Overall	428	249	7	683	36.8*

*percent among graduates for whom gender was reported

Nationalities of Degree Students

Students trained under ACRSP sponsorship came from at least 48 countries. Not surprisingly, the greatest numbers of degree students tended to come from ACRSP prime site countries (Honduras 20, Indonesia 15, Kenya 63, Mexico 100, Peru 16, Philippines 37, Rwanda 26, and Thailand 34) and from the US (171). Other nationalities with relatively high numbers of degree students included Bangladesh (21), China (36), and Vietnam (26).

Gender Distribution of Degree Students

The numbers of men and women working on degree programs (BA/BS, MS, and PhD) are shown below. The percentage of degree candidates who were women was greatest for BA/BS degrees (41.8%), followed by MS candidates (33.1%) and PhD candidates (30.5%). The overall percentage of women candidates (all degrees)

A very low number of supported students did not complete their programs, due to reasons such as withdrawals, transfers, and death, and a few continue to slowly work towards completion while engaged in full-time employment.

Student Distribution by Nationality

Country	No. of Students	Country	No. of Students
Australia	1	Kenya	63
Bahamas	1	Korea	2
Bangladesh	21	Malawi	3
Belgium	10	Malaysia	1
Belize	1	Mexico	100
Brazil	8	Myanmar	3
Cambodia	3	Nepal	8
Canada	2	Nicaragua	1
Chile	1	Pakistan	1
China	36	Panama	17
Colombia	2	Peru	16
Costa Rica	1	Philippines	37
Ecuador	3	Portugal	1
Egypt	5	Rwanda	26
El Salvador	2	Sri Lanka	2
Eritrea	2	Sudan	1
France	1	Sweden	1
Germany	1	Taiwan	1
Guatemala	4	Tanzania	1
Haiti	1	Thailand	34
Honduras	20	Turkey	2
India	8	USA	171
Indonesia	15	Vietnam	26
Israel	1	Unreported	14
Ivory Coast	1		
		Total	683

Degree programs undertaken by males and females over the history of the Aquaculture CRSP.

Degree	Men	Women	Data not Collected	Total	% Women
BA/BS	177	127	0	304	41.8
MS	184	91	0	275	33.1
PhD/PostDoc	57	25	0	82	30.5
Unrecorded	13	5	4	22	27.8*
All degrees	431	248	4	683	36.5*

*percent among graduates for whom gender was reported

SHORT-TERM TRAINING

Short-term training supported by the Aquaculture CRSP included learning opportunities focused on specific topics and compressed into relatively short time periods, i.e., periods of half a day to two or three weeks. Examples are short courses, workshops and seminars, participation in conferences, and so forth. The target audiences for this type of training were typically farmers, extension agents, government officers, or students who wanted to learn about aquaculture basics or needed to learn specific new skills to apply on their farms, in their research or production facilities, or in their education and outreach efforts. Information presented typically included topics such as the status of aquaculture in particular countries or regions or the current state of knowledge about targeted aquaculture species or specialty areas, whereas skills training included topics such as pond construction, broodstock management, fish propagation, hatchery rearing of larval fish, fingerling production, water quality monitoring, extension methods, and survey methodologies, to name a few.

Our estimates for the number of individuals who have received this type of training are *at least* 4500. This estimate is conservative, however, as there was unreporting of data.

Some illustrative examples of short-term training that has occurred include the collaborative efforts of CRSP participants in Honduras (Zamorano, Auburn University, and the University of Georgia), resulting in the training of over 2000 participants, short courses and farmer field days conducted in Kenya, resulting in training for at least 500 participants, and outreach efforts conducted in the Amazon region (Southern Illinois University Carbondale), which reached over 1200 recipients. These examples highlight some of what the CRSP has achieved in the area of short-term training.

Short-term training supported by the Aquaculture CRSP covered a wide range of topics, selected by each project or investigation to target immediate needs and constraints in the country or region of concern. A few examples of short-term training events that were held are shown here.

- Introduction to Fish Farming (Kenya)
- IV Curso Internacional de Acuicultura con Especies Promisorias de la Amazonia (Peru)
- Aquaculture Extension in the Amazon Region (Ecuador)
- Safe Handling of Steroids and Clean Technologies in Aquaculture (Mexico)
- Tilapia course (Honduras)
- Snook Biology and Culture (Mexico)
- Training of Trainers (Kenya)
- Safe handling of steroids and clean technologies in Aquaculture (Mexico)
- Exchange visit seminars on tilapia and cichlid culture (HCPI Exchange Project Phase I Countries: Thailand, Philippines, Mexico, Honduras, & Kenya)
- Echo-Seminars in home countries following completion of the exchange visits (HCPI Exchange Project Phase I Countries: Thailand, Philippines, Mexico, Honduras, & Kenya)
- Two day workshop at the International Conference Center, Huazhong Agricultural University (China)
- Algal Bioassay Workshops (Bangladesh, Nepal, Vietnam)
- Second Sustainable Aquaculture Technology Transfer Workshop (RAS principles) (Mexico)
- Characteristics and management of pond bottom soils in Thailand (Thailand)
- Practice course: Tilapia in Zamorano (Honduras)
- Chiangrai Inland Fisheries Station workshop (Thailand)
- Sex Reversal and Safe Handling of Steroids (Mexico)
- Indigenous Aquaculture for Sustainable Development (US)
- Pond Construction and Management (Kenya)

- Pond Construction and Management (Camargo: SICE)(Ecuador?)
- 1st Cachama and Pacu Culture Extensionist Training Course (Peru)
- Fish Harvesting and Processing (Kenya)
- Training Course For Tropical Nutrition In Fish In The Amazon (Peru)
- Business Planning & Aquaculture Economics (Honduras)

Other examples of short-term training include one-on-one meetings between CRSP PIs and university, government, or non-government personnel to educate them about our program, projects, and investigations or about specific aquaculture information relevant to their situation; on-the-job mentoring and training at field sites, short internships to help participants develop particular skills needed (water quality analyses, QA/QC, computer and software operation, pond seining, fish sampling/harvesting techniques, to name a few), presentations by PIs and other program participants to school groups and other visitors at the research sites, and so forth.

Trainees from many countries were the recipients of ACRSP short-term training, including the following: Bangladesh, Belgium, Bolivia, Brazil, Britain, Cambodia, China, Colombia, Cuba, Ecuador, El Salvador, Honduras, India, Kenya, Laos, Mexico, Nepal, Nicaragua, Panama, Peru, Philippines, Rwanda, Sri Lanka, Thailand, USA, Venezuela, Vietnam.

STUDENT PROFILES

In many ways, student training exemplifies the ideals of the CRSP to provide opportunities to those who might otherwise have none. Notable successes include a number of young host country researchers whose interest was initiated by an introduction to aquaculture in their home countries, followed by training in the US. Other successes include several hundred students who were trained in situ in their host countries, thus both developing in-country training capacity and building aquaculture expertise for a more efficient in-situ use.

To encourage students in their work, each issue of our newsletter, *Aquanews*, has featured a student profile. These would highlight the nature of the student's research, his or her academic background and aspirations for further career development.

GRADUATE STUDENT PROFILE

James Bundi Mugo

James Bundi Mugo was born in the central province, Kirinyaga District, in Gichugu Division, Njuki-ini location, Mirichi sub-location, in Kimweas Village, Kenya. At age 3, Mugo's family moved to the Mwea Division in Marura village where he joined Kangiciri Primary School. After classes, Mugo spent his afternoons fishing with other children. They fished with either hook and line or sisal thread sacks in rice field canals while grazing cattle. Every fish caught was roasted and eaten at the site, except in the case of a big catch, which was taken home for the family. Because of its delicacies and its acceptance in Mugo's family, fishing became routine work for him as a youth. After his graduating, Mugo decided to pursue a Bachelor's of Science degree, specializing in fisheries. The driving force behind his decision was his belief that one's interest at young stage are a determining factor in what that person will most likely become later in life. The fisheries courses became more interesting after his first assignment at Sagana Fish Farm in 2001.

Mugo worked with Aquaculture CRSP from April 2001 to 2003 as an assistant to the outreach and resource people during short courses on pond design, construction and management offered to fisheries officers and fisheries assistants. From this work Mugo gained a lot of practical experience in pond construction. The result of his experience was the construction of three ponds at his home (two measuring 100m² and one at 50m²). These ponds are stocked with Nile tilapia, catfish fingerlings and gold fish. In addition, through the assistance of ACRSP Host Country Principal Investigator, Charles C. Ngugi, Mugo managed to visit Uganda in May 2003 as a consultant for one week. During this visit he assisted the Uganda Commercial Fish Farmers on pond site survey and construction, hatchery managements and cage farming. In April and July 2005, Mugo participated as a resource person in a hatchery management course for fisheries extension officers, farmers, and fish hatchery managers.

In 2006, Mugo received an ACRSP Scholarship through Moi University for an M.Phil. in Aquaculture. Previous students have already made great strides in addressing major problems in *Clarias* production, e.g., in its culture, low survival rates, growth, etc.; therefore, Mugo chose to work on Nile tilapia and formulated research based on problems facing tilapia farmers. Through the guidance of the ACRSP Principal Investigators, Ngugi and James Bowman, Mugo decided on an investigation and so titled his research the "Effects of dietary protein levels on gonad maturation, age and size at first maturation and fecundity of Nile tilapia (*Oreochromis niloticus*). Culture of Nile tilapia (females) remains constrained by early sexual maturation, poor spawning synchrony and low fecundity adding to significant reductions in net returns. To avoid these problems, a number of investigations have been directed towards the production of all-male population of Nile tilapia for aquaculture. The technologies used to prevent early reproduction includes hormonal sex reversal, hybridization, intermittent harvesting, manual sexing, use of predators, cage culture in large water bodies, high stocking density, sterilization and the use of YY male broodstock. However, Mugo feels there are some limitations in the techniques involved. Problems include: labor intensive techniques, broodstock contamination, vigilance required in selection and maintenance of broodstock, requirement of high levels of control, and limited consumer acceptance of hormonally sex reversed in countries where it is practiced. Mugo thinks the use of an effective protein level of the diet to reduce incidence of early gonad maturation and increase fish size at first sexual maturation could solve these problems. Mugo hopes to continue research and further his education in aquaculture after he graduates. "I would also like reaching out to fish farmers and offering technical advice in fish farming," he said.

Current Status: Mugo completed his degree in December 2008.

Graduate Student Profile

◆ Bernardita Campos Campos

by Ian Courter

As an undergraduate Bernardita Campos Campos studied biology at the Universidad Juárez Autónoma de Tabasco (UJAT), where she finished her degree in 1990. She gratefully acknowledges the support and mentoring received from Blanca Priego during that time.

In 1998 she began her research as a University faculty member. Three years later, through her previous relationships with PD/A CRSP principal investigators, she started her current 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. Hormones used on fish are often incompletely metabolized, and little is known about the effects of excess hormones in water effluent and fish meat. Therefore, scientists are interested in finding alternative methods of sex-reversal of fish.

Campos was inspired by Leandra Salvadores of UJAT to pursue a graduate education. Her interest in Environmental Engineering enticed her to stay at UJAT. Once accepted to the Masters program at UJAT, she joined Wilfrido Contreras-Sánchez at UJAT's Laboratory of Aquaculture; Contreras-Sánchez serves as her advisor.

In the early stages of her degree at UJAT in Environmental Engineering, Campos found her work challenging because of her incongruous background in biology. She noted that it is often frustrating that the

equipment necessary for valuable procedures, such as radioimmunoassay, is not readily available in Mexico. Conversely, 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, but a PhD is not in her immediate plans. She also hopes to have the opportunity to study the effects of ultraviolet light on the elimination of methyltestosterone in masculinization systems.

As a native to Tabasco, Campos knows a lot about the status of aquaculture in Mexico. In particular, she advocates further investment of resources into the industry as well as more technical support for the farmers. Although she acknowledges that some shortcomings exist for the aquaculture industry in Mexico, Campos feels that southeastern Mexico has good potential because of its vast water resources in the form of rivers and lagoons. Furthermore, Campos sees national and global benefits of expanding the aquaculture industry to provide high quality foods to growing populations.

Campos has very little free time. When asked what she does in her spare time, she joked about not having the time to do anything except work. However, further questioning revealed that she enjoys Egyptian mythology and reading. During a rare break from the rigors of graduate school, Campos might relax by reading one of her favorite books, such as *War and Peace*, a classic Tolstoy novel.

Status Update: Bernardita completed her MS in 2004.

GRADUATE STUDENT PROFILE

◆
Fred Chu Koo*by Steve Sempier*

Fred Chu Koo is working hard to improve aquaculture techniques and resource use in his home country of Peru. Fred earned an undergraduate Biological Sciences degree (1995) from Peru's Universidad Nacional de la Amazonía Peruana, and an M.S. (2000) in Aquatic Biology and Fisheries from Universidade Federal do Amazonas in Brazil. Fred then joined the Instituto de Investigaciones de la Amazonía Peruana (IIAP) in his hometown of Iquitos, Peru, and through that institute's collaborative research agreement with Southern Illinois University at Carbondale (SIUC) Fred joined SIUC as a graduate student. He has been working with his major advisor, Dr. Chris Kohler, and Dr. William Camargo at SIUC on ACRSP-funded projects for five years, and anticipates defending his Ph.D. dissertation, "Nutritional Studies and Ecological Role of Two Amazon Fish *Colossoma macropomum* and *Piaractus brachipomus* (Pisces: Characiformes)" this year.

Fred's ACRSP research has focused on evaluating the nutritional feasibility of mixing native Amazon plants and agricultural by-products with commercial feedstuffs to produce nutritional, balanced diets for cultured fish species while "aiming to reduce feeding costs for local fish farmers back in Peru." At SIUC, Fred investigated native Peruvian plant species as potential components of fish diets, and nutrient digestibility of these plants for Amazonian cultured fish. He performed grow-out trials comparing fish growth and feed conversion of the plant-based pelleted diets, incorporating hematological and compositional analyses of experimental fish in his

analysis. Fred also described the seed-dispersing role of two Amazon fishes at IIAP in Peru.

Fred has enjoyed immensely the opportunity to study at SIUC under Drs. Kohler and Camargo, broadening his academic and cultural horizons through meeting and collaborating with students from different countries and traveling in the U.S. And he is excited about the future of freshwater fish aquaculture in his home country. He has seen his own research applied in Amazonian Peru through local fish farmers' use of low-cost balanced fish diets. As a graduate student in Peru, Fred realized the growth potential of aquaculture, and since then the "aquaculture of native Amazon fishes has really been extended along the entire Peruvian Amazon thanks mainly to the efforts done by IIAP and its partners (NGOs, CRSP, EU, etc.)." help Peru face challenges to the development of its aquaculture industry: opening international markets for Amazon aquaculture products, and balancing profitability with sustainability through the control of diseases and environmental impacts incurred by fish farming technologies and increased fish production.

Fred is currently heading an Aquaculture Research & Extension Project at IIAP, and after his defense at SIUC this coming year he plans to begin a postdoctoral fellowship in Brazil, the U.S., or France. Fred is also looking forward to the promising future of aquaculture in Peru, and hopes to see more beneficial impacts of research-based advances in his field.

GRADUATE STUDENT PROFILE

◆
Carlos Leyva

By Ian Courter

Carlos Leyva, native to Honduras, became interested in aquaculture while attending the Escuela Agrícola Panamericana (EAP), Zamorano. "I was amazed going through a production cycle from stocking to harvest and astounded by the large amounts of succulent products resulting from it," said Leyva. After graduation in 1986, Leyva worked as an extension agent. He went on to receive a B.S. from Kansas State University and began working for a shrimp farm in Choluteca, Honduras. During his time in Choluteca, he received invaluable technical support from Dan Meyer, a CRSP host country Principal Investigator based at EAP, who would ultimately influence Leyva to pursue a graduate degree in aquaculture. Leyva returned to Zamorano in 1991 and worked in the aquaculture department at EAP.

In the fall of 2002, Leyva began working on a graduate degree at the University of Arkansas at Pine Bluff (UAPB). His thesis project, titled "Central American Aquaculture Markets: Optimizing Tilapia Marketing in Honduras," focuses on the shortcomings of domestic marketing of tilapia in Honduras. Leyva has been responsible for gathering information from small- and medium-scale farmers for use in a model that aims to optimize marketing efforts in the region.

The most challenging aspect of Leyva's studies has been learning to use the mathematical programming tools involved in the modeling process, although, in addition to networking with other aquaculture enthusiasts, Leyva finds mathematical programming to be the most exciting and useful facet of his studies thus far.

According to Leyva, "Tropical conditions and the country's natural resources are factors that favor aquaculture in Honduras." Both marine and freshwater

species thrive in the warm, wet climate year-round. However, Leyva believes that the infrastructure of the Honduran market is a stumbling block for small producers. There is little organization among growers, which gives the middlemen excessive control over prices. Through his research, Leyva hopes to shed some light on the constraints to tilapia culture in Honduras.

When asked about the state of aquaculture globally Leyva replied, "Aquaculture is expanding rapidly; technology can hardly catch up with commercial needs." However, Leyva believes that advocates for capture fisheries are overly critical of aquaculture in an attempt to lower market interest in cultured products.

Leyva was born and raised in Tegucigalpa, Honduras, and he plans to return to Honduras after graduation in May 2004. He will be working for Mountain Stream Tilapia, a past employer who has maintained close contact with him. More specifically, he will start a market support department that will focus on quality and research and development.

In the future, Leyva plans to start his own farm, but not for tilapia. He hopes to raise red snapper in sea cages. Ocean cage culture is one of the most exciting and rapidly developing fields in the industry.

In addition to his own research, Leyva spends time helping his fellow students in the laboratory and in the field. He also finds time to go fishing, hunting, play soccer and racquetball, and spend time with his family.

Status update: Carlos completed his MS in 2004 and is currently working with the Aqua Corporation tilapia farms in Honduras, El Salvador, and Belize.

GRADUATE STUDENT PROFILE



Arkady Uscanga-Martinez

The AquaFish CRSP, like its predecessor program the Aquaculture CRSP (ACRSP), relies on participating US and Host Country institutions to undertake and present continuing high-quality research in aquaculture and fisheries-related fields. The program provides support for undergraduate and graduate students, who are integral parts of its research teams. Arkady Uscanga-Martinez was supported by the ACRSP for his Master's degree from the Universidad Juárez Autónoma de Tabasco (UJAT), graduating in December 2006. After completing an undergraduate degree in Biology at UJAT, Arkady went on to study Environmental Sciences under Drs. Wilfrido Miguel Contreras Sánchez (now an AquaFish Host Country PI) and Roberto Civera Cerecedo, totaling four years of ACRSP-sponsored work. Arkady was impressed with UJAT's aquaculture facilities and camaraderie that allowed him to pursue his interests in the fields of aquaculture and aquatic nutrition. The cichlid *Petenia splendida* is an important native species cultured in Tabasco, Arkady's home state in southeastern Mexico. This fish fetches high prices in local markets, and Arkady's research focused on the challenges of improvement of *Petenia* broodstock management, larval culture, and nutrition. His thesis project, entitled "Determination of Protein Requirements in Masculinized and Non-masculinized Juveniles of the Native Cichlid *Petenia splendida*," involved filtration systems that incorporated ultraviolet light, bacterial filtration and

sunlight. Arkady's experiments related to the elimination of methyltestosterone residues from intensive masculinization systems, to reduce harmful substances in aquaculture and improve the culture of native species in the southeast region of Mexico. Arkady is proud that his ACRSP-funded research at the aquaculture laboratory at UJAT contributed to the development of optimal *Petenia* culture technology. He has enjoyed working with researchers in Mexico and the United States, and traveling to international meetings to present his work and learn about similar research in his field of interest. Arkady would like to continue his training in aquaculture and is currently pursuing a PhD at the Universidad de las Palmas de Gran Canaria in Spain to improve his knowledge of fish nutrition and the digestive physiology of cichlids. He looks forward to a career in academia in Mexico, teaching undergraduate and graduate students about the culture and nutrition of fish. Perhaps one day Arkady himself will serve as an AquaFish CRSP Host Country PI. He appreciates the ACRSP's contributions to the study of native species, and the "support that [the] ACRSP has provided to undergraduate and graduate students in Mexico, making the difference for many of us that otherwise wouldn't receive economic support for ourselves and our investigations." The AquaFish CRSP appreciates his hard work and looks forward to future collaborations with this accomplished student.

GRADUATE STUDENT PROFILE



Alejandro MacDonal Vera

by Ian Courter

Growing up in Palenque, in Chiapas State in southern Mexico, Alejandro MacDonal Vera spent much of his time enjoying the outdoors. His interest in nature and animals, particularly fish, led him to the field of science. Today, he studies aquaculture at the Universidad Juárez Autónoma de Tabasco (UJAT), Tabasco, in southeastern Mexico.

After completing his undergraduate degree in biology at UJAT, Vera decided to continue his education under the supervision of Wilfrido Contreras-Sánchez. Many professors at UJAT helped Vera along the way, but Contreras-Sánchez was the most significant influence on his decision to get his Masters degree. Prior to being accepted into the UJAT Aquaculture graduate program, Vera volunteered in Contreras-Sánchez' lab.

As a graduate student in 2001, Vera began working on the CRSP-sponsored investigation titled "Diversification of Aquaculture Practices by Incorporation of Native Species and Implementation of Alternative Sex Inversion Techniques." " , Vera is working on an investigation with Kevin Fitzsimmons, US Principal Investigator from the University of Arizona, titled "Sustainable Polyculture of Tilapia and Shrimp." The project is scheduled to finish in July 2003. For this project Vera is responsible for organizing and conducting a survey of tilapia-shrimp polyculture in Northern Mexico. He is also designing a study on stocking densities for tilapia-shrimp polyculture in Mexico. Even though he's working on several projects at once, Vera expects to finish his studies in early 2004.

According to Vera, the most challenging aspect of his research on tilapia-shrimp polyculture is that few farmers in Mexico are aware of the opportunity to have a polyculture of tilapia and shrimp. However, he finds it exciting to be working on an unexplored idea and to generate information that can be used by aquaculture

producers. The data collected from farmers can later be brought to Tabasco and be applied as alternatives to monoculture.

Despite optimal climatic conditions, an abundance of natural resources, and plenty of good aquaculture species, Vera feels that aquaculture in Mexico struggles because of the lack of modern facilities for research and development of aquaculture, as well as lack of facilities for training personnel with the necessary knowledge to develop aquaculture.

In particular, he feels that Mexico is in need of people with fish breeding knowledge. These are problems that he believes are echoed throughout much of Latin America. Vera feels that aquaculture has not developed at the same rate in developing poor counties, particularly in Latin America, compared to other parts of the world. However, he does feel that in countries with more trained personnel and institutional resources, aquaculture has developed substantially in recent years.

After graduation Vera plans on continuing his graduate studies, with hopes of procuring a Ph.D. in Mexico. In addition, he hopes to have the opportunity to study sharks, but he has yet to have the opportunity to work with any of those species. He also wishes to settle down in Southeastern Mexico, preferably somewhere quiet and in a rural setting where he would like to apply the knowledge he has gained at UJAT and perhaps start his own aquaculture farm. At the minimum, Vera plans on staying in the aquaculture or fisheries field.

When not working on his studies, Vera enjoys fishing, soccer, listening to music, and spending time in the outdoors. He expresses a sincere love for exploring and learning about new places.

Status Update: Alejandro completed his MS in 2006.

GRADUATE STUDENT PROFILE

◆
Potjanee Nattirom

Potjanee Nattirom got hooked on fisheries science while fishing as a child. She grew up in Putthaisong, which is in the Buriram Province in northeastern Thailand. When she was old enough to attend college, a school in the same region as Putthaisong—Khon Kaen University—was just starting a degree program in fisheries science. Even though the fisheries science major was still in its infancy, Potjanee was undeterred and was one of the first to enroll in the program.

Aquaculture was emphasized in Nattirom's fisheries science coursework. As she took more classes at Khon Kaen, her interest in aquaculture developed. After graduation she joined the Asian Institute of Technology (AIT)—a well-known and well-respected aquaculture institute and CRSP research site in Thailand. Nattirom was first introduced to the CRSP in 1994 while working at AIT as a research assistant. During that time, she worked on the CRSP-funded high-input deep pond experiment in Thailand's Udonthani Province. Nattirom gained valuable, practical experience as a research assistant but wanted to strengthen her academic knowledge in the field of aquaculture. In 1997 she decided to pursue a Master of Science degree at AIT. "Nattirom and her major professor CRSP principal investigator Yang Yi are concentrating on a new CRSP project that ties in with Nattirom's requirements for her master's degree.

Nattirom began working on her master's project in September of 2000. Her research compares growth performance of different sex genotypes of Nile tilapia (*Oreochromis niloticus*) and the effects of androgen treatment. She is building on past findings that indicate that genotypic females do not grow as quickly as sex-reversed males. She notes that her experiment should shed more light on this issue by comparing growth performance between different phenotype/genotype combinations. (See the box at the end of this article for related publications by CRSP researchers.)

Nattirom believes her work will enable farmers to obtain market-sized tilapia in less time and provide larger tilapia in the marketplace. She stresses, "If results show that existing production practices for Nile tilapia can be improved, it could mean that farmers adopting improved techniques in production could have the edge over their competitors." She believes that Nile tilapia has great potential for alleviating poverty since it is such a fast-growing species. If the growth performance is improved, she feels that Nile tilapia will gain even more importance in the aquaculture arena. Nattirom emphasizes, "Of course the problem of early maturation and recruitment is still unresolved and as such is a management challenge when culturing [Nile tilapia]."

Nattirom also identifies several challenges that face the aquaculture industry in Thailand. She believes the largest constraint is the decline of the environment due to lack of concern for water quality. This problem has impeded aquaculture development in Thailand. Potjanee also states a need to increase the quality and quantity of fish seed to farmers, especially in rural areas. Finally, the needs of the farmers are not being met due to lack of technological development.

When asked about men's and women's participation in aquaculture in Thailand, she noted, "Like anywhere else in the world, aquaculture and fishery work has always been male-dominated, but in Thailand today it seems that there is a greater degree of balance, with more and more women taking up aquaculture." She believes that the industry should recognize that there are many highly qualified women in the aquaculture field today.

Potjanee Nattirom is a motivated individual who would like to get further involved with development work after graduation. Until then, you can find her working hard on her growth performance project, drawing, painting, or reading by day and stargazing by night.

Status update: Potjanee completed her MS in 2002.

GRADUATE STUDENT PROFILE

♦
Ivano Neira*by Anna Gupta*

Developing countries, world cultures, and fish: these are all interests held by CRSP graduate student Ivano Neira. As such, his work with the PD/A CRSP fits him perfectly.

Neira is a Master's degree candidate at the University of Arkansas at Pine Bluff, where he is working with researcher Carole Engle on a CRSP-sponsored activity entitled "Development of Central American Markets for Tilapia Produced in the Region," which focuses on tilapia production in Honduras and Nicaragua.

One of the major objectives of this activity is to identify potential domestic markets for tilapia. Tilapia aquaculture in Honduras and Nicaragua has exploded in the past ten years, but the majority of the product is exported. By identifying potential local buyers, the researchers hope to encourage growth in the domestic tilapia market. The activity, including Neira's part, is funded exclusively by the CRSP.

Neira recently returned from a trip to Nicaragua, where he conducted surveys of restaurants, supermarkets, and fish markets. Neira will use the survey results to identify characteristics of fish buyers who are likely to buy tilapia, and then develop recommendations for marketing strategies to be used by different sizes of tilapia farms in various target markets. He will conduct part of the analysis on the survey results. In one section, he will use a logit analysis to relate buyer preferences and characteristics to their probability of purchasing tilapia, and in a second part, he will develop a transportation cost model to identify target markets for different tilapia farm sizes in different regions of Honduras and Nicaragua.

Having the chance to travel to Nicaragua was something Neira greatly enjoyed. He has done a lot of traveling just to get to this point in time in his life. Neira is originally from Lima, Peru. He received his undergraduate degree in Fishing Engineering from Agraria University, also in Lima, in 1995. He then turned his attention to agricultural business, in which he received a post-graduate certificate.

From Lima, Neira then moved to Aquafuture, Inc., in Turner Falls, Massachusetts, where he worked with

striped bass, then to Bioshelters, Inc., in Amherst, Massachusetts, where he worked on recirculating systems for tilapia. One of the reasons he decided to come to the US was to improve his English language skills. He was also interested in applying his knowledge of recirculating systems to real-life situations. His manager at Bioshelters, Inc., knowing that Neira was interested in continuing his education, told him about the research position with Engle, which was advertised on the popular aquaculture website "AquaNet." From there he moved to Pine Bluff, where he entered the CRSP pond.

"I'm interested in helping developing countries," he said, pointing out that his home, Peru, is also a developing country. He is particularly interested in estimating fish markets and determining ways to sell fish. "I would like to have more knowledge and background applicable to my country and other countries, in order to help them."

Neira hopes to finish his degree by December 2001. The work of international organizations interests him, and he sees himself working on further projects for developing countries after he graduates.

The spark that set Neira off on this aquaculture track was his own backyard. "When I was a little kid I was always interested in all kinds of life—especially doing experiments. My house was a zoo. I had all kinds of small animals (a rabbit, mouse, snakes, frogs, ducks, chickens, etc.). When I was eight years old I was on the shore of a pond, and I caught some fish which I took home with me. I started to grow ornamental fish (spawning them and doing experiments)." He continued growing ornamental fish until he left for the US.

Neira doesn't find himself with much free time outside of his research, but in his spare time he does like to run and read books. Luckily, one of his greatest interests, traveling, fits in with his research needs: "I like to travel a lot, and know more about cultures." Neira is optimistic that the current CRSP activity will have applicability in countries beyond just Nicaragua and Honduras: "I would like to do research in all of Central America, but I know that is too broad." With goals such as his, however, Neira is certain to spread ripples throughout and beyond the CRSP pond.

STUDENT RESEARCH AWARD

Herbert Ssegane

Herbert Ssegane, a University of Georgia at Athens (UGA) graduate student from Kampala, Uganda was recently awarded the prestigious E. Broadus Browne Research Award. The College of Agriculture and Environmental Sciences at UGA selects one outstanding master's degree student each year to receive this award. Herbert's research focuses on the utilization of tools such as Google Earth Pro to extract watershed variables and integrate derived variables into erosion prediction and sediment yield models for riparian buffer zones protecting streams. He has been a graduate

student at UGA's Department of Biological & Agricultural Engineering with Dr. Bill Tollner since 2005, and has applied his work to an ACRSP-funded project under Dr. Tollner in the Nzoia watershed in Kenya. Included in this award, Herbert receives a certificate of achievement for outstanding research performance and a fully paid trip to a national meeting in his discipline. Herbert and Dr. Tollner presented their work at the American Society of Agricultural & Biological Engineering in Minneapolis, Minnesota.

GRADUATE STUDENT PROFILE

George Owiti Osure

by Ian Courter

George Owiti Osure was born and raised in Yala, Western Kenya. Living near Lake Victoria, Osure developed a childhood interest in fish, as they were an important part of his diet. Osure's early fondness of fish inspired him to want to know more.

In 1992 Osure enrolled at Moi University, Kenya, and began studying fisheries. Four years later he graduated with a bachelor's degree in Fisheries and began working for the Kenya Department of Fisheries, in the Ministry of Livestock and Fisheries Development Division.

In addition to his own ambition, while at Moi University, Osure was inspired to study aquaculture by Mucai Muchiri, B.C.C. Wangila, and in particular Charles Ngugi, all instructors at Moi.

Osure continued to work for the Department 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. His study objectives were to compare the reproductive efficiencies, growth performance, and microsatellite variability of Egypt, Ivory Coast, Sagana, and Lake Victoria Nile tilapia (*Oreochromis niloticus*) strains.

Osure concedes that the most difficult yet most exciting aspect of his research was the analysis of genetic variability of the four strains of tilapia using microsatellites, or molecular markers. During his

research, Osure relied on the technical expertise of Ron Phelps, Leonard Lovshin, and John Zhanjiang Liu.

According to Osure, Kenya is an excellent place to develop aquaculture. He emphasizes the abundance of water and land resources as well as the high demand for fresh fish in local markets. Osure believes that expanding aquaculture would benefit Kenya socially and environmentally through macro- and micro-economic development, reducing fishing pressure on wild stocks, and providing a much needed protein source. Osure also feels that aquaculture is the only way of sustaining production levels that satisfy the expanding global demand for seafood.

Osure successfully defended his thesis in September—and received the Best M.S. Student Award to boot. This is an annual award given by Auburn's Department of Fisheries and Allied Aquaculture in memory of the Department's founder H.S. Swingle.

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, perhaps to inspire others like himself to continue following their interests and achieving their goals.

In his spare time, Osure enjoys sharing his faith with others in addition to playing table tennis and soccer. He also spends considerable time reading fisheries literature to stay abreast of recent developments in fisheries science.

Status Update: George completed his MS in 2003.

GRADUATE STUDENT PROFILE

♦
Jon Rauni*by Ian Courter*

Kenyan Jon Rauni began work with the Pond Dynamics/Aquaculture CRSP in February 2002. Just two months later he began working on his masters degree in aquaculture at Moi University, Kenya. Rauni's interest in pursuing his masters is attributed to his relationship with N.K. Kinyajui, who served as Sagana Fish Farm Head of Station at the time. After working with Rauni, Kinyajui advised him to develop his expertise in aquaculture. Rauni then applied for a CRSP scholarship through Moi University. After his application was accepted, Rauni dove into a rigorous schedule, balancing course work and thesis research under the supervision of PD/A CRSP Host Country Principal Investigator, Charles C. Ngugi.

As a youngster, Rauni grew up fishing near his hometown, Meru, located on the slopes of Mount Kenya in the Samburu Region. His love for fishing kindled his interest in aquaculture. It is fitting that Rauni's CRSP research project is on *Clarias*, because he boasts a five hundred gram *Clarias* as his most prized catch while fishing. *Clarias*, a type of catfish, is Africa's most widely distributed fish.

Rauni expects his thesis project, titled "*Clarias* Fingerlings as Bait Fish," will take him about two years to complete. He is working with Ngugi, Jim Bowman, and Baraza Wangila to explore the issues surrounding *Clarias* culture. Their research focuses on maximizing *Clarias* fingerling production through alteration of shading regime, stocking density, and grow-out period. A recent increase in demand for *Clarias* fingerlings stems from longliners in popular fishing areas such as the Winam Gulf. *Clarias* is the preferred bait for longlining in Kenya, with an estimated demand between 5,000 and 50,000 fingerlings per fishing day. This amounts to a demand of

1.5 to 15 million *Clarias* fingerlings per year. *Clarias* is a naturally abundant species, dwelling most often under floating shoreline vegetation. However, capturing the fingerlings can be destructive to native cichlid populations. Due to the importance of the cichlid fishery in Kenya, beach seining and fishing with mosquito nets have been banned in Kenya. Rauni and his colleagues feel that successful aquacultural production of *Clarias* is just what the Kenya freshwater fishery needs, providing an inexpensive supply of bait fish without damaging wild fish populations.

When asked what makes Kenya an excellent place to develop aquaculture, Rauni replied, "An abundant water supply, cheap agricultural products, and an ideal tropical climate. Kenya has a long history of aquaculture and now has Sagana and Moi University as good research and training centers."

What does the future hold? After graduation Rauni hopes to continue research and further his education, particularly with respect to *Clarias*, a fish which he has become increasingly fond of. He believes that *Clarias* is an important species because of its widespread distribution throughout Africa, marketability, and potential as a biological control species.

Rauni recognizes the increasing importance of aquaculture worldwide, but he also knows when it's time to take a break from the hectic atmosphere of graduate school. When not in class or conducting aquaculture studies, Rauni finds himself fishing or relaxing to the melodious music of Charlie Pride and other country style favorites.

Status update: Jon completed his MS in 2004.

GRADUATE STUDENT PROFILE

◆
Kom Silapajarn*by Mary Nidiffer*

CRSP graduate student Kom Silapajarn attributes his interest in the aquacultural sciences to his childhood love of the sea. Prompted by this early interest, Silapajarn was led to further studies of fisheries, which recently brought him to the PD/A CRSP.

Silapajarn is “attending Auburn University in pursuit of a Ph.D. Auburn’s excellent reputation in the areas of fisheries and aquaculture lured him to the program, as did the prospect of working with CRSP researcher Dr. Claude Boyd. “Hav[ing] the chance to study under the direction of Prof. Boyd makes me most proud,” said Silapajarn.

Silapajarn became began working with the CRSP in July 2001 and is now involved in Boyd’s Pond Dynamics investigation, “Effects of Pond Age on Bottom Soil Quality,” which connects Auburn University and Kasetsart University in Thailand, where Silapajarn studied Fisheries Biology as an undergraduate student. The four objectives of this investigation are to determine relationships between pond age and other key bottom soil quality variables; to evaluate the neutralizing value, particle-size distribution, and calcium and magnesium content of liming materials normally used by fish farmers in Thailand and use the data on soil characteristics and liming materials to improve the liming technique; to compare different methods of pond soil organic matter analyses; and to prepare recommendations on pond bottom soil management that consider changes in soil quality in ponds. Silapajarn will bring his expertise to the project from having over 20 years of experience as a fisheries scientist. He says that the results from this study could bring about better understanding of water and

soil pond dynamics and ultimately improve the information required for pond management.

Silapajarn recalls that developing tropical mollusk hatchery techniques in Thailand has been one of the most challenging things that he has ever done. “Molluscan hatcheries are new businesses in tropical countries like Thailand. It started about fifteen years ago and I had a chance to be part of the pioneer group working on this project,” says Silapajarn.

Although Silapajarn’s project will not be complete until April 2003, he is already looking forward to life after graduation, when he hopes to bring his knowledge of aquaculture and pond management back to Thailand. He is enthusiastic about the many factors that make Thailand well suited for aquaculture, such as an ideal temperature range for the rapid growth of most aquatic species, tropical weather rarely troubled by severe storms, and muddy soils suitable for pond construction. Silapajarn mentions that a major obstacle facing aquaculture development in Thailand seems to be an insufficiency in resource management and planning. At the same time, however, he notes that Thai people have a long history of prosperous work in the aquaculture industry.

Silapajarn wishes to eventually teach at the university level in Thailand. When he isn’t working with the CRSP, Silapajarn enjoys traveling abroad to meet different people and see different cultures.

Status update: Kom completed his PhD in 2004.

GRADUATE STUDENT PROFILE

◆
Steve Sempier*by Heidi Furtado*

Steve Sempier joined the PD/A CRSP staff as a Graduate Assistant in September 2000 when he started his masters program at Oregon State University. Sempier chose OSU because he found the area to be welcoming and the professors very receptive. Chris Langdon, a PD/A CRSP researcher and one of Sempier's masters project advisors, was one of the people who helped in his decision to attend OSU. Sempier was informed of the PD/A CRSP through a friend of former CRSP Graduate Assistant Matt Niles.

Sempier is working on his masters in marine resource management, with a minor in fisheries science and a focus on aquaculture. His main project will consider potential marine aquaculture species off the Oregon coast. He plans to develop a website that will allow dissemination of the information he gathers on this subject. Through working with the PD/A CRSP, Sempier has found that "there are many websites that address aquaculture, but few that serve as a comprehensive resource." He hopes that this website can serve as a source of information for people interested in aquaculture.

Before arriving at OSU, Sempier received his undergraduate degree at Eckerd College in St. Petersburg, Florida, where he majored in marine science with a concentration in biology. After graduation, Sempier took a three-year break from school to explore job options and learn more about his interests. Indulging his love of travel and the outdoors, Sempier spent time in Utah as a National Park Ranger, in Idaho with the US Forest Service working with the fisheries hydrology crew,

and in Minnesota working as a naturalist and a children's instructor.

Sempier has always loved the ocean, but his interest in aquaculture developed when he took a job as Senior Aquarist at the Catalina Island Marine Institute. Throughout the two years he spent there, Sempier took care of the plumbing system that supplied water to the aquarium tanks and worked directly with the animals and algae. He really enjoyed the hands-on experience and was stimulated by the problem solving involved with interpreting the marine animals' needs. He found it exciting and rewarding when the animals flourished in their environment. In addition to serving as Senior Aquarist, he was also an instructor and part-time administrator on Catalina Island.

Sempier has been working on a number of CRSP activities. He writes articles for *Aquanews*, researches and publishes EdOp Net, assists in maintaining the CRSP website, and answers frequent emailed questions regarding aquaculture. Sempier has had the opportunity to gain new skills and through his management of EdOp Net to discover the variety of job opportunities available in aquaculture. The PD/A CRSP staff is fortunate to have Sempier as part of our team. His energy and diligence are much appreciated as part of the Information Management and Networking Component.

Current Status: Sempier completed his masters degree and for awhile worked in the Program Management Office before moving with his family to Mississippi in 2004. Sempier now works for SeaGrant.

GRADUATE STUDENT PROFILE

Taworn Thunjai

by Anu Gupta

Diverse may be the best word to describe Taworn Thunjai's interests and accomplishments. He has a diverse background, having lived in both Thailand and the US, a diverse education, with two bachelor's degrees and two master's degrees, and diverse experience, with past work in both the scientific and extension realms. He is "a Ph.D. candidate working with PD/A CRSP researcher Claude Boyd at Auburn University, Alabama, on characteristics of pond soils.

Thunjai first became involved with CRSP work in 1997, when he met Boyd during one of his visits to Thailand. At the time Thunjai was working with the Thai Ministry of Agriculture and Cooperatives, Department of Fisheries. The two were interested in working together, and in June of 1997 Thunjai moved to Auburn University for eleven months. During that time he conducted research on pond soil samples from CRSP sites and developed an interest in the environmental aspects of aquaculture. He is particularly concerned with sustainable practices and aquaculture development and has thus focused on pond soil quality and water quality. In June 1998 Thunjai returned to Auburn University to pursue a second master's degree.

The focus of his master's thesis was on soil pH measurements. There are a variety of methods used to measure soil pH, and Thunjai found that the methods had never been compared. One of the goals of his project was to determine the best methods for measuring pH. He has done most of his research using samples from CRSP sites. His results show that the most accurate method for measuring pH is to insert a dual or combination electrode into a stirred slurry consisting of a 1:1 ratio of pulverized, dried soil and distilled water. Thunjai, who finished his master's degree in November 2000, will continue working on characteristics of pond soils as he further pursues a Ph.D.

The road to Auburn has been long, with many turns and twists. Growing up in Chiang Mai, a small village in northern Thailand nestled in a setting of abundant natural resources, may have been the spark that ignited Thunjai's interest in the life sciences. He began his studies in fisheries, attending Kasetsart University, at the time the only university in Thailand with a Fisheries Department. He graduated in 1987 with a major in fisheries biology and a minor in aquaculture and then began to work at the Ministry of Agriculture and Cooperatives as a fisheries biologist and extension officer.

It was while at the Ministry that he noticed that scientists and farmers often had different approaches for solving the same problems. This dichotomy between methods led Thunjai to want to know how to link fisheries sciences with the social sciences. He went back to school in 1994 to get his first master's degree in Social Development and Management from the National Institute of Development Administration.

Simultaneously, Thunjai worked on his second bachelor's degree, a B.A. in Public Administration from Sukhothai Thammathiraj University, an "open" university that allowed students to study at home. He finished the degrees in 1996 and 1997, respectively. As if working on two degrees simultaneously did not keep him busy enough, he continued working with the Ministry while he was in school.

Thunjai notes that both the natural sciences and the social sciences must be integrated with each other before advances in environmental quality and productivity can occur. He hopes that his training in both the natural and social sciences will enable him to address some of the aquaculture problems in Thailand and around the world. A blend of natural and social science—combining flexibility and open communication—can often lead to more productive results when working with traditional aquaculturists, who may initially be resistant to changing long-practiced methods.

Leaving Thailand in 1997 was quite a change for Thunjai, as it was his first time abroad. However, he was excited to work with Boyd and wanted to learn about different cultures. Given that the US and Thailand are quite different, he had to adapt to the different culture and weather patterns. He still misses home, especially the food and his family.

Thunjai spends a lot of time in the lab, but he loves to travel and collect field samples. When he is not working he likes to garden, swim, or visit the nearby Appalachian mountains. Before he returns to Thailand he hopes to visit Alaska in order to see some of the diversity of the US and to see real snow. This diversity that Thunjai thrives on, in both his interests and his experiences, is sure to make quite a difference when this CRSP student enters the world.

Status update: Taworn completed his MS in 2001 and his PhD in 2004 at Auburn University.

GRADUATE STUDENT PROFILE

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Elizabeth Trejos-Castillo

by Steve Sempier

Elizabeth Trejos-Castillo is one of the newest arrivals to the PD/A CRSP. She brings a unique background that will help facilitate CRSP research in Honduras. Trejos grew up in Costa Rica and completed her undergraduate degree at Iowa State University with a double major in psychology and English. Trejos and her husband, Pablo Rolando Martinez-Mejia, then moved to Honduras. While in Honduras Martinez worked at the Escuela Agrícola Panamericana (Zamorano), which hosts the CRSP Honduras Project.

Joe Molnar, a CRSP researcher from Auburn University, interviewed Martinez during a visit to Zamorano. During the interview Martinez told Molnar about Trejos's background. Molnar was looking for a graduate assistant to study aquaculture's sociological impacts on local communities in Honduras and thought Trejos might be a candidate for the position. While Molnar was still at Zamorano, he interviewed Trejos and decided she would be a great addition to the CRSP. She is now back in the US and "enrolled at Auburn. She will return to Honduras this spring to perform her CRSP fieldwork.

Trejos's work will revolve around a Food Security Research investigation under the Tenth Work Plan. The title of the investigation is "Income, Food Security, and Poverty Reduction: Case Studies of Functioning Clusters of Successful Small-Scale Aquaculture Producers." The three objectives of this investigation are to identify clusters of small- and medium-scale producers who have engaged in repeated cycles of tilapia production; to review the circumstances and conditions that contribute to successful implementation and continued practice of tilapia culture; and to formulate principles and guidelines for providing technical assistance and research support for small- and medium-scale tilapia farmers in Honduras.

Trejos believes her work can lead to the development of guidelines on how the adoption process works and clarify

the dynamics of growing tilapia on small farms in Honduras. The intensive portion of Trejos's fieldwork will entail interviewing farmers, extensionists, and community leaders in Honduras. She will speak with individuals and groups for a month and will focus on regions where successful tilapia producers are active.

Trejos is optimistic about tilapia aquaculture in rural Honduras. She notes the benefits of tilapia culture include a new source of income, diet improvement, and increased employment by private aquaculture companies. Trejos also projects that the potential for aquaculture growth in Honduras is strong since there is an adequate supply of water resources. Finally, she notes that women play a vital role in aquaculture ventures in Honduras because they are able to maintain the ponds and feed fish while their husbands are working in the fields.

Although the possibility for aquaculture growth exists, aquaculture development faces several constraints in Honduras. Trejos mentions the lack of technical support, no organized marketing network for tilapia in Honduras, and limited motivation of rural people to adopt a new form of agriculture as obstacles to development. Trejos's project will dig further into these issues and illuminate the sources of these challenges so they can be addressed.

Trejos is busy outside of her CRSP work and graduate studies. Her greatest challenge is balancing graduate school, additional personal goals, and raising two boys. She finds relaxation in photography, art, music, movies, and reading. After completing her project with the PD/A CRSP and graduating from Auburn, Trejos would like to return to Costa Rica to work as a field or community extension agent.

Status update: Elizabeth completed her MS in 2004.

GRADUATE STUDENT PROFILE

Emmanuel Vera Cruz

Emmanuel Vera Cruz first became interested in aquaculture as a high school student in the Philippines. From Emmanuel's point of view, "the Philippines are gifted with an abundance of available land and water resources ideal for many types of aquaculture. However, the conflicts between aquaculture and other forms of agriculture have slowed growth and limited the resources available to aquaculturists. In addition, the development of disease and pollution of important bodies of water caused by poor aquaculture practices and industrial contaminants also suppress[ed] aquaculture's popularity and productivity in the region." Therefore, he chose to learn more about aquaculture, and the science involved in advancing this field.

Emmanuel earned an undergraduate degree in Inland Fisheries at Central Luzon State University in the Philippines in 1984. More recently he was supported by the Aquaculture CRSP to pursue a Ph.D. in Biology from Florida International University (FIU) under Dr. Chris Brown, who characterizes Emmanuel as "just a superb and scholarly chap." Emmanuel's dissertation research,

entitled "Insulin-like Growth Factor-I Gene Expression as a Growth Indicator in Nile Tilapia *Oreochromis niloticus*" centered on the use of hepatic insulin-like growth factor-I (IGF-I) as a growth indicator in Nile tilapia reared under laboratory conditions. Emmanuel is excited about the potential applications of his research. "If hepatic and/or circulating IGF-I gene expression can be proven to be an efficient rapid and short-term indicator of growth in this species of fish, then we can save time and money in growth evaluation studies." He hopes his work will contribute to research-based successes in aquaculture in the Philippines, namely improved design of aquaculture facilities, formulation of feeds and culture of live foods, disease prevention and control, and genetic improvement of farmed fish like tilapia.

After graduating from FIU in December 2006, Emmanuel is now back at Central Luzon State University at the College of Fisheries and Freshwater Aquaculture, where he plans to continue the application of biotechnological research to Nile tilapia and other species of freshwater fish economically important in his home country.

GRADUATE TRAINING SUCCESS

Mr. Enos Mac'Were

Mac'Were Enos was sponsored for his Master's thesis research by the Aquaculture CRSP from 1999 to 2000. After this, he participated as a resource person for Aquaculture CRSP-sponsored aquaculture short courses (12 training series to date) for Kenyan Fisheries Officers (Department of Fisheries and Kenya Marine and Fisheries Research Institute). These courses emphasized pond design, pond construction, pond management, and business planning. Mr. Mac'Were also served as the Farm Manager at the Moi University Fish Farm near Eldoret. He "holds a position as Aquaculture Manager with Dominion Farms, a firm developing a large commercial fish farming enterprise in western Kenya.

Mr. Mac'Were testified to the benefits of his training funded by the Aquaculture, "My exposure to research methods through my thesis work and farmer based research as well as hands-on experience as well as training in fish pond design and construction, and farm

and business planning prepared me effectively for my role as a trainer." He adds, "[The training] also helped to be able to do projects for the government, enabling me to teach aquaculture at Moi University and also to be a consultant for Support Program for Private Extension and Development, a USAID project undertaken by Chemonics International."

Mr. Mac'Were is now a consultant for a number of private fish farmers and farmers-to-be in Uganda and Kenya.

Mr. Were says that his interest in aquaculture was mainly stimulated by Aquaculture CRSP PIs including Host Country PI Dr. Charles Ngugi, Head of the Moi University Department of Fisheries. Mr. Mac'Were has evidently benefited directly from the Aquaculture CRSP investment in his training. He is now passing his knowledge along to others and contributing tangibly to the development of aquaculture in Kenya.

CREATING VALUE FROM NEW FISH SPECIES



Mr. Rafael Martinez Garcia

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

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

Rafael's senior project focused on antibodies and reproduction in the female gar. With most species, hatchery workers determine fish maturity through a biopsy of the eggs, which in turn lets them know when to induce spawning. Gar, however, possess a uniquely sticky egg that is nearly impossible to biopsy and presents a barrier to reproduction. Rafael's research developed a system to measure proteins in reproductive antibodies and determine gar maturity. This is the first indirect sign of spawn readiness for this new culture species, and it provides technicians with a new tool to save time and increase production levels. In addition to his student research, Rafael plays a large role in UJAT's efforts to extend aquaculture to the surrounding population. This work allows the students to present

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

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

Status update from 2008 Aquanews

Rafael Martinez-Garcia was one of six graduate students worldwide selected to receive the Borlaug LEAP Fellowship this spring. The AquaFish CRSP as well as Dr. Raul Ponzoni of the Worldfish Center in Malaysia supported Rafael. Raphael will conduct his research at University of Arizona. Another AquaFish CRSP student, Ravelina Velasco, also received a Borlaug award.

DEVELOPING SUSTAINABLE FEEDING REGIMES IN AFRICAN AQUACULTURE

Victoria Boit

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

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

Victoria conducted an experiment comparing three feeding regimes for rearing catfish larvae at the Moi University hatchery (Chepkoilel Campus, Eldoret) in the summer of 2005. In all treatments she offered live rotifers to the larvae for the first four days of feeding. In one treatment she kept the fry on rotifers for an additional ten days and then switched them to a commercial diet (chick mash). In a second treatment, she substituted *Artemia* nauplii for ten days,

after which she switched to chick mash. In the third treatment, the fry were switched to the chick mash immediately after the first four days on rotifers. The overall duration of the experiment was 30 days. Preliminary results suggest that the best feeding regime was the one in which the fry were fed rotifers for the first 14 days and chick mash for the remaining 16 days. After completion of her Master's degree, Victoria hopes to work at Moi University teaching fisheries and aquaculture and conducting further research. She would also enjoy participating in extension work, for example conducting seminars geared towards promoting aquaculture in the region, and collaborating with organizations like the CRSP, where there might be opportunities to conduct additional studies. She also plans to continue her education by working towards a Ph.D. at some point in the future.

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

Status update:

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

MODELING FISH MANAGEMENT STRATEGIES FOR POLYCULTURE

Vu Cam Luong

Dr. Vu Cam Luong became a lecturer at the Fisheries Department of the University of Agriculture and Forestry in Ho Chi Minh City of Vietnam in May 1997 after he received his Bachelor's degree from the same university that April. He joined the Asian Institute of Technology (AIT) as a Masters student in January 1999 with a DANIDA Master Research Abroad Fellowship, and received his M.Sc. degree in December 2000. He conducted the research entitled "Trophic model and technical-economic aspects of cove aquaculture in Tri An Reservoir of Vietnam" under the supervision of Aquaculture CRSP Host Country PI, Professor C. Kwei Lin.

He was selected as an exchange student to be trained for Ecopath modeling and research methodology from

January–April 2000 at center, Aarhus and Copenhagen University in Denmark, and in September 2001 he started his doctoral study at AIT, with support from the Vietnamese Government Ph.D. Research Abroad Fellowship. The Aquaculture CRSP sponsored his dissertation research entitled "Management strategies of natural food webs for marble goby-carp polyculture in coves based on natural food webs in Tri An Reservoir, Vietnam." His project linked with an Aquaculture CRSP project in Vietnam under HCPI Yang Yi's supervision. He successfully obtained his doctoral degree in December 2004, and returned to his home institution where his research interests are limnology, aquaculture, food web interaction and trophic modeling.

Status update: Luong completed his PhD in 2005.

AWARD-WINNING SHELLFISH RESEARCH IN BANGLADESH

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Md. Asaduzzaman

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

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

In the future, Asaduzzaman wants to implement his knowledge of aquaculture from the classroom into practice for sustainable aquaculture development in Bangladesh. To make this a reality, he plans to study for a Ph.D. in crustacean aquaculture with a focus on farming systems management and monosex culture strategies. Although he was involved in a number of finfish research projects with Aquaculture CRSP, his interests focus on freshwater prawn farming systems. Some of his findings on freshwater prawns were presented by Wahab at the WAS AQUA 2006 conference in Florence, Italy in the crustacean aquaculture session. His presentation was entitled "Farming systems of giant freshwater prawn *Macrobrachium rosenbergii* in Bangladesh: A combination of tradition and technology." The study demonstrated that there were both traditional and improved extensive (combination of traditional and new techniques) freshwater prawn farming systems in terms

of management practices. The study revealed that farmers faced problems with limited access to credit, insufficient supply and high priced quality post-larvae, high priced quality feed, transport and marketing problems, natural disasters, lack of institutional and administrative support, and inadequate infrastructure and extension services. Asaduzzaman's present aim is to raise freshwater prawn productivity without the massive investment common to many intensive systems by combining and upgrading two approaches. The first one is based on microbial control of water quality and recycling of protein through the adjustment of the carbon/nitrogen ratio in the pond. The second one is based on the application of vertical substrates and development of periphyton in extensive ponds, increasing productivity by 70–250%. This new technology is referred to as "C/N controlled periphyton based pond (C/ N-CPP) systems." The expected outcome of this technology will benefit both Bangladesh and exporting countries. Dr. Marc Verdegem from the Wageningen University has been assisting as an external expert.

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

Status Update: Asaduzzaman completed his MS in 2005.

LEGACY BUILDING

Training the next generation of scientists, researchers, and aquaculture and fisheries policy makers has resulted from the long-term nature of the CRSP. It can be said to be a CRSP legacy. Two examples of individuals also trained by CRSP who now serve as major professors for CRSP students.

Wilfrido Contreras-Sánchez received his Master's and PhD degrees at Oregon State with Martin Fitzpatrick, and now is a Host-Country Principal Investigator working at Universidad Juárez Autónoma de Tabasco (UJAT), 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. Wilfrido is division chief at UJAT and the major professor of many students, some of whom were featured in the Graduate Student profiles section of this report.

Yang Yi began as a Ph.D. student under a formed UM CRSP PI, C. Kwei Lin, and is now one of the Aquaculture CRSP's longest involved collaborators, who studies fertilization and alternative feeds at the Asian Institute of Technology in Thailand. Yang Yi served as an AIT professor until he moved to China where he is now serves as lead coordinator of research for the UM AquaFish CRSP project.

INSTITUTIONAL STRENGTHENING

Throughout the reporting period, the Aquaculture CRSP steadily increased its connections with domestic and international institutions, establishing about 340 informal linkages with institutions worldwide.

Such linkages ranged across the full spectrum of organizations from those with global reach and influence (e.g., World Bank, the UN's Food and Agriculture Organization) to small, locally oriented institutions. Among the latter, for example, we established connections to support the Aquaculture for Local Community Development Programme (ALCOM) in Zimbabwe, the Bangladesh Rural Advancement Committee, the Malawi National Aquaculture Center, and the Research Institute for Aquaculture No. 1 in Vietnam, to name a few.

In terminology used by USAID toward the end of the Aquaculture CRSP, we had fostered relationships with three "rebuilding nations" through various approaches.

Colombia:

Prior to offering extension services to farmers in the Peruvian Amazon, the Aquaculture CRSP conducted focused diffusion research to determine local farmers' specific needs based upon gender and current farm production systems. The Aquaculture CRSP developed a focused outreach program based upon these findings, culminating in short-term aquaculture trainings for producers, students, and families from many countries of the Amazon Basin, including Colombia, Ecuador, Bolivia and Peru. Afterwards these participants returned to their home countries, effectively building local and national capacities. So far this project has trained 729 aquaculture producers and 1,233 students, with over 14,800 visits to their outreach website. Researchers in Peru have also developed training materials, including a Spanish-language manual, that is extending knowledge from these outreach activities beyond national borders.

Haiti:

Similarly, the Aquaculture CRSP project in Honduras recently held an international shortcourse on "Tilapia Culture, Marketing, Pond Design, and Construction for Aquaculture and Water Harvest" in the Dominican Republic that welcomed 17 aquaculture producers from Haiti. These participants also returned to their home country, bolstered by the knowledge they gained and

new access to a wide network of international researchers and practitioners.

Nepal:

Our relationship with Nepal, is a result of a steadily building institutional relationship between the Aquaculture CRSP project at the Asian Institute of Technology in Thailand and the Institute of Agriculture and Animal Science (IAAS) in Rampur, Chitwan, Nepal. Since 2003, the Aquaculture CRSP has conducted 6 separate experiments in Nepal. So far these experiments have utilized 18 farmer ponds and 15 ponds at IAAS. The experiments also involved collaboration mainly with Host Country Principal Investigator Madhav K. Shrestha, a staff scientist at IAAS, 2 graduate students, and one research assistant. The net results of these studies include training of local scientists and students, involvement of farmers in testing new production technologies, production increases in polyculture tests compared to monoculture systems commonly used in Nepal, better techniques for intensifying and feeding high valued fish in cages and ponds, and assessment methodologies for determining environmental impacts of non-indigenous species.

INSTITUTIONAL STRENGTHENING IN KENYA

Given the challenges of developing a robust aquaculture research technology in a host country, the Aquaculture CRSP Kenya project has achieved notable successes during its 10-year duration (1997 to 2007). In particular, collaborative efforts between two US institutions (Oregon State University, Auburn University) and two Kenyan institutions (Department of Fisheries, Moi University) resulted in the development of two aquaculture facilities. Today, these have the capacity to independently conduct much-needed aquaculture research. Through these collaborations several personal successes emerged, driven by various forms of training, both formal and informal.

Sagana Aquaculture Center

Sagana Fish Culture Farm has undergone a total overhaul since the Aquaculture CRSP first began working there with the Kenya Department of Fisheries (DOF) in 1997. Several notable improvements were made through Aquaculture CRSP efforts, perhaps reflected in its name change to Sagana Aquaculture Center.

Major improvements to the facility include:

- Installation of a full-featured weather observation system
- Expansion and upgrading of the station's water quality laboratory
- Renovation of ponds to make them suitable for aquaculture research

These changes occurred early in the life of the project, making it possible to proceed with Aquaculture CRSP experiments.

Sagana has provided facilities several times each year for training courses such as those for Fisheries Officers. Some training has been supported within Aquaculture CRSP work plans and some has been funded directly by the DOF or the Kenya Marine and Fisheries Research Institute (KMFRI). Several officers have taken advanced training abroad and returned to bring their new expertise to Sagana.

The DOF has prioritized developing Sagana as a center of excellence for the region and has recently renamed the station: Sagana Aquaculture Center (SAC). Its ponds have been redesigned for experimental work and a number of additional small ponds constructed by trainees in short courses, along with staff trained in advanced techniques at several international institutions, the Center is poised to serve as one of Kenya's top aquaculture research and training centers.

Moi University Fish Farm

Early ties, dating from the project's inception, with the Moi University Department of Fisheries, were formalized through a subcontract between Oregon State University (OSU) and Moi University (MU) in 2000.

At the time the contract period began, MU had only two small ponds and a reservoir on their farm. They had little in the way of an aquaculture program. Through the years of Aquaculture CRSP collaboration, often as a result of training courses that included pond construction exercises, MU steadily developed their farm. Today the facility's ponds cover 2.5 hectares comprising 47 ponds of varying sizes. The university also expanded their reservoir to three times its original size, greatly increasing capacity for aquaculture research.

Much of the research done at the MU facility is done by graduate students, some of whom have been supported by the Aquaculture CRSP. Investigations covering all aspects of tropical aquaculture are addressed, with a focus on tilapia and catfish. Data resulting from the research is exchanged with international researchers and provides evaluation of aquaculture practices that can be replicated by farmers in the field.

Short courses sponsored by the Aquaculture CRSP and run in collaboration with the DOF are developed and conducted at the MU facility as well as at Sagana Aquaculture Center. The development and operation of this facility has created a cadre of highly trained personnel for Kenya's aquaculture industry and fisheries management. It has also empowered local communities by providing extension services through on-farm visits and by training students and officers.



Research ponds constructed with CRSP funding at the Sagana Fish Farm (upper left and right) and Moi University (lower right). CRSP researcher Charles Ngugi at the CRSP weather station at Sagana (lower left).

SUCCESS STORY

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An Informal Training Success: Mr. William Kiama


Today Mr. William Kiama is a successful fish farmer, raising both ornamental fish (goldfish) and tilapia.

When he was first contracted by the Aquaculture CRSP, Mr. Kiama was a horticulturist in the Sagana area. Initially, he was offered work to help renovate some of the fish ponds at Sagana Fish Culture Farm (now Sagana Aquaculture Center).

When the CRSP project began many of Sagana's ponds were too large for research. Between 1997 and 2002, six of the large ponds were modified, to create 24 research ponds. Mr. Kiama worked alongside Aquaculture CRSP US PI Karen Veverica throughout this process, becoming skilled in pond construction. During this time, Mr. Kiama formed the "African Bulldozers," who constructed ponds manually, rather than by using heavy machinery. Through his involvement with the CRSP, Mr. Kiama gained experience using plastic liners for growing goldfish in ponds. In turn, this experience triggered his initial thinking about farming ornamental fish commercially.

Mr. Kiama reflected on his beginnings as a fish farmer, "When comparing the amount of water and the cost of pumping it to grow horticultural crops and growing fish in liners, I found that it was much cheaper to grow fish than continue with horticulture."

In 1999, Mr. Kiama started with two small ponds, which he stocked with tilapia and gold fish. Mr. Kiama expanded his operation to seven ponds fully stocked with various types of ornamental fish. He has imported several species from Thailand and successfully bred them on his farm. He sells fish to customers in Kenya, Uganda, and Tanzania, and plans to purchase more land to culture tilapia and catfish. To meet challenges of marketing his products, Mr. Kiama plans to develop a marketing strategy including a budget for market research. Other challenges include controlling predators such as frogs, aquatic insects, and birds.

Mr. Kiama commented, "I would like to be a centre of excellence in ornamental fish by maintaining high standards and quality supplies in the region. One way is to hire a breeder who can carry out selective breeding to get the best colours as well as fast growing fish." He says that he will consider hiring an aquaculture graduate to assist with the management of his farm to meet the rising demand for fish and training for other farmers.

Status update:

Mr. Kiama is now a full-time fish farmer, planning to add another pond in 2009 due to the high demand for ornamental fish. He has enthusiastically embraced his new profession, offering consulting services in fish pond structure in Kenya and Uganda and currently serving as the treasurer of the Aquaculture Association of Kenya, which received startup funding from the AquaFish CRSP RCE-Africa.



VI. PROGRAM DESCRIPTION

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 research conducted in developing countries and the United States by US and host country scientists. 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 USAID grants. It has developed a flexible research agenda to meet changing host country research needs, an evolving international development context, changes at USAID, and budget fluctuations. Flexibility has not compromised research robustness. Teams of talented researchers in the US and host countries have conducted research activities through collaborative efforts. Excellence is maintained through external peer review and program 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 experiments to meet country-specific research and information needs. However, funding constraints during 1986 and 1987 forced a reduction in operations that eventually resulted in a concentration of activities in fewer countries (Rwanda, Thailand, Honduras, and Panama).

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

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

Meanwhile, the Africa Site Selection Team initiated a search for a new host country in East

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

The Continuation Plan 1996–2001 represented a significant evolution of the program. Proposed research emphasized an approach to aquaculture development that addressed environmental effects and social and economic aspects, as well as production optimization. This fourth grant ushered in a new era of oversight, as the Aquaculture CRSP modified its original advisory structure to increase representation among participating institutions and provide an effective mechanism for new institutions to be represented on the Board of Directors and Technical Committee. The Program Management Office (PMO) 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 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 functions within this most recent grant to this day.

A program such as 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 operating under continual short-term extensions and funding uncertainty. The Aquaculture CRSP confronted this very situation by increasing flexibility in its funding mechanisms, project horizons, and research focus.

The initial extension of the Continuation Plan 1996–2001 was allocated to fulfill all objectives originally proposed as part of the five-year grant but which could not be addressed owing to annual budget cuts over the grant period. Projects funded after 2002, within the Eleventh and Twelfth Work Plans, focus on three program areas — Production Technology; Watershed Management; and Human Welfare, Health, and Nutrition. The Aquaculture CRSP peer-review process was further enhanced at this time through adoption of peer-review panels modeled after the National Science Foundation's acclaimed process.

In 2006, the Aquaculture CRSP reached its tenth year of operations under the existing grant. Hoping to extend the program into 2006–2007, the Aquaculture CRSP Director submitted an Extension Plan for funding at the request of USAID. This one year of supplemental funding allowed the Aquaculture CRSP to continue research involving graduate students and focus on outreach activities to further ensure the long-term impact of the program. Also in 2006, a newly mandated Aquaculture & Fisheries CRSP was hotly competed among US universities, with a transparent peer review process managed by USAID. OSU won the competitive bid for the new AquaFish CRSP on 29 September 2006. Both programs ran concurrently for two years, until ACRSP ended on 30 September 2008.

The Aquaculture CRSP ended in the midst of an active era of cooperation as it leveraged its funds and successfully networked with other government agencies and NGOs. Two notable examples of leveraging have led to 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, which involved long-time Aquaculture CRSP investigators from Honduras, Kenya, Mexico, the Philippines, and Thailand, completed its site visits in 2006 to observe and exchange information related to each country's experience with cichlid culture to further advance production and environmental sustainability in each home country.

In 2004 a USAID SPARE (1) Panel made the following statements that clearly establish the context in which ACRSP was ended and the new Aquaculture & Fisheries (AquaFish) CRSP was put in place. "Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and invaluable providers of employment, cash income, and foreign exchange. Fisheries products are the world's most widely traded foods, with commerce dominated by the developing countries. Fisheries products are the primary protein sources for some 950 million people worldwide, and are an important part of the diet of many more. In comparison to other sectors of the world food economy, however, the fisheries and aquaculture sectors are poorly planned, inadequately funded, and neglected by all levels of government. This neglect occurs in a paradoxical situation: fishing is the largest extractive use of wildlife in the world; and aquaculture is the most rapidly growing sector of the global agricultural economy... The lack of US engagement in international fisheries and aquaculture not only compromises America's financial position: an important part of our Nation's food security is at risk; and our domestic fisheries and aquaculture industries are rapidly losing their competitive position."

The motivation for change was USAID's desire to end old CRSPs and initiate new ones. USAID wanted to realign the dated CRSP portfolio to better meet a changing world's needs and at the same time attract new talent and greater value to its research portfolio. CRSPs remain the primary vehicle through which USAID can accomplish research and capacity building in agriculture. Within this context, USAID decided to end the Aquaculture CRSP. In its place came the idea for a new CRSP — called Aquaculture & Fisheries — and an RFA (Request for Assistance) seeking proposals for a new Management Entity was issued 24 May 2006. Oregon State University competed against a number of other fine universities to win the award for the new CRSP. Because of a good faith agreement with the CRSP Council, USAID allowed the Aquaculture CRSP and the new Aquaculture & Fisheries (AquaFish) CRSP to operate concurrently. Both are managed by Oregon State University, although only the Aquaculture CRSP is the subject of this Final Report.

In the final funded year of Aquaculture CRSP, in 2006, 683 students had completed their university degrees — over 357 with advanced graduate degrees — in disciplines related to business, ecology, health, agriculture, and natural resources. Aquaculture CRSP offered short-term trainings and topical workshops to over 4500 people in developing countries. Over time, Aquaculture CRSP managed a portfolio of 41 direct agreements with US universities and had extended subcontracting relationships with 32 US institutions, involving 24 countries. Technologies developed by Aquaculture CRSP include Decision Support Software; the world's largest database on ground-truthed pond variables; pond construction techniques allowing improved use of up to 13 million hectares (ha) of land in Southeast Asia; and novel feeding technologies to reduce costs by about \$400/ha, translating into a 17% increase in the net value of the crop.

LOCATIONS

During the reporting period, the Aquaculture CRSP developed formal and informal linkages with thousands of participants across hundreds of geographical locations. A complete list of

linkages with institutions and their locations is provided in Appendix 5. Formal ties between US and Host Country institutions, represented by MOUs were established as follows:

US Institution, Host Country Institution, Host Country

An abbreviated list of international collaborating institutions. Refer to Appendix 5 in Volume 2 for a complete listing.

- | | |
|---|--|
| • Bangladesh Agriculture University, Bangladesh | • Carbondale |
| • EMBRAPA, Brazil | • Instituto de Investigaciones de la Amazonia Peruana, Peru |
| • University of Georgia | • Universidad Nacional de la Amazonía Peruana, Peru |
| • Escuela Agrícola Panamericana Zamorano, Honduras | • Florida International University |
| • Auburn University | • University of Hawaii at Manoa |
| • Moi University, Kenya | • Freshwater Aquaculture Center, Central Luzon State University, Philippines |
| • Department of Fisheries, Ministry of Livestock Fisheries Development, Kenya | • Central Luzon State University, Philippines |
| • Ministry of Agriculture & Rural Development, Kenya | • Stellenbosch University, South Africa |
| • Oregon State University | • Purdue University |
| • Universidad Juárez Autónoma de Tabasco, Mexico | • Fisheries Aquaculture Development Division, Tanzania |
| • University of Hawaii at Hilo | • University of Michigan |
| • Universidad Autónoma de Sinoloa, Mexico | • Asian Institute of Technology, Thailand |
| • Institute of Agriculture & Animal Science, Nepal | • Can Tho University, Vietnam |
| • Southern Illinois University at | • Research Institute for Aquaculture No. 1, Vietnam |
| | • University of Agriculture & Forestry, Vietnam |

Host Countries

The Aquaculture CRSP conducted investigations are being conducted in 24 countries including:

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

Previous activities were conducted in the following seven countries:

Egypt	Mali
Indonesia	Rwanda
Laos	Senegal
Malawi	

2006 Lead Subcontracting US Institutions

Auburn University, Alabama
 Cornell University, New York (NY Sea Grant)
 Florida International University
 Oregon State University
 Purdue University, Indiana
 Southern Illinois University at Carbondale
 The Ohio State University
 The University of Michigan
 University of Arizona
 University of Arkansas at Pine Bluff
 University of Georgia

University of Hawaii, Hilo
 University of Hawaii, Manoa
 University of Oklahoma
 Institute of Agriculture and Trade Policy
 University of California, Davis
 University of Texas, Austin
 Michigan State University
 Institute for Fisheries Economics & Trade

Subcontracting US Institutions

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

Puerto Rico Sea Grant
 Texas Sea Grant
 Indigenous Environmental Network, Minnesota
 Hofstra University, New York
 University of Delaware
 Heifer International
 NOAA Sea Grant, US Department of
 Commerce

The total number of student nationalities trained in formal degree programs through Aquaculture CRSP activities is broader than the country list above with 25 additional nationalities. The global impact of the Aquaculture CRSP extends beyond its active host countries given the fact that 99% of Aquaculture CRSP students return to their home countries following completion of their degree program.

PROGRAM MANAGEMENT

From the outset, we recognized that mutually beneficial development strategies have the best chance of being sustained over time. Likewise, the organizational structure of the CRSP encourages collaboration among researchers, institutions, and countries. The Management Entity (ME), located at Oregon State University, administered our programs. ME activities at OSU are carried out through a Program Management Office (PMO), which is supported in the task of program administration by advisory bodies.

A Technical Committee assisted the Management Entity in guiding the research program. Researchers from US universities and host country institutions, and occasionally from IARCs and the private sector comprised the Technical Committee, which advised the ME on technical matters. The organization of the TC centered around three strategic research areas: production optimization, environmental effects, and social and economic aspects. The composition of the TC is diverse, representing various disciplines and institutions and including women and men from US and Host Country CRSP projects. TC members served two-year terms. In accordance with BIFAD guidelines, the USAID Cognizant Technical Officer, CRSP Director, and CRSP Assistant Director serve as ex-officio members of the TC.

The Board of Directors was initially the primary policy-making body for the CRSP. Later, perceived conflicts of interest concerning this internal board led to the creation of the EPAC (External Program Advisory Council), an external policy advisory board to the Director. The former internal Board of Directors became Institutional Representatives not concerned with policy-setting.. An External Evaluation Panel of eminent aquaculture specialists evaluated the accomplishments of the individual research projects and the overall program to ensure that research remained focused, relevant, and cost-effective on a multi-year basis (in 2000). After the full review by the EEP, and USAID's administrative management review (AMR), the EPAC evaluated the program almost annually and all of those reports have been submitted to USAID.

To establish a portfolio of activities, the Director, through a consultative process, set overall themes for aquaculture and responsible aquatic resource management research and outreach in developing countries, and conducted regional priority setting processes to engage regional stakeholders in Africa, Asia and Latin America. Through a peer-reviewed competitive process, the ME selected focused projects and managed those projects through completion. The projects involved in the Aquaculture CRSP are diverse and draw upon the great depth and expertise in the US university, NGO, governmental and private sector community. The overall context for the program is sustainable aquaculture development in coastal and inland areas, while specific project areas (themes) covered key research needs of the aquaculture community.

OVERALL DESCRIPTION OF ACTIVITIES

Appendix 1 (Volume 2) provides a complete list of Aquaculture CRSP activities from the Eighth Work Plan reporting period through the end of the program.

In all 313 Investigations are listed together with their research status. More than half (187) of the Investigations were Successfully Completed, whereas most of the others (118) were Successfully Completed With Modification. Modifications, in most cases, were for specific technical reasons and required additional technical review prior to approval. A small number (8) of Investigations were Suspended for reasons specified in the table in Appendix 1.



VII. LESSONS LEARNED

The Aquaculture CRSP overcame many challenges as it developed research, education, and outreach in aquaculture all around the globe.

Aquaculture CRSP projects identified several consistent limitations for consistent solid growth of the programs it initiated or participated in. Such constraints were foremost in planning as the CRSP built on previous investments, and sought new research directions and opportunities for collaboration.

Major constraints included:

- Inefficient or inconsistent aquaculture productivity
- Poor understanding of social and /or economic factors in farm profitability
- Insufficient human capacity
- Poor or outdated information management
- Political or structural inadequacies
- Limited networking capabilities

Of course, this report encompasses the means by which Aquaculture CRSP PIs dealt with such constraints. Here we focus on the lessons we learned, so this knowledge can benefit future aquaculture development and capacity building.

Lesson 1. Select motivated, capable Host Country personnel and provide them opportunities for leadership

The most frequent comment by reporting PIs regarding lessons learned was the need to recruit excellent Host Country personnel and to involve them appropriately.

Host Country Principal Investigators (HCPI) facilitate communication to help in expand local research opportunities. They can liaise with host country governments to procure funding or other support. The HCPI has a crucial role in recruiting students to participate in research and outreach. A motivated, productive HCPI will motivate productive students.

HCPIs and participants also need opportunities for leadership roles. One Aquaculture CRSP Lead PI commented, "Projects that rely heavily upon the expertise and input of host country PIs are probably the best ones." (Claude Boyd, Auburn University)

HCPIs with many responsibilities take ownership of their projects and are more dedicated to providing input and follow-through. Furthermore, HCPIs should be the primary leaders of local outreach activities. Their working knowledge of regional languages, appropriate speakers, and interested parties gives them unparalleled advantages in organizing workshops and seminars in host countries, and in collaborating with other PIs for such events. Another Aquaculture CRSP Lead PI (William Tollner, University of Georgia) noted that the Kenya project "...underlined the requirement to have a good involvement of host country personnel in workshop planning. All workshops had good attendance [when] host country people were involved in doing the groundwork."

An Aquaculture CRSP project in Honduras suffered from the lack of HC personnel training and

leadership. No Honduran counterpart to the US CRSP researcher existed when the project was completed, so once-productive research facilities are now inadequately managed and deteriorating. Aquaculture CRSP Lead PI Kevin Fitzsimmons (University of Arizona) sums up these lessons "...any successful effort in international development requires a strong commitment and partnership between the US and host country collaborators. The best-laid plans will flounder if a committed host country scientist is not there to push the progress of the project. It is only the host country PI who can spread the training, concept, or technique to the large numbers of people we desire to impact."

Lesson 2. Take advantage of alternative sources (NGOs, local universities/institutions) when confronted with poor HC government support

Several Aquaculture CRSP Lead PIs reported problems communicating with or obtaining local government support or AID Mission support in host countries. As in the above Lesson Learned, Aquaculture CRSP PIs reported the need for strong and effective Host Country PIs to serve as communication liaisons with host country government personnel. Aquaculture CRSP Lead PI William Tollner observed, "It is important to work with interested governmental organizations such as FAO and [African fisheries] ministry officials... host country people were instrumental in making these contacts."

When government support is unavailable or inconsistent, several Aquaculture CRSP PIs reached out to alternative resources to help support their projects. Often, these were mutually interested non-governmental organizations and local universities. An Aquaculture CRSP PI on a project in Honduras reported, "Many NGOs have fish culture components in their development activities and extension agents to provide guidance and advice to rural farmers and families." Their collaboration resulted in this project being able to provide training programs in Nicaragua, El Salvador, Chile, Guatemala, and the Dominican Republic.

Educational institutions share with the CRSP a similar conceptual framework regarding the interconnected roles of education, research, and extension. They can therefore provide invaluable help managing funds, facilitating communication, and eliciting responses from decision-makers. Jim Bowman, an Aquaculture CRSP Lead PI, reported of his Kenya project, "University faculty seem to have been better able [than government] to grasp the hows and whys of research and how research relates to farmer needs, training, extension, and aquaculture development."

Include students in research, workshops, and outreach

Aquaculture CRSP Lead and Host Country PIs consistently spoke highly of the talent, productivity and energy students brought to their projects.

When students were given responsibility within a project, their productivity and interest reflected their sense of ownership. Claude Boyd, an Aquaculture CRSP Lead PI working in Thailand, was able to provide only minimal direct supervision over his host country graduate student. However he performed site visits and reviewed her work while giving her a lead role in developing a publication on pond bottom soil best management practices. Boyd reported that "She felt considerable pride in the results, and this was a positive aspect of her graduate school experience."

The relationship between students and Aquaculture CRSP projects was inter-dependent, yet synergistic for both sides. Aquaculture CRSP projects provided excellent opportunities for graduate student research opportunities that met thesis requirements. Conversely, those students supplied the labor and, in some cases, knowledge, needed for the project's completion. Jim Diana, a Lead Aquaculture CRSP PI reported, "The CRSP in Southeast Asia has considerably expanded the short-term and long-term capacity for research on aquaculture in the

region. This capacity has been mainly built through student involvement, since students are young, active, in search of research projects, and eventually move on to other institutions where we can continue this interaction. We have had great success with student-run projects and believe they are the secret to long-term research capacity.”

PIs from Africa, Latin America and Asia also report the success of using students to recruit local farmers into research programs, and to organize outreach activities. Host country students speak regional languages and dialects. This capability facilitates communication and offers possibilities for collaboration with local farmers. Kevin Fitzsimmons wrote, “Development of polyculture systems has been implemented faster than scientists can run experiments and document the impacts.” Without student and farmer involvement, that gap would be larger still.

Lesson 3. Engage farmers in research, workshops, and outreach

In prioritizing the recruitment of excellent host country personnel, project managers must also involve local farmers in CRSP projects.

Some research endeavors are indeed best suited to dedicated research facilities, but other projects may be more effectively performed at private fish farms. By including working farms, researchers increase the quantity of data, and demonstrate the benefits of applying research findings to farms throughout the host country or region. Aquaculture CRSP PIs stress the importance of selecting farmers who will support the scientists’ efforts. The potential bias of non-random farm selection is offset by the higher quality of data. Jim Diana, an Aquaculture CRSP PI with many on-farm trials conducted in Southeast Asia, notes that one way to ensure sustainable recruitment is to follow up with farmers, so “they may see some tangible outcome from their involvement.”

University faculty and government agents may have a deeper understanding of aquaculture theory and practices, but farmers who are often best able to communicate with other farmers. Aquaculture CRSP PIs have commonly reported that farmers should be used to recruit other farmers for research and outreach activities. Aquaculture CRSP Lead PI Kwamena Quagraine has suggested using “farmer associations to mobilize training participants and [recruit] subjects for surveys.” Moreover, at Quagraine’s workshops, farmers were happily willing to share fish farming experiences, and to demonstrate the importance and techniques of good record keeping. In this way, local farmers augment networking and information management, two of the major constraints to productive aquaculture in host countries.

Make every effort to understand social or cultural differences in order to facilitate communication and enhance productivity

Communication barriers can slow or even halt the progress of the most productive project. Whether those communication barriers comprise interpersonal differences or incompatible technologies, the best solution is to proactively examine potential limits to communication. Effective Host Country PIs are best positioned to provide successful communication between Lead US PIs and host country personnel.

Not all HC project participants may be fluent in English. So, for example, effective workshops include native language speakers and thorough training materials in the local language as well as English. Even when fluency is not an issue, nuanced differences between cultures may diminish communication. Jim Bowman reported of his Aquaculture CRSP project in Kenya that misunderstandings resulted in resentment although “the people involved had nothing but the best of intentions towards one another and with respect to project goals.” His recommendation is that “Collaborators therefore have to practice their very best communications skills, they have

to recognize that the same language is used differently in different locations... and they have to go out of their way to be sure that all sides have interpreted every conversation the same way.” He also noted that potential problems may be multiplied where project participants use different languages.

When reporting on lessons learned, Aquaculture CRSP researchers stress the need for sensitivity to social or cultural differences within host countries. Cultural values or technological literacy may affect participant attitude or motivation, and influence individual or project success. Aquaculture CRSP PIs suggested consulting social scientists to enlighten US personnel on cultural differences, and to achieve effective communication within host countries.

Different attitudes and views regarding gender roles should be considered when working in some regions. PIs from Central America to Africa to Asia reported issues of gender inclusion in their Aquaculture CRSP research projects and outreach. Although aquaculture tends to be male-dominated, PIs often found that women want to participate in aquaculture workshops and research.

Project organizers should make every effort to include women, while also understanding the social or cultural factors inhibiting their involvement. Dale Baker and Michael Timmons reported of their project in Mexico that they purposefully selected a female Host Country PI, with the understanding that they might encounter additional problems in that country’s male-dominated society. Their Host Country PI was able to surpass several cultural barriers, reinforcing the importance of choosing motivated, productive host country personnel. Training the next generation of female aquaculturists will be achieved through including female fish farmers in outreach activities and female graduate students in Aquaculture CRSP research projects. One Aquaculture CRSP PI reported that such inclusion “is overcoming gender barriers that exist in the more senior members of university faculty.”



VIII. FINANCIAL SUMMARY

These financial data are intended to supplement and not replace the official financial reports filed by the University with USAID. SF269 reports and other financial data are sent to USAID on a quarterly basis. The final financial report will be submitted independently of this Final (Technical) Report by the university administration. This section provides a summary of program funding from 1996 through 2008.

The following data show obligations from USAID to the ME, and allocations to projects and activities from the PD/A CRSP ME. The total award amount for PD/ACRSP was originally \$13,773,223 for the first 5-year Continuation Plan. During the second peripatetic 5 years, and additional \$8.15 million was authorized, for a total of \$21,923,223. This averaged to \$2.15 million per year over the 10 years of funded life on the grant, but less if the two no-cost extensions at the grant's end are included. The CRSP received \$500,000 less than the authorized ceiling in actual obligations from USAID. Not reaching the ceiling was not uncommon for programs of this magnitude and is a shared experience among many CRSPs.

PD/ACRSP Grant Modification History 1996-2008

description	date signed	grant amount	obligated amount	obligated date
ACRSP grant	9/9/96	\$13,773,223	\$2,250,000	6/30/97
Modification 1	7/2/97		2,200,000	4/30/98
Modification 2	5/15/98		1,500,000	
Modification 3	8/21/98		200,000	4/30/99
Modification 4	2/9/99		55,000	
Modification 5	5/3/99		1,750,000	4/30/00
Modification 6	7/14/00		1,950,000	4/30/01
Modification 7	7/27/01		2,150,000	4/30/02
Modification 8	7/17/02		1,718,223	7/31/03
Modification 9	7/28/03	2,150,000	2,150,000	8/31/04
Modification 10	8/31/04	6,000,000	2,150,000	7/31/06
Modification 11	5/2/05		2,150,000	
Modification 12	7/31/06		1,270,000	6/30/07
Modification 13	6/20/07		no cost extension	6/30/08
Modification 14	8/14/07		Correction	
Modification 15	6/5/08		no cost extension	9/30/08
		\$21,923,223	\$21,493,223	

Buy-in funding from other groups in support of CRSP activities shows that at least \$2,674,092 was leveraged over 10 years. Leveraged-funding reporting was not a grant-reporting requirement. Thus, the data underestimates the true contributions from other sources, excluding formal cost-share. Our best guess is that two or three times that amount was leveraged for the full 12 years.

Buy-ins documented from 1996-2006 (not counted as cost sharing)

FY 97	\$60,780
FY 98	\$52,082
FY 99	\$85,500
FY 00	\$104,500
FY 01	\$226,167
FY 02	\$1,140,288
FY 03	\$647,870
FY 04	\$10,700
FY 05	\$107,375
FY 06	\$238,830
Total	\$2,674,092

Buy-ins were received by CRSP US University subcontracting partners from a number of sources from 1996 through 2006.

US Institution	Source of Funding	Type of Funding
Auburn University	Honduran Ministry of Agriculture	Host Country Government
Auburn University	ANDAH (Honduran National Association of Aquaculturists)	NGO
Auburn University	The University of Machala, Peru	Host Country Institution
Auburn University	Shrimp growers in host countries	Host Country Private Sector
Oregon State University	InterCRSP	NGO
Oregon State University	Food and Agriculture Organization and Oregon State University	United Nation/ Public Institution
University of Arkansas, Pine Bluff	Intervet, Inc.	US Private Sector
University of Hawaii	The GIFT Foundation	NGO
Auburn University	Alabama Catfish Producers Association	NGO
Auburn University	Chilean Nitrate Corporation	Host Country Private Sector
Oregon State University	UJAT and PROMEP	Host Country Institution
Auburn University	LVEMP secretariat	Host Country Government
Oregon State University	Auburn University Environmental Institute	Public Institution
Oregon State University	National Council for Science and Technology	National Organization
Oregon State University	Centla Wetlands Reserve Trust Fund (FIRB-Centla)	NGO
Ohio State University	Secretariat of Agriculture, Catting, Fisheries and Food (SEGARPA)	Host Country Government
SIUC	NAU La Molina	NGO
Oregon State University	Terra Nuova	NGO
Ohio State University	National Program for Professor's Improvement	Public Institution

US Institution	Source of Funding	Type of Funding
University of Arizona	Ohio State University Research Foundation (OSURF)	Public Institution
University of Arizona and SIUC	The China Aquatic Products Processing and Marketing Association	Host Country Private Sector
Oregon State University	FONDEPES	Host Country Institution
Oregon State University	NOAA/ SeaGrant	US Government
Oregon State University	Heifer International	NGO

US universities contributed substantial matching funds from non-federal sources, typically State funds. The cost-share contributions amounted to over \$3.8 million, \$319,000 over the amount required in the Grant. Under this Grant, cost-share was reported as non-federal contributions following OMB regulations. US universities were required to match 25% of costs that were not excluded. Exclusions included such costs as host country student degree training and funds spent in or on behalf of host countries, along with other exceptions. Even with these exclusions, overall cost-share contributions were higher than required at 22.5% from the research, research support, and advisory components. As with all CRSPs that followed earlier BIFAD Guidelines, management costs were exempt from cost share requirements. Regardless, the ME at Oregon State University contributed over one-third of the cost share under the Grant.

Aquaculture CRSP Grant Non-Federal Cost Share Summary

US University	Actual Total Cost Share Received
University of Arkansas, Pine Bluff	152,825
University of Oklahoma	43,632
University of California, Davis	29,642
University of Michigan	301,935
University of Texas at Austin	4,066
Auburn University	625,558
University of Arizona	224,145
Southern Illinois University	473,119
University of Hawaii, Manoa	23,166
University of Georgia	120,185
Florida International University	166,944
The Ohio State University	226,656
Michigan State University	37,931
University of Hawaii, Hilo	28,457
Institute for Agriculture and Trade Policy	4,457
Cornell University	14,577
Purdue	6,292
Oregon State University	1,349,060
Total Cost Share Committed	\$3,832,648

Aquaculture CRSP Grant Non-Federal Cost Share Summary

US University	Actual Total Cost Share Received
Cost Share Required under the grant	\$3,519,659
Cost Share Over the Requirement	\$319,314
Cost Share: grant modification reference	
Original grant document 8/1/96	Modifications of Assistance 9, 10, 12

Host Country institutions were also asked to contribute resources to CRSP efforts in the form of in-kind supplies and services, direct financing, and personnel support. These contributions to the CRSP provide an essential indicator of Host Country support of project activities, and in turn an indicator of program robustness overall. Host Country institutions were not required under the Grant. However, estimates of over \$400,000 per year by Host Country researchers indicate that the Host Countries were institutionalizing the CRSP -- they found that CRSP activities were well worth contributing to. Most of the Host Countries provided in-kind support for lab space, utilities, faculty time, and student assistantships.

Of the \$21,493,223 million awarded to CRSP over its 12 years of operations, through 30 September 2008, 74% was allocated to research and research support activities; 20% was allocated to central capacity building activities and management; and 6% was allocated for CRSP advisory groups, planning, and program evaluation.

ACRSP, through OSU, allocated funds to 41 separate subcontracts or MOUs. Multiple awards were made to a single institution for a variety of reasons such as timing (previous subcontract had lapsed during a competitive funding cycle); change of department within a university, and on request of the Principal Investigators of a participating US university. Institutions receiving multiple awards included: Auburn University (10 awards); Oregon State University (10 awards, plus Advisory Groups index); University of Arkansas at Pine Bluff (3 awards); University of Michigan (2 awards), and University of Georgia (2 awards).

Over time, seven universities stand out as key recipients of CRSP funds: Auburn University, University of Michigan, Southern Illinois University at Carbondale, University of Arkansas at Pine Bluff, University of Arizona, Florida International University, and Oregon State University. Each university was allocated over \$500,000 in CRSP subcontracts. Many universities issued secondary subcontracts involving others (see list in Chapter VI). These secondary relationships were encouraged as a means to broaden the reach of CRSPs.

Regionally the funding went to the areas of the world that were most active and able to engage in aquaculture, when it was still a relatively new farming activity. Country level reporting shows attributions across the board. The idea is that all aspects of the program support the CRSP mission primarily in various countries, and secondarily to a much lesser extent in the US.

Aquaculture CRSP Allocations 1996-2008*

University	Allocated Amount
RESEARCH COMPONENT	
University of Arkansas, Pine Bluff	686,260
University of Oklahoma	117,280
University of California, Davis	78,101
University of Michigan	2,237,576
University of Texas at Austin	19,767
Auburn University	2,511,243
University of Arizona	618,271
Southern Illinois University	1,118,019
University of Hawaii	100,061
University of Georgia	577,940
Florida International University	486,264
Ohio State University	378,477
Michigan State University	57,020
University of Hawaii, Hilo	258,030
Institute for Agriculture and Trade Policy	17,687
Cornell University	82,265
Purdue	41,407
Indirect paid by OSU on behalf of subcontracts	198,617
OSU Dept F&W (Africa)	1,095,093
OSU Dept Bioresource Engineering	313,524
OSU Dept F&W (Mexico Fish Reprod)	932,727
OSU Dept Ag & Resource Economics	14,150
OSU Dept Bioresource Engr (Global Database)	279,714
OSU Host Country Pls	457,772
TOTAL RESEARCH	12,677,265
RESEARCH SUPPORT COMPONENT	
IIFET 2006 Portsmouth	35,000
OSU PD / A CRSP (Info Mgnt Networking IMNC)	2,974,659
OSU OIRD (Education Dev Component EDC)	244,970
TOTAL RESEARCH SUPPORT	3,254,629
RESEARCH & RESEARCH SUPPORT	15,931,894
ADVISORY, PLANNING & EVALUATION	
OSU - Advisory Bodies	672,721
OSU Planning, Policy, Global Analysis	589,396
TOTAL ADVISORY & EVALUATION	1,262,117
MANAGEMENT	
OSU - Program Management Office	4,299,212
TOTAL PROGRAM	21,493,223

* Estimated figures are presented as official grant financials were not closed out as of the due date of this Final Technical Report