AQUAFISH COLLABORATIVE RESEARCH SUPPORT PROGRAM

IMPLEMENTATION PLAN 2009-2011

APRIL 2010

AquaFish CRSP
College of Agricultural Sciences
Oregon State University
418 Snell Hall
Corvallis, OR 97330-1643 USA

USAID FROM THE AMERICAN PEOPLE

OSU Oregon State University

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The mission of the AquaFish Collaborative Research Support Program (CRSP) is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. Bringing together resources from host country institutions and US universities, the AquaFish CRSP emphasizes sustainable solutions in aquaculture and fisheries for improving health, building wealth, conserving natural environments for future generations, and strengthening poorer countries' ability to self-govern.

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

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INTRODUCTION

The seven core research projects described herein represent all of the key regions, themes, and topic areas called for in the IEHA and second AquaFish CRSP Request for Proposals, both issued in 2009 by Oregon State University, which serves as Lead Institution for the oveall AquaFish CRSP. As a group these projects include 16 countries, 15 US universities, and over 20 HC institutions in formal funded partnerships, plus more than 70 additional collaborators in informal partnerships. The seven core research projects contain over 40 investigations accounting for approximately US$3.25 million from the USAID, not including management costs or other outreach expenditures. Each project additionally provides over 50% in matching funding for each federal dollar received.

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

1. Develop sustainable end-user level aquaculture and fisheries systems to increase productivity, enhance international trade opportunities, and contribute to responsible aquatic resource management;

2. Enhance local capacity in aquaculture and aquatic resource management to ensure long-term program impacts at the community and national levels;

3. Foster wide dissemination of research results and technologies to local stakeholders at all levels, including end-users, researchers, and government officials; and

4. Increase Host Country capacity and productivity to contribute to national food security, income generation, and market access.

USAID (May 2006, RFA) looks to the AquaFish CRSP to "develop more comprehensive, sustainable, ecological and socially compatible, and economically viable aquaculture systems and innovative fisheries management systems in developing countries that contribute to poverty alleviation and food security."

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

Also included in this *Implementation Plan* are three additional projects located at Oregon State University:

- **Impact Assessment** — An evaluation of the Phase I (2007 – 2009) and Phase II (2009 – 2011) AquaFish CRSP investigations by examining research productivity and project impact assessment. The analysis will focus on systems relationships. Investigations are coded under Topic Area.
- **Synthesis** — A characterization of the Phase I (2007–2009) project accomplishments on the basis of porject objectives and resources. A framework will be developed to assess investigation accomplishments by Topic Area.
- **Journalism** — A journalistic approach for preparing stories to illustrate project successes and sustainable benefits. Stories will be developed for a variety of venues and project staff will be

trained in communication techniques for explaining their work to international media and decision-makers.

Global AquaFish CRSP Project Themes (Goals)

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

Each project identified one AquaFish CRSP theme as its primary focus, but also addressed all four themes in an integrated systems approach. The global themes of the CRSP are cross-cutting and address several specific USAID policy documents and guidelines, including the *Policy Framework for Bilateral Foreign Aid*, *Agriculture Strategy*, EGAT Offices of Agriculture & Natural Resource Management Strategic Objectives, and IEHA (Initiative to End Hunger in Africa). The themes also address global initiatives and strategies that relate to the overall program goal.

AquaFish CRSP Topic Areas for Research, Outreach, and Capacity Building

Thematic projects contain work plans (investigations) organized around a number of specific areas of inquiry called Topic Areas. Projects contain between five and eight investigations. Projects focus on more than one topic area in describing aquaculture research that will improve diets, generate income for smallholders, manage environments for future generations, and enhance trade opportunities. Projects were formed around *core program components*, as identified by USAID:

1. a systems approach
2. social, economic, and environmental sustainability
3. capacity building and institution strengthening
4. outreach, dissemination, and adoption
5. gender integration

A systems approach requires that each CRSP project integrate topic areas from both *Integrated Production Systems* and *People, Livelihoods and Ecosystem Interrelationships.* USAID also encourages the CRSP portfolio (the sum of all funded projects) to address biodiversity conservation and non-GMO biotechnology solutions to critical issues in aquaculture. While not every investigation individually addresses each element recommended by USAID, each overall project describes a comprehensive development approach to a problem.

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

Research and Outreach Topic Areas: Integrated Production Systems

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

pest management (IPM) approach and be careful to consider consumer acceptance and environmental risk of selected treatments.

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

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

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

Research and Outreach Topic Areas: People, Livelihoods, & Ecosystem Interrelationships

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

6. **Food Safety & Value-Added Product Development (FSV)**
Ensuring high quality, safe, and nutritious fish products for local consumers and the competitive international marketplace is a primary research goal. Efforts that focus on reducing microbial contamination, HACCP controls and hazards associated with seafood processing, value-added processing, post-processing, and byproduct/waste development

are of interest. Consumers and producers alike will benefit from research that contributes to the development of standards and practices that protect fish products from spoilage, adulteration, mishandling, and off-flavors. Certification, traceability, product integrity and other efforts to improve fish products for consumer acceptance and international markets are desired. Gender integration is important to consider as women are strongly represented in the processing and marketing sectors. (Aquaculture-Fisheries Nexus Topic Area)

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

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

9. **Watershed & Integrated Coastal Zone Management (WIZ)**
Aquaculture development that makes wise use of natural resources is at the core of the CRSP. Research that yields a better understanding of aquaculture as one competing part of an integrated water use system is of great interest. The range of research possibilities is broad—from investigations that quantify water availability and quality to those that look into the social context of water and aquaculture, including land and water rights, national and regional policies (or the lack thereof), traditional versus industrial uses, and the like. Water quality issues are of increasing concern as multiple resource use conflicts increase under trends toward scarcity or uneven supply and access, especially for freshwater. Ecoregional analysis is also of interest to explore spatial differences in the capacities and potentials of ecosystems in response to disturbances. Innovative research on maximizing water and soil quality and productivity of overall watersheds is of interest. Pollution is a huge concern, as over 50% of people in developing countries are exposed to polluted water sources. Additionally, aquatic organisms cannot adequately grow and reproduce in polluted waters, and aquaculture may not only be receiving polluted waters, but adding to the burden. Rapid urbanization has further harmed coastal ecosystems, and with small-scale fisheries and aquaculture operations in the nearshore, integrated management strategies for coastal areas are also important. (Aquaculture-Fisheries Nexus Topic Area)

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

Program Regions

Projects were selected that focused on one USAID-eligible country within a region, but had activities in nearby countries within the same region. Proposed activities received USAID country-level concurrence prior to award. Non-concurrence meant that a project or investigation was not approved for funding, as was the case with an investigation that included Bangladesh. The USAID Mission in Bangladesh did not concur due to perceived management overload; another CRSP was also denied the privilege of working in Bangladesh. Each project site will be described in a separate volume of site descriptions due for completion in 2008.

Rules of Conduct

Rules of conduct are described in greater detail in each project's subcontract with the Management Entity and in other program documents. The following subset of rules especially pertains to the *Implementation Plan*.

Fostering Respectful Partnerships: Projects aim to foster linkages with organizations including US minority-serving institutions, non-governmental organizations (NGOs), national agricultural research institutions, other CRSPs, international centers, private businesses, and others as desired. Projects that link Host Country researchers from one CRSP site to another CRSP site are encouraged. US and Host Country PIs share in budgetary decisions and overall priority setting for the project, as well as in other collaborative activities related to the CRSP. Proposals, work plans, and project budgets must be developed collaboratively between HC and US researchers. US PIs must actively establish an effective working relationship with the ME and other CRSP US and Host Country PIs and program participants.

Memoranda of Understanding: Upon award selection, the Lead US Institution of each project is required to enter into Memoranda of Understanding (MOUs) with institutions at Host Country sites. Subcontracting US institutions under the US Lead institution may also enter into MOUs with HC partners to strengthen institutional relationships and streamline administrative processes. MOUs between Host Country institutions are not discouraged but will not take the place of MOUs between US and Host Country institutions. MOUs must provide the opportunity for other CRSP projects to function under the authority of the agreement and must provide for joint authorship of reports and site visits at the discretion of the CRSP Management Entity. Draft MOUs are submitted to the ME for review prior to execution.

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

- Biotechnical investigations will be conducted primarily on research stations in Host Countries.

- Research protocols, policies, and practices will be established prior to implementation to ensure that potential environmental impacts are strictly controlled.

- All training programs and outreach materials intended to promote the adoption of CRSP-generated research findings will incorporate the appropriate environmental recommendations.
- All sub-awards must comply with environmental standards.

- CRSP Projects will not procure, use, or recommend the use of pesticides of any kind. This includes but is not limited to algaecides, herbicides, fungicides, piscicides, parasiticides, and protozoacides.

- CRSP Projects will not use or procure genetically modified organisms (GMO).

- CRSP Projects will not use, or recommend for use, any species that are non-endemic to a country or not already well established in its local waters, or that are non-endemic and well established but are the subject of an invasive species control effort.

From April through May 2007, the six projects were evaluated for environmental compliance, and by late May, all six projects had made the necessary changes to receive concurrence from USAID environmental officers. The investigations presented herein are in compliance with USG environmental regulations. Each project PI must seek additional environmental compliance approval if significant changes are made through the course of the project.

At least 50% of funds must be expended in or on behalf of the Host Country or region. Each project must supply an additional 50% or more of matching funding from participating institutions. Collaborative efforts that involve undergraduate students, graduate students, and post-doctoral fellows are encouraged. CRSP funds will not be used to support US expatriate personnel or consultants, as the CRSP model is intended to build institutional networks and capacities. In furtherance of the Title XII initiative that authorizes all CRSPs, projects must demonstrate return benefits to the US. Under Title XII, CRSP has responsibility to provide mutual benefits and discoveries that can apply to the HC region and US and that will support future development of sustainable aquaculture and fisheries.

Investigations

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

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

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

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

Investigations provide a transparent means for evaluating different types of work under the CRSP, be they quantitative, empirical, biologically-based, qualitative, policy-based, or informal. Each project was required to include at least one *experiment* or *study*. Projects were also required to

include outreach *activities* such as training, formal education, extension, and conference organizing to supplement the scientific research being proposed.

In addition to the investigations presented in Part II of this *Implementation Plan*, projects also submitted to USAID and the lead US Institution (or Management Entity at OSU):

(i) A plan for outreach and dissemination. The CRSP seeks to build capacity of HC researchers, farmers, and other stakeholders through improved understanding of aquaculture technologies, including soft technologies such as best practices and knowledge-based systems, as well as hard technologies.

(ii) A gender "inclusivity" plan. Projects identified intended beneficiaries, stakeholders, and end-users in each investigation or for their projects in their entirety.

Research Priorities

All six projects address the following general research priorities:

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

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

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

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

PART I. RESEARCH PROJECT SUMMARIES

LEAD US INSTITUTION: AUBURN UNIVERSITY

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PROJECT TITLE
HYDROLOGY, WATER HARVESTING, AND WATERSHED MANAGEMENT FOR FOOD SECURITY, INCOME, AND HEALTH: SMALL IMPOUNDMENTS FOR AQUACULTURE AND OTHER COMMUNITY USES

AQUAFISH PROJECT THEME
INCOME GENERATION FOR SMALL-SCALE FISH FARMERS AND FISHERS

Investigations

1. 09WIZ01AU	Effects of Watershed-Water Quality-Aquaculture Interactions on Quantity and Quality of Water from Small Catchments in South Africa and Uganda
2. 09WIZ02AU	Surface Catchment Development and Sustainability Evaluation for Multipurpose Water Supply for Meeting Aquaculture and Other Water Needs
3. 09BMA01AU	Evaluation and Improvement of Production Technology in Uganda: Case Studies of Small-Holder Cage Culture in Watershed Reservoirs and as an Alternative Livelihood For Fishers
4. 09MER01AU	Market Assessment and Profitability Analysis of Aquaculture Enterprises in Uganda
5. 09BMA02AU	Training and Outreach in Uganda and Surrounding Nations

US & Host Country Institutions

USA	Auburn University (Lead US institution) Alabama A&M University University of Georgia
Uganda	Makerere University (Lead Host Country institution) Gulu University National Fisheries Resources Research Institute (NaFRRI)
South Africa	Stellenbosch University

Other Collaborators and Linkages

[to be completed]

Project Summary

Our vision is to provide research results that increase the knowledge base on water resource uses that work in the African context. The studies identify best practices in water use, enterprise development, and fish culture and contribute a legacy of trained individuals capable of leading

and guiding aquacultural development as part of watershed management. Four studies address a broad range of water management, production, credit, and extension issues in Uganda and South Africa with intent and potential to extend findings and training to other countries. In Uganda, we build on a three-year intensive USAID-funded effort to build an aquaculture industry that brings to the project an extensive network of contacts and institutional knowledge. We have a strong network of women scientists and extension professionals as Host Country Partners. Some host country partners have a sustained record of meaningful impact in the aquacultural sector in their own and neighboring countries whereas others are new to aquaculture by bring other disciplines and approaches to the broader context of watershed management.

Introduction

Much research on small-holder aquaculture in developing nations has focused on integration of aquaculture with other activities on small farms. Our approach was to consider how to integrate aquaculture into watershed management schemes that focus on capturing overland flow in one or more small impoundments for multiple use, e.g., community water supply, aquaculture, livestock watering, small-scale irrigation, etc. We acknowledge the fundamental resilience that women lend to small-scale aquaculture through their labor, vigilance, and interest in the activity.

The proposed study would use climatic and hydrological variables, as well as topographic and geologic features to develop a procedure for identifying sites where such schemes could be installed. This study would provide basic data on precipitation, evaporation from water surfaces, temperature, and evapotranspiration needed in modeling and engineering efforts, complemented by case studies of water use and management for fish farming. Other work refines hydrologic models and proposes appropriate layout and engineering guidelines for designing and constructing small impoundments and water conveyance systems. In addition, watershed management practices for protecting the quality and quantity of the water source are delineated. The other components consider how aquaculture could be interwoven with other uses in environmentally and socially sound ways. Finally, there would be a component dedicated to considerations of how stakeholders could organize themselves to guide multiple land uses and land owners, to develop reasonable procedures for allocating water for different uses, and to optimize benefits to surrounding communities.

Vision Statement

We draw our broader view of small-holder aquacultural development from the FAO Limbé Declaration that asserts a number of principled conclusions (Moehl et al. 2005). The statement concludes that aquaculture development in sub-Saharan Africa (SSA) is at a crossroads. Burgeoning population growth and declining natural sources of fish make it imperative that aquaculture contributes as substantially to continental fish supply as possible. The region is the only one in the world where per capita fish consumption is declining and is projected to decline further. Reasons for this situation include civil conflict, weak management structures, low levels of investment in rural economies, and lack of economic growth. At the same time, however, new opportunities exist that brighten the prospects for aquaculture development. In particular, we see women as key practitioners of small-scale aquaculture as a source of income and food security for rural households.

The FAO document asserts that small- and medium-scale commercial enterprises are the most efficacious engines of economic growth (Moehl et al. 2005). Researchers at the International Food Policy Research Institute found that "... even small increments to rural incomes that are widely distributed can make large net additions to growth and improve food security." The CGIAR has identified interventions that lead to improved incomes at the level of the rural farmer and resource manager as "having a larger impact on countrywide income than increases in any other sector." To increase the benefits accruing from aquaculture, development planners should consider how to move from the current situation of dominance of small-holder artisanal/large-scale commercial investors, to one where there are many small- and medium-scale commercial investors, without losing the benefits currently being generated by aquaculture.

The project addresses a number of constraints to the development of aquaculture, which includes basic insights into water availability and hydrological context, seed and feed production, as well as inefficient extension and outreach. Such considerations are vital for protecting wetlands and promoting biodiversity. It addresses women directly and recognizes their role in sustaining small-scale aquaculture. We endeavor to clarify how public/private partnerships between investors and knowledge delivery structures can facilitate sectoral growth by providing farmers with the highest quality of technological, managerial and marketing information available (Moehl et al. 2005).

While appreciating the need to address major constraints identified (water, seed, feed, extension), there is a need to examine other areas, such as market development, access to capital and other policy issues (Moehl et al. 2005). There is a clear need for cost-effective financial and institutional arrangements that can complement government and donor resources to deliver a limited number of critical research, advisory and technical services to high-potential farmers.

Aquaculture can provide high quality food for rural and urban consumers, generate employment and general commercial activities in otherwise impoverished local economies, make sense in the land and water context, and contribute to national wealth through increased revenue from markets and trade. The growth and expansion of fish farming must take account of the soil and water systems that provide a sustainable context for this productive enterprise. Our vision is to provide research results and visible examples that increase the knowledge base on developmental production paths that work in the African context, that guides aquaculture development in ways that protect wetlands and enhance biodiversity, that identify best practices based on successful experiences, and to contribute to a legacy of trained men and women capable of leading and guiding aquacultural development in the long term. The insights and approaches developed in Africa also have parallels and implications for problems confronting communities and watersheds in the U.S. (Boyd et al. in press). The next step for this project if future funding became available would be to expand the geographic scope of the project in Uganda, enhance training for Ugandan farmers and technical personnel, and conduct research to ameliorate the malleable constraints to aquacultural development. Our exit strategy is to leave behind a trained cadre of business-sensitive technical personnel with functioning feed suppliers who can work with capable farmers to advance the aquaculture industry in Uganda.

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LEAD US INSTITUTION: NORTH CAROLINA STATE UNIVERSITY

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PROJECT TITLE
IMPROVING THE COST EFFECTIVENESS, SUSTAINABILITY AND INCOME OPPORTUNITIES OF FARMING FISH IN THE PHILIPPINES AND INDONESIA

AQUAFISH PROJECT THEME
INCOME GENERATION FOR SMALL-SCALE FISH FARMERS AND FISHERS

Investigations

1. 09QSD01NC	Nile Tilapia Broodstock Selection, Seed Quality and Density-Dependent Growth in the Philippines
2. 09SFT04NC	Feeding and Feed Formulation Strategies to Reduce Production Costs of Tilapia Culture
3. 09TAP02NC	Internet-Based Podcasting: Extension Modules for Farming Tilapia in the Philippines
4. 09MER03NC	Improving Supply Chain Opportunities for Tilapia in the Philippines
5. 09MNE02NC	Ration Reduction, Integrated Multitrophic Aquaculture (milkfish-seaweed-sea cucumber) and Value-Added Products to Improve Incomes and Reduce the Ecological Footprint of Milkfish Culture in the Philippines
6. 09FSV02NC	Demonstration of Sustainable Seaweed Culture and Processing in Aceh, Indonesia and the Philippines - Opportunities for Women to Improve Household Welfare

US & Host Country Institutions

USA	North Carolina State University (Lead US institution) University of Arizona
Philippines	Central Luzon State University (Lead Host Country institution) Southeast Asian Fisheries Development Center (SEAFDEC) AQD, Iloilo
Indonesia	Ujung Batee Aquaculture Center, Banda Aceh

Other Collaborators and Linkages

Aquaculture without Frontiers (AwF), USA
Florida International University
Genetically Improved Farmed Tilapia (GIFT) Foundation International, Inc., Munoz, Philippines
Indonesian Department of Fisheries, Indonesia
Ladong Fisheries College, Indonesia
World Aquaculture Society (WAS), Baton Rouge, Louisiana
U.S. Department of Commerce, Milford Connecticut
Department of Agriculture, Philippines

Project Summary

Aquaculture in the Philippines and Indonesia is a high food security priority particularly in the light of the countries' rapidly growing populations and their continued dependence on fish protein. The incomes from family farming, however, are generally poor with 43% of small-scale tilapia farmers in Central Luzon, Philippines falling below the poverty line. The difficult socioeconomic conditions are even more pronounced for fishers in coastal regions where traditional livelihoods have been lost, and many seek transition to milkfish farming, but with some uncertainty. In Indonesia, a tsunami eliminated shrimp-farms, and the livelihoods of entire communities continue to rebuild. In the proposed studies we seek to develop and implement strategies that will improve the cost effectiveness, sustainability and income opportunities of farming fish in the Philippines and Indonesia and the subsequent livelihood of their people. A cluster of integrated investigations will assess key areas of research and outreach that form a natural extension of the activities and accomplishments of the first phase of our AquaFish CRSP. We will continue to develop methods to reduce farming costs for tilapia and milkfish, conduct an extensive supply-chain analyses to specifically address the marketing opportunities and constraints of expanding tilapia products to reach more lucrative retail supermarkets, assess the utility of integrative/polyculture systems to reduce environmental impacts of farming fish while providing additional products for market and home consumption, develop a series of short Tilapia Podcasts designed for disseminating current culture practices and cost-saving strategies to the farming community of Central Luzon, and provide training on the harvest and processing of seaweeds in the Philippines and Aceh region of Indonesia. The research and outreach activities proposed incorporate specialists from Central Luzon State University (CLSU) the Southeast Asian Fisheries Development Center (SEAFDEC), Ujung Batee Aquaculture Center, North Carolina State University (NCSU), University of Arizona, and the United States Department of Commerce, their collaborators and the farming communities of the host countries. Nine workshops are proposed, as are a community-based training program and the involvement of over 30 students.

Tilapia and milkfish are the two most prominent finfish cultured in the Philippines. They are low trophic species whose culture is expanding rapidly both in inland and coastal regions and in a more intensive fashion. Feed is clearly one of the most costly aspects of fish farming, representing as much as 80% of total production costs for tilapia and 60-70% for milkfish. Feed wastage and the escalating cost of fishmeal in commercial diets contribute to this problem; sources are rapidly declining and demand remains high. The proposed studies aim to improve management strategies and will deliver more cost-effective formulations to reduce feed usage and costs. Controlling costs is a requisite to increasing income for small-scale farmers, while also preserving the biodiversity of bait fisheries. Limiting nutrient load from feed wastage will also help mitigate the environmental imprint of fish farming and promote its sustainability. We propose a series of studies to reduce feed costs for tilapia farmers that incorporates a combination of sub-satiation feeding; decreases in feed formulation costs through reductions in crude protein, amino acid supplementation, and replacement of fishmeal with lower cost protein sources; and use of a cheaper manufacturing process that uses pellet rather than extrusion processing. This aspect of our work features a unique synergy between a Filipino feed company, CLSU and NCSU researchers, and Luzon farmers in the Philippines.

Additional studies to reduce ration levels and integrate seaweeds and sea cucumber in the culture of milkfish are proposed to limit feed inputs and reduce the ecological imprint of milkfish culture clusters in coastal regions near where fish kills have been reported. Integrated milkfish culture systems may not only improve water and sediment quality, but will benefit farmers' incomes through the delivery of additional marketable seafood products. SEAFDEC will introduce the integrated system to the farming communities, through season-long training programs using their cages as a demonstration facility. The SEAFDEC training staff and several of the seaweed farmers recruited for this project will be women, which will foster and expand the role of women in traditionally, male-dominated fish farming. Additionally, the seasonal training program will

incorporate a workshop on the processing and production of value added milkfish products geared toward women that should allow for improvements in household incomes.

The need for improved-quality tilapia seed is expected to triple over the next decade. To enhance reliability and production of high quality seed and limit the risks of entry of new farmers, we will undertake studies to establish practical methods for selecting broodstock with high fecundity that can be used by hatcheries in the Philippines and elsewhere. We will utilize appetite, eye color, and social behavior patterns in tilapia to select broodstock with low susceptibility to stress and higher yield of robust fry. This investigation should provide practical technologies for selecting individuals for breeding programs as well as for pairings to improve seed production. We will also evaluate the density-dependent stress and growth response of tilapia, and quantify hormones mediating the responses in hapa and tank enclosures frequently used by a growing number of farmers that intensively culture tilapia in the Philippines and USA. These studies build upon our current effort to develop suitable biomarkers of growth and stress that can be used to optimize conditions for tilapia culture, toward addressing the USAID priority of establishing suitable biotechnologies for the advancement of aquaculture.

There is currently a strong desire to expand tilapia culture in the Philippines to meet the growing demand for fish products in the domestic retail supermarket and fast-food chains. Toward this goal we propose a study to evaluate and develop an efficient tilapia supply chain to foster the development of viable fast food and supermarket purchases of tilapia from small-scale producers. We anticipate that this work will facilitate development of domestic tilapia markets that can expand tilapia farming, increase sales, improve farm incomes, and increase small farmer participation.

In Indonesia and the Philippines, the polyculture of seaweeds in shrimp and fish ponds has proven to be popular in several coastal communities based on our initial work in the first phase of the AquaFish CRSP project. In phase I of our AFCRSP we provided training on seaweed polyculture and several farming communities embraced this new practice, but wish to learn more about how to handle and process the seaweed produced. We will conduct a series of workshops in communities of Aceh, Indonesia and the Philippines to assist farmers on management, harvest and processing of seaweeds. We will assist farmers on how to process their raw seaweed into more valuable semi-processed forms for sale to commercial agar buyers and for use in making candy and desserts for local markets, the latter providing an option for home businesses, especially those operated by women.

Finally, we propose to further develop Tilapia Podcasting, following our successful launch of the first podcast at CLSU. This emerging technology is a powerful approach to information distribution that has been met with considerable enthusiasm in the Philippines and the tilapia community. Following its recent link to a trackable server at NCSU we found the Podcast was uploaded over 100 times in the past month, alone. In the proposed studies we will train a CLSU student and produce 8 short tilapia-related podcasts with information on tilapia culture methodology, new production technology, cost-saving feeding practices, etc. These podcasts will be laid out on a CLSU, AquaFish CRSP, and NCSU website where they will be fully accessible by Central Luzon farmers and the worldwide tilapia community.

Project Vision

The long-range goals of our work will be to continue to tackle the excessive production costs associated with commercial feeds in finfish aquaculture. We anticipate continuation of refinements of feed strategies and formulations for tilapia and milkfish that should directly benefit farmers and their capacity to improve incomes, including the production of value added "organic" products that might include algal enrichment with omega-3 fatty acids. We also anticipate developing additional culture systems and methods to reduce environmental impacts of fish farming, possibly including integrative culture systems using bivalves and water reuse technologies to limit nutrient outflow in waterways. The retail and export market demand for tilapia and milkfish continue to

grow, and we hope to develop the requirements and recommendations needed for small farmers to sell products to domestic retail, and eventually export markets. This endeavor has only begun, but may show the strongest promise for increasing incomes of farmers. Other areas of research might include enhanced selective breeding of tilapia for all-male production and production of superior culture traits. Because of the wide popularity of tilapia we anticipate the management strategies applied to its production in the Philippines will be applicable to addressing similar constraints in other underdeveloped countries in Africa, Asia, and Central/South America. Our contributions – because of continued publication in respectable international journals and our podcasting efforts – are likely to reach far beyond the Southeast Asian region. We feel, once the management strategies and research capabilities for sustaining and expanding aquaculture are established that our mission will have been completed.

LEAD US INSTITUTION: PURDUE UNIVERSITY

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PROJECT TITLE
IMPROVING COMPETITIVENESS OF AFRICAN AQUACULTURE THROUGH CAPACITY BUILDING, IMPROVED TECHNOLOGY, AND MANAGEMENT OF SUPPLY CHAIN AND NATURAL RESOURCES

AQUAFISH PROJECT THEME
INCOME GENERATION FOR SMALL-SCALE FISH FARMERS AND FISHERS

Investigations

1. 09MER02PU	Value Chain Development for Tilapia and Catfish Products: Opportunities for Women Participation
2. 09SFT02PU	Assessment of Integrated Pond-Cage System for the Production of Nile Tilapia for Improved Livelihood of Small-Scale Fish Farmers in Kenya
3. 09SFT05PU	Develop Feeding Strategies for *Moringa oleifera* and *Leucaena leucocephala* as Protein Sources in Tilapia Diets
4. 09QSD04PU	Evaluation of Performance of Different Tilapia Species
5. 09TAP04PU	Harnessing the Opportunities and Overcoming Constraints to Widespread Adoption of Cage Aquaculture in Ghana
6. 09IND06PU	Development and Diversification of Species for Aquaculture in Ghana

US & Host Country Institutions

USA	Purdue University (lead US institution) Virginia Polytechnic Institute & State University (VT) University of Arkansas at Pine Bluff (UAPB)
Ghana	Kwame Nkrumah University of Science & Technology (KNUST)
Kenya	Moi University Ministry of Fisheries Development
Tanzania	Sokoine University of Agriculture (SUA)

Other Collaborators and Linkages

FAO Regional Office, Ghana
Fisheries Department, Ministry of Food & Agriculture, Ghana
Kenya Business Development Services (KBDS)
Kenya Marine & Fisheries Research Institute
Kingorwila National Fish Center, Tanzania
Lake Victoria Environmental Management Project
Mbegani Fisheries Development Centre
Ministry of Agriculture Fisheries Directorate (MOQ-FI), Ghana

National Investment Center (NIC)
Nyegezi Fisheries Institute
Sagana Aquaculture Centre, Kenya
Tanzania Fisheries Research Institute, Tanzania
United Nations Food & Agriculture Organization (FAO)
University of Dar-es-Salaam, Tanzania
Water & Sewerage Company, Ghana

Project Summary

The overall goal of this continuation project is to develop physical and human capacity for the aquaculture industry in sub-Sahara Africa through new and better technology of fish production, better management of the natural resources, development of indigenous species, and responding appropriately to market demands for fish products. Results from the various investigations will help to vitalize rural aquaculture entrepreneurship by providing capacity and opening up a larger market for rural aquaculture producers. They will also help to provide additional employment and income generation that will create demand for other products and thus support the growth of other rural economic activities.

Individual proposals included in this project build on and add value to currently funded AquaFish CRSP studies. In Kenya, past CRSP research studies suggests a strong production focus, leaving many fish consumer and marketing questions unanswered. Therefore, an investigation is included to consumer preferences and developing linkages between fish consumers and production with the development of a Farmed Fish Market Information System in Kenya. A second study in Kenya looks at fish feeding efficiencies to enhance productivity in open ponds. The integrated system being examined will allow open pond water to utilize cage wastes as fertilizers, generating natural food in the pond. This is an environmentally friendly technology that permits less waste nutrients to be released to the public water systems.

In Tanzania, we are building on the current nutrition study by developing fish feeding strategies for local protein sources in Tanzania. The current research has revealed that *Leucaena leucocephala* leaf meal and *Moringa oleifera* leaf meal can replace up to 25% of soymeal as protein sources and still obtain good growth. Therefore, an experiment will be conducted to test the effects of different diets and feeding regimes on growth performance of Nile tilapia. In addition, there will be an investigation to compare the performance (growth rate, survival, feed conversion ratio and mature body size) of five different strains of Nile tilapia (Oreochromis niloticus) that has proliferated the industry. There is a need for bio-prospecting for various species of tilapia to identify the species better suited for aquaculture in Tanzania.

In Ghana, cage culture is becoming popular with several multi-million investments into the technology in the Volta Lake. Many small-scale farmers are looking into the technology of cage aquaculture. The only specie being farmed in these cages is tilapia. There is concern about the market price and the viability of small-scale tilapia producers given the trends towards industry-type tilapia production. Therefore, one study will look at the opportunities and challenges to the adoption of cage culture as an alternative production system in Ghana, while a second study examines the development of alternative species with emphasis on indigenes to provide guarantees against potential biodiversity degradation that could result from unbridled spread of aquaculture species. Numerous opportunities exist for the development of new species and expansion of the variety of production systems in Ghana to provide a safety net and access to new markets for small-scale aquaculture producers.

LEAD US INSTITUTION: UNIVERSITY OF ARIZONA

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PROJECT TITLE
DEVELOPING SUSTAINABLE AQUACULTURE FOR COASTAL AND TILAPIA SYSTEMS IN THE AMERICAS

AQUAFISH PROJECT THEME
ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUATIC RESOURCES USE

Investigations

1. 09TAP01UA	Aquaculture & Fisheries CRSP Sponsorship of the Ninth International Symposium on Tilapia in Aquaculture to be held in Shanghai, China
2. 09SFT03UA	Expansion of Tilapia and Indigenous Fish Aquaculture in Guyana: Opportunities for Women
3. 09QSD02UA	Sustainable Integrated Tilapia Aquaculture: Aquaponics and Evaluation of Fingerling Quality in Tabasco, Mexico
4. 09IND05UA	Consolidation of Native Species Aquaculture in Southeastern Mexico: Continuation of a Selective Breeding Program for Native Cichlids and Snook Reproduction in Captivity

US & Host Country Institutions

USA	University of Arizona (lead US institution) Texas Tech University, Lubbock
Guyana	Department of Fisheries
Mexico	Universidad Autónoma de Tamaulipas, Ciudad Victoria & Reynosa Universidad Juárez Autónoma de Tabasco

Other Collaborators and Linkages

American Soybean Association, USA
Anna Regina Fish Culture Station, Guyana
Aquaculture without Frontiers, USA
BIOTECMAR, Caracas, Venezuela
China Aquatic Products Processing & Marketing Association
Cooperativa Pesquera San Ramón, Mexico
Cornell University
Delaware State University
Global Aquaculture Alliance, USA
Goldman Sachs, USA
Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico
Instituto Sinaloense de Acuacultura, Mazatlán, Mexico
Intervet-Schering Plough Animal Health, The Netherlands

Maharaja Oil Mill, Guyana
Mariano Matamoros Hatchery, Teapa, Tabasco, Mexico
Ministry of Agriculture & Land Reclamation, Egypt
Mon Repos Aquaculture Center, Department of Fisheries, Guyana
National Aquaculture Association of Guyana (NAAG), Guyana
Oregon State University
Partners of the Americas, USA
Peanut CRSP, USA
San Carlos University, Guatemala
Secretariat of Agricultural Development for the State of Tabasco (SEDAFOP), Mexico
Shanghai Ocean University, China
Sinaloa State Fisheries Department, Mexico
Texas Parks & Wildlife Department, Texas
Tilapia International Foundation, The Netherlands
Trafalgar Union Women's Cooperative, Guyana
UK Department for International Development (DFID), England
United Animal Feed Producers
United Cooperative of Fishermen
University of Costa Rica, Costa Rica
University of Texas
US-Mexico Aquaculture TIES Program
USAID Farmer-to-Farmer Program, Guyana
USAID GTIS Programme, Guyana
Von Better Aquaculture, Guyana
World Aquaculture Society, USA
WorldFish Center (ICLARM), Penang, Malaysia
Zamorano University, Honduras
Texas A&M University

Project Summary

The aquaculture industry in Central and South America is dominated by shrimp and tilapia culture. While these industries have generated thousands of jobs, millions of dollars of exports and improved household nutrition, we feel that great strides can be made to make aquaculture more sustainable and profitable in the region. We believe that though use of polyculture, domestication of native species, and integration of aquaculture with agriculture, aquaculture can produce fewer environmental externalities while at the same time improving production efficiencies and increasing profits.

The team from Mexico, Guyana and the University of Arizona feel that we have made solid progress in the first phase to address these issues and expect to build upon these successes. We believe that we can further expand our outreach to additional audiences, further improve the skills of those we have worked with in the first phase, and conduct additional trials to develop more cost effective diets, improve environmental sustainability of aquaculture in Mexico and Guyana, and raise the profile of the AquaFish CRSP and US-AID as critical supporters of sustainable aquaculture in these countries.

In the first phase of the Developing Sustainable Aquaculture for Coastal and Tilapia Systems in the Americas project our group had several notable achievements. Advances were reported on the reproductive biology of the snook. With captive broodstocks and induced spawning, we hope to eventually have the capability of stock enhancement and replenishing the overfished stocks of snook in the Gulf of Mexico. The advances in husbandry of two native cichlids, the Tenhuayaca (*P. splendida*) and Castarrica (*C. urophthalmus*), are equally impressive. The potential that both of these fishes could be restocked and domesticated as food fish are well on the way to fruition with captive spawning and transfer of the techniques to the private sector. The problem of hormone

residues escaping from hatcheries using methyltestosterone, was addressed with directed bacterial degradation and through the use of titanium dioxide. In Guyana, a number for locally available ingredients were examined for use in fish diets. The proximate and mineral analyses allowed us to develop cost-effective practical diets for use on local farms. The experimental diets are now being tested with replicated trials of fingerlings and adult fish.

The outreach portion of the project has been equally successful. The Eighth International Symposium on Tilapia in Aquaculture had over 500 participants and the Ninth ISTA to be held in Shanghai China should have over 1000 participants, including many of our AquaFish colleagues. The number of training sessions, workshops, field days, conference sessions and presentations and symposia completed exceeded our expectations and we hope to further that success. An intern program between Mexican universities and US tilapia farmers proved to be especially useful for almost a dozen interns and the US and Mexican tilapia farms. We expect to also direct our workshops and training efforts to serve women to increase their participation in aquaculture and preparation of healthy seafood.

Our proposed research will address several critical issues of special concern to aquaculture producers in Mexico and Guyana. One is the use of locally produced protein sources for the replacement of fishmeal in tilapia, pacu and shrimp diets. Another is the management of YY supermale and GIFT strain tilapia stocks. In both cases the project will assist by providing nucleus breeding centers and support for pedigreed selective breeding programs. We will also evaluate these strains with others already available to local growers. To be clear, we will not be involved with introductions of new species. In fact, we will not even be involved with the importations of new strains. The Mexican and Guyana governments have already started the imports. We will assist to document the impacts and train staff on hatchery techniques and how to maintain pedigree records. It should be remembered that Nile Tilapia is already a significant industry in both countries and their surrounding neighbor countries. In fact in Mexico, Nile tilapia represents a $300,000,000 annual industry producing 100,000 metric tons of fish for domestic consumption, with registered farms in every state in Mexico. The YY supermale Nile tilapia that are genetically male are much less likely to become established in the wild, compared to precociously spawning Nile tilapia that are mixed sex populations.

The integrated aquaculture and agriculture (hydroponics, vegetables, and field crop culture) research has garnered enormous interest. Several groups have requested collaborations ranging from small farmer cooperatives, to government agencies (INIFAP, EPA), NGO's (Farmer to Farmer, Partners of the Americas), the Peanut CRSP, and even the investment firm Goldman Sachs. Integrated aquaculture-agriculture may be one of the most long lasting contributions of the project. Demonstration and research result supported outreach could help the Western Hemisphere aquaculture producers develop an industrial version of the small-scale integrated fish, rice, and vegetable production common across eastern and southern Asia. This could contribute to a quantum step forward in productivity and sustainability, vastly improving the quantity, quality, and profitability of both crops and seafood. Increased farm efficiency and training in handling of aquaculture products should improve household nutrition, income and overall welfare. These improvements in the welfare of the rural poor will help both the residents of the host country and reduce the need for citizens of the host countries to migrate to other countries in search of improved circumstances.

LEAD US INSTITUTION: UNIVERSITY OF CONNECTICUT-AVERY POINT

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PROJECT TITLE
DEVELOPMENT OF ALTERNATIVES TO THE USE OF FRESHWATER LOW VALUE FISH FOR AQUACULTURE IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM: IMPLICATIONS FOR LIVELIHOODS, PRODUCTION AND MARKETS

AQUAFISH PROJECT THEME
ENHANCED TRADE OPPORTUNITIES FOR GLOBAL FISHERY MARKETS

Investigations

1. 09SFT01UC Alternative feeds for freshwater aquaculture species in Vietnam.

2. 09IND02UC Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia and Vietnam

3. 09TAP03UC Development of alternatives to the use of freshwater low value fish for aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: implications for livelihoods, production and market.

4. 09FSV01UC Maximizing the utilization of low value or small-size fish for human consumption by improving food safety and value added product development (fermented fish paste) through the promotion of women's fish processing groups/associations in Cambodia.

5. 09MER04UC Value chain analysis of snakehead fish in the Lower Mekong Basin of Cambodia and Vietnam

6. 09MNE04UC Developing Management Recommendations for Freshwater Small-Sized/Low Value Fish in the Lower Mekong Region of Cambodia and Vietnam

US & Host Country Institutions

USA	University of Connecticut-Avery Point (lead US institution) University of Rhode Island
Cambodia	Inland Fisheries Research & Development Institute (IFREDI), Phnom Penh
Vietnam	Can Tho University

Other Collaborators and Linkages

Australian Centre for International Agricultural Research (ACIAR), Nelson Bay, Australia
Fisheries Administration in Cambodia (FiA), Cambodia
FAO in Asia-Pacific, Bangkok
Inland Aquaculture Extension & Productivity Improvement Project (JICA-FAIEX), Cambodia
International Development Research Centre (IDRC), Ottawa, Canada
Department of Fisheries, Mekong River Commission (MRC)-Aquaculture/Fisheries Projects, Cambodia
National Oceanic and Atmospheric Administration (NOAA), International Sea Grant
Network of Aquaculture Centers in Asia (NACA), Bangkok, Thailand
Oxfam America, USA
Prek Leap National School of Agriculture, Cambodia

Royal University of Agriculture, Cambodia
Southeast Asian Fisheries Development Center-Aquaculture (SEAFDEC-AQD), Philippines
USAID–Micro, Small & Medium Enterprises (MSME)-Aquaculture–DAI
WorldFish Center, Malaysia

Project Summary

In the Mekong region, many capture fisheries resources have been largely overexploited and, as a result, development of aquaculture has been encouraged to provide the protein, income, employment and export earnings for some countries. Such a development trend implies that sufficient feed for aquaculture production will be available. One source of feed is low value/trash fish (Low value/trash is defined as fish that have a low commercial value by virtue of their low quality, small size or low consumer preference). There is increasing demand and trade in the lower Mekong region of Cambodia and Vietnam for low value/trash fish for (1) local consumption (e.g. fresh, dried); (2) direct feed (e.g. livestock, high value species aquaculture); (3) fishmeal production (e.g. poultry, aquaculture); and (4) value-added products (e.g. fish sauce).

The price of low value/trash fish has tripled since 2001 and it is predicted to continue to rise as aquaculture expands (FAO-APFIC 2005). The use of artificial fish based feeds and/or fresh fish resources have further increased pressure on wild fish stocks. Inevitably, a dangerous spiral has evolved where the demand for low value/trash fish for aquaculture feed has supported increased fishing pressure on already degraded resources. It is predicted that as aquaculture grows in the region, it will be difficult to meet the demand for low value/trash fish. There is a general concern that the rapid expansion of aquaculture may ultimately be constrained by the dependence on low value/trash fish and fishmeal, popularly referred to as the "fishmeal trap". The Asia-Pacific countries may need to increase imports of fishmeal from the global market for the aquaculture industry, or replace these with other feed materials. There is a need to address the increasing demand for low value/trash fish by aquaculture by improving feeds for aquaculture through changing over from direct feeding to pellet feeding and reduction of fishmeal content by substitution of suitable ingredients in pellets.

There is also increasing conflict between the use of low value/trash fish for feed and for human consumption. In some cases, such feeds are comprised of fish species traditionally used as cheap food for people and this allocation of fish resources to aquaculture may result in negative impacts of food security and livelihoods. It is the economics of the different uses of low value/trash fish in different localities that direct the fish one way or the other. There are also trade-offs between direct food benefit and the indirect employment and income generation opportunities afforded by feeding to aquaculture. It has been argued that it would be more efficient and ethical to divert more of the limited supply to human food, using value-added products. Proponents of this suggest that using low value/trash fish as food for domestic consumers is more appropriate than supplying fishmeal plants for an export, income oriented aquaculture industry, producing high-value commodities. On the other hand, food security can also be increased by improving the income generation abilities of poor people, and it can be argued that the large volume of people employed in both fishing and aquaculture has a beneficial effect. This raises some important questions regarding the social, economic and ecological costs and benefits of aquaculture, its sustainability and future trends.

The focus of this project is equally on the aquaculture of carnivorous fish and the management of lower value/trash fish. Investigations 4, 5 and 6 address the uses and bioecological characteristics of low value/trash fish. Investigations 1, 2 and 3 address alternative feeds for freshwater aquaculture and feed technology adoption.

The vision of this project is for sustainable freshwater aquaculture development in the Lower Mekong basin region of Cambodia and Vietnam, taking into consideration the balancing of social, economic and environmental/natural resource needs and implications. This vision takes into

account that the main driver of this project is the continued expansion of aquaculture and its dependency on capture fisheries for low value/trash fish for feed. It also takes into account that: capture and culture fisheries continue to play an important role in the food security, poverty alleviation and economies of both countries; the strong interdependency between capture fisheries and aquaculture; management of these two sub-sectors cannot be carried out in isolation of each other; there is increasing intra-regional trade; and there is increasing competition and conflict between the use of low value/trash fish for feed and human consumption. This project will address this issue through six separate but complementary investigations on the management of low value/trash fish fisheries; development of alternative feeds and feeding strategies; outreach and feed technology adoption; market and trade development; and value-added product development.

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To date, the project has made considerable progress in accomplishing the objectives set forth in the first phase. Developed weaning methods so that small, hatchery-reared snakehead can be quickly adapted to pelleted diets. Determined that *Channa striata* snakehead survive as well on pelleted diets in which up to 50% of the fishmeal has been replaced by soybean meal as they do on pelleted diets made purely of fishmeal. Development of best practice compared between traditional product and modern product of fermented fish product, then determine the issues related to low value fish processing practice and value added product development, market and trade to recommend policies and strategies to address the identified problems and issues in order to ensure high quality, safe and nutrition low value fish products for local and international trade, and to support value-added product development. Information was collected about issues on snakehead farming in the region. Market research has revealed a range of markets in the region for the processed products from low value fish.

The work undertaken through this activity will be sustained after the life of the project by the partners in Cambodia and Vietnam and through partnerships developed with other regional organizations such as the Network of Aquaculture Centers in Asia (NACA), the Southeast Asian Fisheries Development Center-Aquaculture (SEAFDEC-AQD), and the WorldFish Center. Additional funding to continue the work started through this project has been or will be secured through such sources as Australia Center for International Agricultural Research (ACIAR), International Development Research Center (IDRC), US Agency for International Development country missions, and funds from each country. Future activities associated with the project are the development of feed and feeding strategies for other fish species, further on-farm trials of feed formulations, policy and technology for trade and value-added product development for low value/trash fish, development of farm made feeds, improved management strategies for capture fisheries, and policy development for sustainable aquaculture and capture fisheries. The project has allowed strong partnerships to be developed between IFREDI and Cantho University researchers which are expected to continue in the future. The exchange of information and knowledge is ongoing and will continue.

LEAD US INSTITUTION: UNIVERSITY OF HAWAI'I AT HILO

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PROJECT TITLE
HUMAN HEALTH AND AQUACULTURE: HEALTH BENEFITS THROUGH IMPROVING AQUACULTURE SANITATION AND BEST MANAGEMENT PRACTICES

AQUAFISH PROJECT THEME
IMPROVED HEALTH AND NUTRITION, FOOD QUALITY, AND FOOD SAFETY

Investigations

1. 09IND01UH Developing hatchery methods for the mangrove oyster, *Crassostrea corteziensis* for the Pacific Coast of Mexico

2. 09IND03UH Induced spawning and larval rearing of the "chame" *Dormitator latifrons* in laboratory conditions

3. 09IND04UH Stock assessment of "Chame" *Dormitator latifrons* in Nayarit and South of Sinaloa México

4. 09HHI01UH Co-management and bivalve sanitation for black cockles (*Anadara* spp.) in Nicaragua

5. 09HHI02UH Capacity building in aquaculture, fisheries management and coastal management for coastal women. Workshop: "Opportunities for Coastal Women in Fisheries, Aquaculture and Coastal Management

US & Host Country Institutions

USA	University of Hawai'i at Hilo (lead US institution) Louisiana State University Ohio State University
Mexico	Research Center for Food & Development (CIAD), Mazatlán Universidad Autónoma de Sinaloa, Culiacán Campus Universidad Autónoma de Sinaloa, Mazatlán Campus
Nicaragua	Centro de Investigación de Ecosistemas Acuáticos-Universidad Centroamericana (Center for Research of Aquatic Ecosystems-Central American University: CIDEA-UCA)

Other Collaborators and Linkages

Comite Estatal de Sanidad Acuicola de Sinaloa (State Committee for Aquaculture Sanitation of Sinaloa (CESASIN)
Coastal Resources Center/University of Rhode Island (CRC/URI)
Ecocostas, Ecuador
Federation of Shrimp Cooperatives, Mexico
Fisheries Industry Technology Center/University of Alaska
Nicaraguan Ministry of the Environment (MARENA), Nicaragua
Pacific Aquaculture & Coastal Resources Center/University of Hawai'i at Hilo (PACRC/UHH)
Pacific Shellfish Growers Association, Olympia, Washington

Sinaloa Institute for Aquaculture (ISA), Sinaloa, Mexico
University of Alaska
U.S. Food & Drug Administration (FDA), Washington, DC
USAID Sustainable Coastal Communities & Ecosystems Program, SUCCESS Program
Women's Oyster Culture Cooperatives of Nayarit, Mexico
Women's Oyster Culture Cooperatives of Puerto Penasco, Mexico

Project Summary

The proposed research, training and outreach activities will add components of aquaculture research, development and training to existing integrated coastal zone management programs for three large estuarine complexes in Mexico and Nicaragua. Design of the research activities is based on extensive prior needs assessments which include feasibility studies, management plans and previous research findings. The overall goal is to increase capacity to implement best management practices in aquaculture sanitation as a means to improve human health through disease prevention and product quality and safety. Improving food security through multiple strategies is also a theme for this work. These efforts aim to develop bivalve culture as a means of increasing utilization of indigenous species which are low on the food chain, have low technology requirements and have high value. Bivalves also provide valuable ecological services and require improved management of their fisheries throughout Latin America and the Carribbean. For this continuation of current efforts, we have chosen to focus on continuing research to determine the effectiveness of a community-based co-management effort for the black cockle fishery in Nicaragua, which may serves as a model for the other troubled bivalve fisheries in Latin America. Additionally, efforts to develop native bivalve species for culture will continue through developing hatchery methods and continuing extension to oyster farming groups in two Mexican States. The members of these groups are largely women, or extended families. Additionally, we propose to continue work sponsored by the ACRSP and the USAID SUCCESS[1] project to develop a native fish species ("chame", *Dormitator latifrons*) found throughout LAC that holds tremendous potential for aquaculture. Expected outcomes include: 1) information critical to decision-making and planning for coastal communities and economic development; 2) increased capacity for extension agents and researchers to work in bivalve culture, fisheries management and shellfish sanitation; 3) improved extension services benefiting coastal communities; 4) developing the basis for shellfish sanitation plans and classification of shellfish growing waters; 5) improved food quality and safety for shellfish and other aquaculture products; 6) improved prices and markets for products; and 7) reduction in the incidence of food-borne illnesses related to aquaculture. Issues of basic food security are also addressed through development of native species that are suited for aquaculture by poor, coastal residents.

Introduction

Improving the health and well-being of stakeholders is the fundamental justification for aquaculture development. Aquaculture can affect human health through a wide variety of direct and indirect causal pathways, including but not limited to: the relationship with environmental quality; use of natural resources (e.g. water, land, inputs); consumption of safe, high protein food products; increased household revenues to improve food security; and involvement of women, youth and marginalized groups.

The ways in which users and resources are affected by and affect aquaculture are complex, not completely understood, and are dynamic in nature. Workers in this area must constantly update

[1] SUCCESS is the global Sustainable Coastal Communities and Ecosystems program of EGAT/USAID, working since 2004 on site-specific (Nicaragua, Ecuador, East Africa) and global activities related to natural resources management and alternative livelihoods. The University of Hawai'i Hilo and the University of Rhode Island were the lead partners. SUCCESS, along with CRSP, sponsored the initial work on bivalve sanitation and co-management, as well as the development of chame.

their knowledge and understanding of the processes involved, new technology and the changing socioeconomic framework. CRSP stakeholder and expert panel meetings of the Africa, Asia and Latin America/Caribbean regions (2002) reveal two critical trends; 1) research and development of new aquaculture technology has been effective in laying the informational basis for development of subsistence aquaculture; and 2) the ability of researchers and extension agents to transfer and implement the outcomes of research and development has not kept pace with the rate of technological innovation nor the rapidly changing socioeconomic milieu of most developing nations and their communities. It is not uncommon for technology transfer to lag technology development in any economic sector, but an opportunity exists to significantly strengthen the collective CRSP and associated stakeholders' ability for technology transfer in human health themes.

Similar issues affect the on-going, community-based coastal management efforts on the Pacific Coasts of Mexico and Nicaragua. There are three on-going coastal management initiatives in these countries that this work will support through carrying out specific recommendations in each area's management plan related to aquaculture, fisheries and development of alternative livelihoods. The coastal management initiatives that this work will support are located at: 1) Santa Maria Bay, Sinaloa, Mexico; 2) Boca de Camichin, Nayarit, Mexico; and 3) Aserradores Estuary, a part of the Estero Real Protected Area and RAMSAR site. This work is also linked to work conducted as part of the USAID SUCCESS program, EU fisheries management programs and other international initiatives.

We are proposing to use support from CRSP to build on current coastal and aquaculture management efforts to: 1) continue an emphasis on bivalve culture, sanitation and co-management as a means to diversify aquaculture and improve food security; 2) research aquaculture methods and fisheries dynamics for a new fish species with high potential; 3) provide extension support to communities to assure adoption of technologies and best management practices developed during Phase I of this project; and 4) improve access to key information for decision-making and planning through publications, outreach, extension and exchanges.

Two types of aquaculture have been selected for their potential to diversify aquaculture, direct impact on food security and which have minimal impacts on the environment. Firstly, since becoming part of the CRSP network in 2003, efforts have focused on promoting culture of native species of bivalves as a sustainable form of aquaculture with low technology requirements and minimal environmental impacts. The health aspects of aquaculture and links with the environmental have also been researched, particularly shellfish sanitation. To date, accomplishments in this area have included the classification of shellfish growing grounds, development of depuration and relaying methods, increased culture of the native oyster species and transfer of culture technologies. The current work will solidify accomplishments and continue to advance in certain key areas, including developing hatchery methods to assure the supply of larvae, now the major constraint to future progress by community groups culturing shellfish. Secondly, in the theme of developing native species which can substitute for introduced species and which offer potential to directly supply food for poor, rural people with minimal impacts, the CRSP and SUCCESS projects have been working to develop the chame fish (*Dormitator latifrons*), which is found along the entire Pacific Coast of the Americas, from California to northern Peru. The chame is euryhaline and omnivorous, and has the habit of ingesting detritus. This fish was once abundant in many areas and with the exception of certain indigenous groups, has been largely distained despite its high quality flesh. Trials in Ecuador under the SUCCESS program demonstrated that it could be successfully cultured using low-protein, locally-sources feeds and has rapid growth rates. Researchers in Mexico will undertake research to determine the nutritional requirements of fingerlings, methods to induce spawning and assess the population dynamics of the wild populations.

Vision Statement
This work aims to further current efforts to develop indigenous species in Mexico and Central America focusing on bivalves such as clams, oysters and scallops as a low-impact alternative to shrimp aquaculture and to more directly benefit poor coastal communities. A thriving bivalve fishery and aquaculture industry in Mexico and Nicaragua that yields safe, high quality products will create jobs, improve food security and reduce the incidence of shellfish-borne illnesses. Development of the chame fish will add an easily-cultured native species to the array of possibilities for small-scale fish culture along the Pacific Coast of Latin America. Training and extension in general food safety and quality for all aquaculture products will build capacity among producers and vendors to reduce risks and improve the value of their products. Additionally, this work will contribute to improving national capacity in Mexico and Nicaragua by training professionals (including one graduate student) to increase their knowledge in these fields. Findings will be disseminated globably through peer-reviewed publications, accessible website material and presentation at international meetings.

LEAD US INSTITUTION: UNIVERSITY OF MICHIGAN

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PROJECT TITLE
IMPROVING SUSTAINABILITY AND REDUCING ENVIRONMENTAL IMPACTS OF AQUACULTURE SYSTEMS IN CHINA, AND SOUTH AND SOUTHEAST ASIA

AQUAFISH PROJECT THEME
ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUATIC RESOURCES USE

Investigations

1. 09BMA03UM	Incorporation of tilapia (*Oreochromis niloticus*) and Sahar (*Tor putitora*) into the existing carp polyculture system for household nutrition and local sales in Nepal
2. 09BMA04UM	Study on the effectiveness of a pond-based recirculating system for shrimp culture
3. 09QSD03UM	Development of polyculture technology for giant freshwater prawns (*Macrobrachium rosenbergii*) and mola (*Amblypharyngodon mola*)
4. 09MNE01UM	Invasion of the red swamp crayfish (*Procambarus clarkii*) in China: genetic analysis of the invasion and the impacts evaluation
5. 09BMA05UM	Development of indoor recirculating culture systems for intensive shrimp production in China
6. 09MNE03UM	Integrating environmental impacts, productivity, and profitability of shrimp aquaculture at the farm-scale as means to support good aquaculture practices and eco-certification
7. 09BMA06UM	Identifying best practices to improve the giant river prawn industry in Thailand
8. 09MNE05UM	The impact of fish stocking on wild fish populations, fish production and the ecosystem of irrigation reservoirs in South Vietnam
9. 09MNE06UM	Evaluating the relationship between semi-intensive aquaculture and natural biodiversity

US & Host Country Institutions

USA	University of Michigan (Lead US institution)
Bangladesh	Bangladesh Agricultural University
China	Shanghai Ocean University (Lead Host Country institution) Huazhong Agricultural University Network of Aquaculture Centres in Asia-Pacific
Nepal	Institute of Agriculture & Animal Science
Vietnam	Nong Lam University

Other Collaborators and Linkages

Department of Fisheries, Thailand
Dong Nai Fisheries Company, Ho Chi Minh City, Vietnam
Haoshideng Shrimp Farm, China
Huiting Reservoir Fisheries Management Company, Jingmen City, China
Rural Integrated Development Society-Nepal (RIDS-Nepal), Nepal
Sichuan Aquacultural Engineering Research Center, Chengdu, China
World Wildlife Fund in Asia
Wuhan University, China
Zhanghe Reservoir Fisheries Management Company, Jingmen City, China

Project Summary

This proposal represents a collaboratively defined series of studies with host country counterparts in China, Nepal, Thailand, Bangladesh, and Vietnam. The experiments listed were defined largely by the host country scientists, in consultation with their university and government colleagues in each country. The priority of each experiment or study is exemplified by the fact that of all possible studies to be done, each investigator believed this was the most important one, currently.

Investigation #1 (09BMA03UM) is the next step of our continuing work in Nepal. We have done experiments testing various species combinations in polyculture, and this experiment adds tilapia and sahar, a highly valued local fish, to the mix. It intends to use sahar as a biological control to limit natural reproduction of tilapia, producing a cash crop of its own as well as allowing for tilapia culture without extensive hatchery systems to produce sex-reversed fish.

Investigation #2 (09BMA04UM) tries to use recirculating technology from indoor shrimp systems to improve water quality and reduce the effects of effluents and solid waste from outdoor pond systems on the local environment. Shrimp culture is very important to China for internal food uses as well as export. However, water quality is equally important, given the difficult state of many natural waters there. This system, if successful, should create a cost effective way for small-scale farmers to adopt recirculating technology without a large investment in water treatment systems. It is also related to Investigation #5 (09BMA05UM).

Investigation #3 (09QSD03UM) returns the AFCRSP to Bangladesh with work on prawn culture in Bangladesh, this time using polyculture of prawns with mola, an important indigenous fish. Prawns are quite valuable and can produce high economic value, but most farmers rely on their ponds for household consumption as well. Adding mola to prawn ponds should provide a food resource for the household along with a cash crop, and allow small-scale farmers to benefit nutritionally as well as economically. This study is also related to Investigation #7 (09BMA06UM).

Investigation #4 (09MNE01UM) continues our work on invasive species, this time looking at the invasion dynamics of red swamp crayfish in China. This species has caused problems in many areas, because it is often introduced by aquaculture systems but escapes and becomes a damaging invasive species. This study will apply genetic techniques, along with population dynamic studies, to evaluate the extent, sources, and routes of invasion of the crayfish in China. This study relates to Investigation #8 (09MNE05UM) as well.

Investigation #5 (09BMA05UM) is another study on improving shrimp aquaculture systems, this time using indoor recirculating technology in China. The study will conduct experiments in a commercial indoor recirculating system, and look at various water treatment options as well as existing technology to determine their effects on water quality and shrimp production. In addition, this study will continue our work on microcystins in pond aquaculture by evaluating a number of natural shrimp ponds and other systems for the existence of microcystins in algae

blooms, and the limnological characteristics associated with these blooms. It is similar in nature to Investigation #3 (09QSD03UM).

Investigation #6 (09MNE03UM) continues the work from the last work plan on life cycle assessment of shrimp production in China. This study applies other techniques, including mass balance models, economic analyses, and best management practices to evaluate the environmental effects of various culture options, and in doing this to assess the likely outcome of some practices from an ecological, social, and economic perspective. It has some related elements to Investigations #3 and #5.

Investigation #7 (09BMA06UM) continues work from our earlier surveys in Thailand, Bangladesh, and Vietnam on prawn culture systems. This study is a workshop to inform practitioners in Thailand on various management practices used in the country, the economic analyses of their success, and other aspects of aquaculture practice for prawns. It will also encourage exchange of information from participants, especially farmers, in an attempt to better educate each other on sustainability of prawn culture.

Investigation #8 (09MNE05UM) will refocus our work on biodiversity in reservoirs and the effects of introduced species on native fauna. Our studies to date have been on larger reservoirs with numerous introductions and large fisheries. While these systems are interesting, they are very difficult to evaluate quantitatively. This study will use surveys of a number of small irrigation reservoirs, as well as local studies on several of these reservoirs, in an effort to better define the effects of introduced fishes on the native fauna.

Finally, investigation #9 (09MNE06UM) will convene a symposium to review the interactions between semi-intensive aquaculture and biodiversity. Participants will include CRSP scientists as well as other recognized experts in this field. The effects of aquaculture on biodiversity is controversial, and needs better resolution and broader analysis in order to gain a better perspective on what aquaculture should do to minimize these deleterious effects. This symposium will focus on semi-intensive aquaculture to deal more effectively with the CRSP mission as well as utilize our experiences in research, and also to help understand the factors involved in small-scale fish farming.

Overall, these nine investigations span a wide variety of university participants, countries, subjects, and methodologies. This breadth is very important to the aquaculture community as well as to the vitality of our research group. We believe that these studies will help provide further information to fine tune aquaculture systems throughout the world, and will result in considerable improvement in aquaculture practice as well as published literature to expand the impact beyond the boundaries of this region.

LEAD US INSTITUTION: OREGON STATE UNIVERSITY

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PROJECT TITLE
ASSESSING THE IMPACTS OF CRSP RESEARCH: HUMAN CAPITAL, RESEARCH DISCOVERY, AND TECHNOLOGY ADOPTION

AQUAFISH PROJECT THEME
HUNGER ALLEVIATION THROUGH IMPROVED DIETS, FOOD QUALITY, AND FOOD SAFETY

Investigations

1. 09BMA07OR	Assessment of AquaFish CRSP Discoveries
2. 09TAP06OR	Assessment of AquaFish CRSP Technology Adoption and Impact
3. 09TAP07OR	Project Planning Meeting on AquaFish Technology Discovery and Impact Assessment

US & Host Country Institutions

USA	Oregon State University (Lead US institution) Montana State University

Other Collaborators and Linkages

Project Summary

This proposal is to characterize and assess AquaFish CRSP's Phase II (2009 – 2011) investigations. The assessments will include the investigations' Phase I (2007 – 2009) histories to the degree that work from Phase I is being materially carried forward into Phase II. The present proposal is to be distinguished from the AquaFish CRSP Synthesis Project presently underway (*Evaluating AquaFish Accomplishments in a Systems Framework*), in which preliminary assessments of the CRSP's 38 Phase I (2007 – 2009) investigations are being conducted by topic category: Integrated Production Systems; Human Health, Food Safety, and Value-Added; Technology and Policy Adoption; Marketing, Trade, and Risk Assessment; and Watershed, Coastal Management, and Environmental Impact Mitigation.

The Synthesis Project focuses, like the present proposal, on a central problem encountered when assessing CRSP and many other agricultural research projects: the wide variety of – and complex systems relationships among – CRSP investigations and consequent problems in characterizing and assessing the investigations as a whole. Investigation heterogeneity in the AquaFish CRSP is manifold. It includes the variety of investigation goals (human capital formation, research, outreach), the variety of outcomes (aquaculture profitability, human health, ecosystem quality), and the variety of their technological and cultural settings. Such variety complicates issues already present in CRSP program assessment, in particular the ever-present data and conceptual difficulties in distinguishing CRSP program influences from other factors affecting a fish farm setting.

AquaFish CRSP assessment faces the additional challenge that the structure for collecting project-specific assessment data, and resources to support such collection, have not been built into the CRSP investigation workplans and must be added after the investigations have been partially completed. Opportunities for collecting some relevant baseline (pre-project) data thus are lost,

and resources for gathering other data are unavailable. Because situations of this nature are often unavoidable, an effective assessment plan must take into account the data that will feasibly be available. See, for example, the recent review of assessment methods at CGIAR centers (CGIAR Science Council 2009), and CGIAR current impact assessments of scientific and policy-oriented research (CGIAR Science Council 2008).

The current synthesis project has succeeded in: (a) conducting a detailed examination of AquaFish CRSP project- and investigation-level settings, objectives, and goals; (b) provided assistance with DTAP terminology definitions; (c) assembling a list of the quantifiable study inputs and outputs of each AquaFish CRSP project and investigation; and (d) conducting a review of the literature on probability elicitation and Bayes probability updating, useful for developing the methods we will use to elicit investigations' probabilistic output information; (e) opening communication with the AquaFish PIs in order to assemble investigations' input data.

Besides deepening our analysis of AquaFish CRSP's inputs and outputs (Investigation # 1, 09BMA07OR), we propose in the following to assess the economic, environmental, and gender impacts of those study outputs (Investigation #2, 09TAP05OR). The Tradeoff Analysis and Minimum-Data methodologies proposed for that purpose already have been developed as part of the Soil Management CRSP that ended in 2007. They have been widely applied and disseminated. Further details are available at www.tradeoffs.montana.edu. We also propose (Investigation #3) to hold a planning meeting in which HC participators will discuss data and methods of evaluating research productivity and project impact assessment.

Besides introducing the work described under Investigations #2 (09TAP05OR) and #3 (09TAP06OR), the present proposal's Investigation #1 (09BMA07OR) will add to current synthesis project in two ways: (a) it will allow attention to the CRSP's 2009 – 2011 activities, while the synthesis project can address its 2007 – 2009 activities; (b) the present proposal includes development of seven investigation case studies, one for each of the AquaFish projects.

This proposal is part of the investigators' career interest in science and technology assessment, project impact, and economic development. We plan to conduct follow-up research on project input-output relationships and impact evaluation in developing countries, possibly with support from the Bill and Melinda Gates Foundation. Our focus will be on constructing assessment methods that are economically rigorous but capable of implementation in low-data and heterogeneous settings.

Problem Statement and Objectives

We propose to extend the on-going AquaFish CRSP synthesis project by developing conceptually sound and practical methods of assessing the impacts and benefits of a wide variety of CRSP investigations and, to the extent practical with the available data and the two-year project timeline, to use these methods to characterize AquaFish CRSP's contributions to aquacultural productivity, poverty alleviation, ecosystem relationships, and human health. Because our proposal is to assess the activities and results of the other AquaFish CRSP projects (hereafter referred to as our counterpart projects), it will have implications for each of the CRSP's four Global Themes: improving human health, generating income for small-scale fish farmers, managing-aquatic environmental resources, and enhancing aquacultural trade opportunities. Each counterpart project concentrates generally on one Theme, with cross-cutting attention to the other three. The individual investigations within the seven projects each specialize more particularly on a given Theme. We therefore will pay particular heed, in designing and applying our assessment methodology, to providing adequate attention to all four Themes.

The Core Program Components of every AquaFish CRSP project are a systems standpoint; an explicit outreach component; orientation toward social, economic, and environmental

sustainability; and human and institutional capacity-building. These components have two implications for the present proposal. The first is that a complete assessment of AquaFish CRSP's studies requires we attend to the manner in which they fulfill all four core components. The second is that our assessments themselves must fulfill the core components.

The variety of AquaFish CRSP's ongoing investigations, the current absence of essential data and any mechanisms that would generate it, and the requirement of addressing all four Global Themes and all four Core Program Components, places a high burden on any assessment methodology. The resources behind our present synthesis project, charged with assessing the current AquaFish investigations, are inadequate to that burden. Clearly, a more comprehensive and flexible assessment strategy – whose applicability would go beyond AquaFish to other USAID CRSPs – needs to be developed.

As an inspiration for doing so, we note that many USAID projects, including those – like AquaFish – targeting global hunger, seek to improve technologies, markets, and ecological practices that small businesses, cooperatives, and households would most likely be willing to adopt. Projects typically consist of: (a) training local individuals to conduct research, market development, and outreach; (b) conducting research and development studies; and (c) extending the study results through training sessions, demonstrations, and other outreach methods. Some investigations contain all three elements, others one or two. All involve, at least implicitly, a training aspect because research and outreach experiences themselves build human capital. Research discovery and outreach therefore are integrally related with one another, and each of the two with training. Assessments of CRSP contributions therefore must be conducted integrally in the same way.

Objectives

The goal of the AquaFish CRSP is "to develop more comprehensive, sustainable, ecological and socially compatible, and economically viable aquaculture systems and innovative fisheries management systems in developing countries that contribute to poverty alleviation and food security." In keeping with this overarching CRSP goal, the present proposal's primary objectives are to:

1. Develop improved methods for assessing the discoveries arising from AquaFish CRSP experiments, studies, and activities, and apply the methods to demonstrate how the CRSP has produced new knowledge and human capital.

2. Develop "minimum data" methods of assessing the adoption and impact of AquaFish CRSP discovered technologies, and apply the methods to quantify impacts in terms of sustainability indicators: fish farm and trader income, environmental quality, human health, gender, and other social outcomes.

The project will consist of three Investigations. The first, *Assessment of AquaFish CRSP Discoveries*, will be oriented to Objective 1. The second, *Assessment of AquaFish CRSP Technology Adoption and Impact*, will be oriented to Objective 2. Both of these will be studies, employing surveys, focus groups, quantitative modeling, and other social science methods. The third, *Project Planning Meeting on AquaFish Technology Discovery and Impact Assessment*, will bring together host-country participants to review assessment methods relevant to Investigations #1 (09BMA07) and #2 (09TAP05OR).

PART II. RESEARCH PROJECT INVESTIGATIONS

TOPIC AREA
PRODUCTION SYSTEM DESIGN & BEST MANAGEMENT ALTERNATIVES

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EVALUATION AND IMPROVEMENT OF PRODUCTION TECHNOLOGY IN UGANDA: CASE STUDIES OF SMALL-HOLDER CAGE CULTURE IN WATERSHED RESERVOIRS AND AS AN ALTERNATIVE LIVELIHOOD FOR FISHERS

Production System Design & Best Management Alternatives/Study/09BMA01AU

Collaborating Institutions & Lead Investigators

Auburn University (USA)	Joseph J. Molnar Karen Veverica
National Fisheries Resources Research Institute (Uganda)	Gertrude Atakunda John Walakira
Makerere University (Uganda)	Theodora Hyuha Monica Karuhanga Beraho
Gulu University (Uganda)	Nelly Isyagi

Objectives

1. Evaluate cage culture performance among small-holder farmers in Uganda through on-farm trials.
2. Document case studies of demonstrator farmers using cage culture technologies and best management practices on watershed reservoirs in four Uganda locations.
3. Conduct site visits to demonstration farms with fishers, farmers, donors, NGOs and government authorities to disseminate information about fish farming in Eastern Africa.

Significance

Storing water for agricultural use is the focus of Experiment 1 and Study 2 in this proposal. Cage culture is a potentially profitable enterprise for both lakes and reservoirs and can be one of the potential "agricultural uses", especially since it does not actually consume water. Demonstrating a small cage culture business that can sustain a family will provide information on the economic importance of cage fish farming as one use of watershed reservoirs. The potential advantages of cage culture and the returns on investment have been demonstrated in Uganda using floating fish feeds imported from the U.S. USAID has provided funds to assist a local feed manufacturer to purchase equipment for the manufacture of floating fish feed in Uganda. The feed is expected to be available beginning in April 2009. New enterprise budgets must be made for the locally made fish feed.

The number of fishers on Lake Victoria has increased tremendously since 2000 and the increased pressure on the fishery has led to adoption of illegal and highly destructive fishing methods. Moving traditional fishers to farming has often been cited as near impossible. However, many of Uganda's fishers are newcomers to fishing because they were not able to subsist on agriculture. This group of people could more easily be moved into fish farming compared to groups who have been fishing for several generations. Rearing of fish in cages is a viable alternative for landless poor men and women if financial management training and facilities are provided, not only on Lake Victoria but on other inland lakes and water harvesting reservoirs.

A three-year USAID-supported project (FISH-Fisheries Income from Sustainable Harvest) is a foundational context for the more focused and limited work proposed here through the network of contacts, trained men and women, and new farmer networks it established (Daniels and Veverica 2007). The predecessor USAID project targeted locales in the South. This study will expand to other areas of Uganda, and the North through Gulu University. A relatively new institution, The Ugandan Parliament authorized the creation of Gulu University in May 2003. The Faculty of Agricultural and Environmental Sciences encompasses nine academic departments. Dr. Nelly Isyagi has a part-time appointment as an instructor at Gulu University and will collaborate with Gulu University faculty in conducting the on-farm trials and organizing the training events described in this investigation.[1]

It was estimated in 2008 that eight cages of 6 m^3 each would provide a farmer with an income that is about three times what they are currently earning from fishing. Cages are available at low cost from the only fish net manufacturer in eastern Africa (Uganda Fishnet Manufacturers). These cages have been purchased by clients in Rwanda, DRC and Kenya. Therefore, the stage is set; the information and inputs are available. The next hurdle will be financing for families that lack the capital to start. AquaFish CRSP on-farm trials have helped men and women farmers realize the importance of managing their revenues from fish production to finance the next season of production inputs. We intend to continue this approach to incorporate business principles into their management practices.

Quantified Anticipated Benefits

Case studies of small-scale cage fish culture will be identify approaches to farmer recruitment, participation, and technical support that can be used by other donors and the Government of Uganda for its poverty alleviation programs. The case studies will document how operating capital was obtained and trace the cash-flow for each of the cage culture sites. The information gathered will be used to make recommendations on how best to provide financial assistance to new cage fish farmers.

Financial aid institutions, potential farmers with access to watershed ponds, and government agencies in the East Africa region will have reliable data-based management recommendations for cage fish farming, including enterprise budgets and cash flow analysis. The cases studies will document some of the first efforts to move fishers to aquaculture on Lake Victoria. At least four men and women students will obtain field training experience in cage culture. More than 400 visitors are expected to see the cage culture demonstrations and have access to publications on small-scale cage culture.

A local feed mill that has invested more than $400,000 of its own money and $220,000 of a USAID Strategic Activities Fund will have a small but assured clientele for some of the floating feed they will produce. The performance of their feed will be documented through these trials. The mill will receive valuable feed formulation and feed quality control advice from the investigators in this study.

1. The main target groups are individual farmers and rural communities. The findings will reveal the potential for commercial fish farming at small-scale production enterprises and the availability of local cages and feeds.
2. Participating fish farmers will directly benefit from this work. They will receive technical assistance and cost-sharing to demonstrate new approaches to fish farming in Ugandan lakes and reservoirs.

[1] The research outlined in study 3 provides information that was not previously documented and will generate practical insights into the actual processes of implementing fish culture technologies in the target settings. Study 3 could not have been possible if the FISH project had not developed the technology "packages" and had not assured the availability of quality feed, seed and cages. However, study 3 now takes this several steps further by: involving NaFIRRI investigators, including links with Gulu University, and by further examining the cash flow dynamics of a real cage culture enterprise.

Research Design & Activity Plan

Case studies

USAID-supported research as well as the Fisheries section of NARO has conducted initial cage culture demonstrations (Daniels, Davis, and Veverica 2007). We recognize that a participatory process is essential to the establishment of effective on-farm trials (Buzzard 2008). NaFIRRI staff and an Auburn graduate student will conduct pre-trial participant interviews and training in each of four selected locales.[1] We will make visits and phone calls to ensure farmer interaction throughout the trial period. We also will hold group meetings with men and women following the trials to share observations, examine differing results, and provide a forum for the exchange of information among farmers, researchers, and extension agents. A written "contract" emanating from these discussions with farmers and farmers groups will be used to clarify their responsibilities and gain commitment (Buzzard 2008). Two farmers near Kampala who use small cages in their reservoir ponds are Blessed Investments, located in Mityana district, with a 2-ha reservoir and Namuyenge mixed farm, owning two reservoirs of 0.5 ha each, in Mukono district. A cage operation located on Lake Victoria (SoN fish farm) has more than 20 small cages in production. This farm is the source of selected sex reversed fry that will be grown in nursery ponds to stock the cages. These three farms have benefitted in the past from technical assistance from the USAID FISH project and can be used to host farmer training. The four sites and cases studies are:

1. Masese--One group of small-scale farmers has obtained permits for cage culture, outside Jinja, within about 5 km of where the Nile River exits Lake Victoria.
2. Kalangala--A well-established fishermen's group in Kalangala has expressed strong interest in cage culture as alternative livelihood for fishers. This group already has a working relationship with a processor and has its own set of fish transport and marketing lines established.
3. Bunyaruguru--an Environmental Conservation Association is just getting started with two trial cages in western Uganda. The importance of developing cage culture on these lakes is 3-fold: to provide alternative livelihoods for the people who currently poach fish from lakes in Queen Elizabeth National Park (QENP); to increase the availability of fish to a people who hold fish consumption in high regard and who are currently only able to access fish carcasses as source of fish and to set up a water quality monitoring program at early stages of lake exploitation.
4. Northern Uganda (probably Lake Kyoga, near its outlet or on a reservoir)--This site will be identified in the first quarter.

Each farmer group will develop a financial management plan with the assistance of the AquaFish CRSP investigators. The plan will address the cash needs for members who want to begin cage culture. The trial will serve to validate the cash flow needs as well as the economic performance of one "family cage culture enterprise". Auburn and Ugandan graduate students will conduct field work in each locale to assess the community context, resource constraints, and prospects for broader participation in cage culture by area residents. A student trainee will be assigned to each site to aid in collection of water quality data and to help with record-keeping. However, all work will be done by the men and women farmer-participants. The overall project results will be reported as a series of case studies of the implementation of cage culture in Uganda (Yin 2003, Harrison 1996).[2]

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[1] NaFIRRI (National Fisheries Resources Research Institute) is the fisheries/aquaculture branch of the National Agriculture Research Organization, NARO. NaFIRRI has been a key collaborator with the USAID-funded FISH project and has collaborated on its field trials for cage culture. A collaborative partnership as proposed here is logical and will be highly beneficial to the development of Uganda's aquaculture research capacity. Auburn University has had a subagreement with NaFIRRI from 2005 through 2008.

[2] The process of conducting a case study can be summarized as follows: 1. Data from a combinations of methods, including documentation (applications, histories, records, etc.), questionnaires, interviews, group discussions, and direct observation are assembled 2. Data is organized into an approach to highlight the focus of the study. 3. A case study narrative integrates and summarizes key information around the focus of the case study. 4. The narrative validated by review from program participants or others knowledgeable about the situations. The cases studies outlined here should provide insights into the implementation and use of aquacultural technologies.

Cage culture field trials

Producers will obtain sex reversed *O. niloticus* fry will be obtained from SoN fish farm and stocked in nursery ponds that belong to the group. Two of the four groups already have nursery ponds; the other two will have to construct a 400 sq meter pond as their nursery. The fry will be grown to 20-g size, which is expected to take two months. In the meantime the farmers will set out the cages. Site selection and cage placement will be done under the guidance of Rashid Asiimwe, who has been involved in cage culture trials since 2006 and following the guidelines from Schmittou et al. (1997) and Asiimwe et al. (2008).[1]

***Regional and Global Integration*:**

We plan a formal integration of this activity with the overall region. The work will be jointly conducted by Makerere personnel (faculty, staff and students). The East African Community includes the three countries listed above as well as Rwanda and Burundi. Small-holder cage culture trials were undertaken in Rwanda on Lake Muhazi in 1986 and have been re-commenced in 2008. Burundi fisheries department are aware of the activities already and have asked the proponents to be kept updated. The activities and publications will be distributed on the ANAF (Aquaculture Network for Africa) website. Funds will be sought from the Strategic Activities fund of the USAID project LEAD to help with initial operating costs for the farmers, especially where feed purchase is concerned. [2]

Schedule

	YR1	Project Year 2				Project Year 3			
		1-3	4-6	7-9	9-12	1-3	4-6	7-9	9-12
Selection of participants and baseline data collection	X	X							
Investigator visits to demonstration sites (at least 3 visits to each site)		X	X	X	X	X	X	X	
Group meetings (at least one per site)		X	X	X					
Stock fry grow-out ponds		X			X				
Student training		X	X	X	X	X	X	X	
Cage trials			X	X	X	X	X		
Case study data collection		X	X			X			
Preparation of deliverables								X	X

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[2] No proposals are yet written; we would proceed using farmers able to operate without cost-share funds. The funding for operating costs would not go to any of the institutions in this proposal; the funds would be attributed directly to the farmers. It is possible that the farmers would receive vouchers for a certain amount of feed, as opposed to actual cash.

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TRAINING AND OUTREACH IN UGANDA AND SURROUNDING NATIONS

Production System Design & Best Management Alternatives / Activity / 09BMA02AU

Collaborating Institutions & Lead Investigators

Auburn University (USA)	Joseph J. Molnar
Makerere University (Uganda)	Monica Karuhanga Beraho
Gulu University (Uganda)	Nelly Isyagi

Objectives

1. Conduct an annual Farmer to Farmer study tour for producers from Kenya and Tanzania.
2. Organize Annual Fish Farmers' Symposium and Trade Show to disseminate project research results, provide reliable technical information, and share producer perspectives on fish farming industry trends and conditions.

Significance

Research, extension and education can contribute greatly to enhancing aquacultural production in a sustainable way and to reducing poverty, but achievements have generally fallen short of expectations in Africa (Sanginga et al. 2008). Farmers trust the experience and knowledge of others who are in situations similar to their own. Their desire to meet and talk with each other has spurred the formation of groups and networks to foster informal gatherings and more formal mechanisms of association to facilitate peer-to-peer learning. Such learning groups are most effective when they have a targeted membership like fish farmers. If member perspectives are too diverse, then participants tend to become disenchanted because the results do not apply to their situations (Barrett and Ewert 1998).

Peer-to-peer learning and support systems become increasing important in the context of privatized extension (Klerkx and Leeuwis. 2009), but in Africa there is often little or no reliable extension system to privatize. External donors endeavor to foster private, nonprofit mechanisms that will be sustainable and provide the information and organizational services that fish farmers need to build an industry.

Farmer innovators appreciate exchange and study visits as ways of gaining new experience, knowledge and techniques, which they informally experiment on at home (van den Ban and Hawkins 1998). Farmer-to-farmer communication is more effective when visitors and hosts are well prepared, and if both groups review the usefulness of the exchange and deliberate on the reporting of lessons learned.

Previous experience with farmer innovators in agricultural development suggests that study tours and farmer-to-farmer interaction led to significant levels of advancement in production practice. The project encouraged innovators to organize themselves into clusters of farmers and exchange experiences within and between clusters. In Tanzania, some farmer innovators started forming local groups with neighboring farmers after returning from the exchange visits. It is not easy to fully integrate the farmer innovation approach to participatory research and extension into the regular activities of national institutions. The concept of farmers as innovators and researchers is still new for many decision-makers. Thus, there are manifold ways that innovator farmers that share a common interest in a focal enterprise such as fish culture will associate themselves to gain the benefits of mutual support and collaboration.

Quantified Anticipated Benefits

1. The main target groups are individual farmers and rural communities. The activities will foster the potential for commercial fish farming in small-scale production enterprises and the availability fish in local markets.

Fish farmer groups tend to gain new members as a result of the symposia.

2. Service providers and suppliers of inputs will gain recognition and possibly clients. The numbers of participating businesses for the trade show can be quantified as can the number of attendees.

Visiting farmers may elect to become sales representatives of the supplies and services they identify as useful for their respective location and circumstances. Each farmer participating in the study tours and fish farmer symposiums will be asked to submit a summary of new ideas they have picked up and enumerate the business contacts they have made.

Activity Plan

Outreach is extension, and implies regular and purposeful communication with stakeholders and beneficiaries at the various intermediate and local levels (Kerrison 2005). When standard forms of literacy-based and electronic communication are no longer available, then outreach takes place in the traditional extension way, with physical visits, dialogues, community meetings etc. Where adequate mass communications, electronic or literacy-based media can be used, mobile phones, email etc. then the need for travel and face-to-face meetings is obviously reduced (Kerrison 2005). The results (and other information) are disseminated through a series of study tours and fish farmer symposiums that involve selected fish farmers from neighboring IEHA countries. We will organize and carry out several training events in Uganda.

Annual Fish Farmer Symposium and Trade Show

The Annual Fish Farmers' Symposium and Trade Show has drawn participants from around the country and the region. The project will participate in organizing these symposiums by helping build the program and in some cases participating as speakers or resource persons. These events also provide a forum from which to disseminate the activities of the AquaFish CRSP. During the trials and particularly for the first cage harvested at each site, a site visit will be hosted by a fish farmers' group that will present their findings and experiences.

In December 2009 the Annual Fish Farmers' Symposium and Trade Show event will be held in Kampala. In December 2010 the Study Tours and Symposium is planned to be held in Gulu, in northern Uganda. We will utilize university or private facilities insofar as the venue is appropriate and cost-effective for the project. For example, previous symposia have been held in the Ugandan Manufacturers Association building in Lugogo, Kampala. This is a well-known site for fish farmers as the previous two symposia were held there. The venue is simple and cost is much less than the hotels that normally host donor-funded "stakeholders meetings". Thus producers in the north and south of the country will have access to the symposium and technical materials if they are otherwise unable to participate in the farm tour.

The Annual Fish Farmers' Symposium and Trade Show in 2009 will be held in conjunction with at least one Uganda fish farmers group (WAFICOS). This group has already co-hosted a fish farmers meeting. A second fish farmers group will be assisted in co-hosting the 2010 fish farmers meeting. Care will be taken to conduct the meeting in a way that fish farmers groups will be able to replicate in later years. To that end, we will request that the WAFICOS leadership help us identify a 3-5 member program planning committee to help plan the events and guide the experience.

The farmers groups will be encouraged to seek additional sponsors, especially for the 2010 meeting. The door prize tradition will be continued at these two fish farmers' symposia. Door prizes are donated by various companies. Every registered participant receives a door prize ticket. At the end of the symposium, winning tickets are drawn for the prizes. People must be present to win. In the past, about 20 prizes have been distributed at each symposium, thus providing some publicity for donating businesses, and a very high level of interest from farmers. Typical door prizes are bags of fish feed (a coupon is given so the winner does not have to carry the bag of feed home), fingerlings (again by coupon), frozen fish fillets, fish farming gear such as nets, and cages, calculators, etc.

Study Tours

Farmer-to-Farmer Study Tours will precede the Annual Fish Farmers' Symposium and Trade Show in Kampala in December 2009. Ten participants from Kenya and ten from Tanzania would be part of a bus tour to a selected set of farms in Uganda. Three days would be spent on the tour; two days at the symposium. In this project, outreach is accomplished primarily through four production trials conducted by fish farmer associations (study 3) that will serve as central points of demonstration and instruction for the study tours.

Study tour participants from Kenya and Tanzania will assemble at a designated point where a project supported Coaster bus will collect them for travel to the first demonstration farm visit. A registration fee paid in advance will secure each participant a seat on the Study Tour bus. Producers will overnight on the demonstration farms with facilities or at nearby motels. The project will cover housing and transport expenses; participants will cost-share their own meal expenses.

Nelly Isyagi will serve as training coordinator to organize logistics for the Uganda tour and symposium. She will liaise with Uganda fish farmer groups, Kenya AquaFish CRSP colleagues, and industry contacts in Tanzania, and if additional funds are available, in Ghana. USPIs and their Uganda colleagues would help develop the Study Tour itinerary and Symposium program. Dr. Isyagi has successfully coordinated a similar program for Kenya farmers who visited Uganda in April 2009. She shall be retained via a monthly stipend to coordinate the project's efforts, receive project visitors, and otherwise provide a central point of contact for the US and HC PIs.

The recruiting process will ensure that about half the participants are women (see statement in Outreach Plan). The process also will seek to ensure bona fide fish farmers actually are selected for the study tour associated with the Annual Fish Farmers' Symposium and Trade Show, endeavoring to avoid rent seeking among government officials and others. The host farms and Dr. Isyagi will provide training materials to accompany the farm visits and symposium. Participating producers will have durable reference materials to guide pond construction, seed stock development, production, and marketing processes. The symposium proceedings will be made available on CD-rom and a web-site (Veverica 2009).

Regional and Global Integration

Nelly Isyagi will provide leadership and coordination in organizing all training sessions and in development of training materials. The Annual Fish Farmers' Symposium and Trade Show will contribute to strengthening our contacts in countries where we have previously interacted and provide opportunities for new contacts in countries that have not had prior relations with the AquaFish CRSP. The Lake Victoria Fisheries Organization is highly interested in this concept and will provide the mechanism whereby member countries can benefit from the information resulting from these activities (Kerrison 2005). Currently, its member states are: Uganda, Kenya and Tanzania.

We link the results of Study 1 Uganda and South Africa and the work produced in study 2 through the study tour associated with the Annual Fish Farmers' Symposium and Trade Show. Khalid Salie (Stellenbosch) will participate in the 2010 fish farmer symposium in Gulu to present the study results. Similarly, one of the Ugandan researchers will travel to South Africa to present the results of research and outreach activities in Uganda in the second year of the project. In particular, we will seek to integrate the project outcomes by bringing presenting research results from both countries and the analytic tools that are being developed to the symposium in Gulu.

Schedule

	YR1	Project Year 2				Project Year 3			
		1-3	4-6	7-9	9-12	1-3	4-6	7-9	9-12
Selection of participating farmers		x				x			
Conference organization	x	x			x	x			
Annual Fish Farmers' Symposium and Trade Show		x				x			
Study Tour		x				x			
Process & report participant assessments			x				x		

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INCORPORATION OF TILAPIA (*OREOCHROMIS NILOTICUS*) AND SAHAR (*TOR PUTITORA*) INTO THE EXISTING CARP POLYCULTURE SYSTEM FOR HOUSEHOLD NUTRITION AND LOCAL SALES IN NEPAL

Production System Design & Best Management Alternatives/Experiment/09BMA03UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA) James Diana
Institute of Agriculture & Animal Sciences (Nepal) Madhav K. Shrestha
Shanghai Ocean University (China) Liu Liping

Objectives

1. To assess the growth, production and productivity of carps, tilapia and Sahar in different polyculture combinations;
2. To assess nutrient recovery in each system;
3. To determine cost and benefits of fish production in each polyculture system;
4. To assess and compare water quality produced by each polyculture treatment.
5. To evaluate performance of the polyculture systems in on-farm trials focused on small family farms with females in management positions.
6. To promote those results in a workshop targeted on polyculture and family nutrition.

Significance

Total fish production in Nepal is 50,000 mt, with about 50% coming from capture fisheries. Current annual fish production of Nepal aquaculture systems is about 3.3 t/ha (DoFD 2008). Increasing fish productivity as well as total production in country is a challenging task and necessary in order to provide for increasing demand for fish as food without increasing import from neighboring countries. Nile tilapia (*Oreochromis niloticus*) was introduced in Nepal in 1985 (Pantha 1993), however, it remained in government control for more than 10 years (Shrestha and Bhujel 1999). Since 1996 some works on tilapia were initiated at Institute of Agriculture and Animal Science. Experiments conducted included: polyculture of tilapia and common carp (*Cyprinus carpio*) (Shrestha and Bhujel 1999), mixed size culture of tilapia (Mandal and Shrestha 2001), and polyculture of grass carp (*Ctenopharyngodon idella*) with tilapia (Pandit et al. 2004). As mixed sex tilapia was used for culture, recruitment control was a problem. Snakehead (*Channa striatus*) is often used to control tilapia fry (Yi et al. 2004). Sahar (*Tor putitora*) an omnivore, which feeds on filamentous algae, insect larvae, small mollusks, and periphyton on rocks (Shrestha 1997) were explored to study its predation capacity on tilapia fry. The Aquaculture CRSP and now the AquaFish CRSP have worked on tilapia and Sahar combinations in polyculture to control excessive recruitment of tilapia and also to provide additional species to increase productivity and to promote culture of high value fish that are indigenous. Experiments have shown that Sahar control tilapia fry (Paudel et al. 2007; Rai et al. 2007; Yadav et al. 2007). Growth of Sahar has been recorded higher in tropical and subtropical ponds than in cages at Pokhara lakes and also in suspended cages in ponds (Shrestha et al. 2005; 2007; Bista et al. 2001; 2007). Sahar has been overfished in rivers and lakes with declining populations (Rai et al. 2001; Rajbanshi 2001; Joshi et al. 2002).

Semi-intensive carp polyculture is an established and recommended system in tropical and subtropical region of Nepal using fertilized ponds with partial feed supplementation. The carp species are: common, silver (*Hypophthalmichthys molitrix*), bighead (*Aristichthys nobilis*), grass, rohu (*Labeo rohita*), naini/mrigal (*Cirrhinus mrigala*), and Bhakur/Catla (*Catla catla*). Though all seven species are recommended in certain ratios with a combined density of 7000 fish/ha (Pandey et al. 2007), fingerlings of all species are rarely available when needed for stocking. In most of the cases,

the number of species cultured ranges from four to six. Addition of well proven species (such as tilapia and Sahar) with increased stocking density into the existing carp production system can have a positive impact by increased productivity and economic value.

This study is intended to continue research on carps, tilapia, and Sahar production in polyculture in order to better develop the model for best production and to determine the costs and benefits of various polyculture combinations. It involves both on station and on farm trials, and the research will use female students as researchers. Since the target for this research is increased production of fish mainly for household consumption, we will also use ponds run by female culturists for the on-farm trials. The Rural Integrated Development Society, Nepal, and Women in Aquaculture are cooperators in our research in Nepal, and both target improving food security for families by focusing their efforts on females in households. As a result, they should also help us both in the research dissemination as well as in identifying possible participants for the on farm studies. In order to insure that the participants are comfortable with research protocols and requirements, we will have female graduate students participate in this research on farm. This should help both in extending information to the female culturists, and also in producing methods and extension materials that are appropriate for female farmers. We plan to develop a workshop outlining the results of polyculture studies and how these results can influence household nutrition. This workshop will target women who bear most of the responsibility for household nutrition, and will be held in Nepal in late summer 2011.

Quantified Anticipated Benefits:

The results of this study will provide an additional species in polyculture system of Nepal with increased productivity, production, and income. It will add high valued fish in the culture system and will supplement income. As carp polyculture is an established culture system, increasing species will be easier to adopt by fish farmers. It will also help in production of Sahar and decrease fishing pressure in nature. It will benefit fish culturists in south Asia and other countries where carp culture is popular. Knowledge on polyculture and expansion to endemic species not only benefits Nepal, but sustainable aquaculture systems throughout the developed world as well. Immediate impact will be measured by the increased production and economic returns in on-farm trials for the different polyculture systems. The workshop will train 15-20 women on polyculture practices and household nutrition. Also, fact sheets will be developed for further dissemination. Deliverables for this study include a workshop and fact sheet on Sahar polyculture.

Research Design & Activity Plan

The polyculture experiments will first be developed on station at IAAS, then tested on-farm using the best production results determined in the on station trials.

- Location: Institute of Agriculture and Animal Science (IAAS), for on-station; and fish farmers' ponds in Kathar, Chitwan for on-farm

- Methods:
  - Pond Research
  - Pond facility: 12 earthen ponds of 100 m2 will be used for both on-station and on-farm trials.
  - Culture period: 10 months each for on-station and on-farm trials.
  - Test species: Carps (Common, Silver, Bighead, Grass, Rohu, Mrigal and Catla), Nile tilapia and Sahar
  - Stocking size: Carps (5-10 g size); Mixed-sex Nile tilapia (5-10 g size); Sahar (5-10 g size)
  - Nutrient input: Fertilization and alternate day feeding with locally made feed at 2%BW
  - Water management: maintain at 1 m deep.
  - Sampling schedule

- Water quality: Standard CRSP protocol, biweekly water sampling and monthly diel analysis at various depths.
- Fish growth: monthly sampling
- Nutrient content: Initial and final sampling of bottom mud and fish for TN and TP content
- Partial enterprise budget: variable costs and value of fish crops.

- Statistical design, null hypothesis, statistical analysis:

On-station trial: The on station trial will include four treatments with three replicate ponds each. The treatments will be:

(1) Existing carp polyculture (7000/ha) (control)
(2) Control + tilapia (3000/ha)
(3) Control + tilapia (3000/ha) + Sahar (500/ha)
(4) Control + tilapia (3000/ha) + Sahar (1000/ha)

The trials will be conducted in completely randomized design, and data will be analyzed using one-way ANOVA, as well as Analysis of Covariance (ANCOVA) to test density effects.

Null hypothesis: Incorporation of tilapia and Sahar in carp polyculture has no effect on growth, production, and economic return in different polyculture system.

On-farm trial:
There will be two treatments with six replicates each: (A) existing carp polyculture (control); (B) best result from on-station trial. The on-farm trial will be conducted in two locations with three replicates in each location using randomized complete block design. Data will be analyzed using two-way ANOVA.

Null hypothesis: There are no significant differences in the growth, production, and economic return between two treatments.

Schedule

1 October 2009 to 29 September 2011. Report submission: no later than 29 September 2011.

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STUDY ON THE EFFECTIVENESS OF A POND-BASED RECIRCULATING SYSTEM FOR SHRIMP CULTURE (PRODUCTION SYSTEM DESIGN AND BEST MANAGEMENT ALTERNATIVES

Production System Design & Best Management Alternatives/Experiment/09BMA04UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA)	James Diana
Hainan University (China)	Lai Qiuming
Shanghai Ocean University (China)	Liu Liping
Network of Aquaculture Centres in Asia-Pacific (Thailand)	Yuan Derun

Objectives

1. To evaluate effectiveness of combining a screen drum filter, foam fractionating unit and a biofilter to remove solid wastes and improve water quality of shrimp culture ponds;
2. To compare water quality parameters in recirculating and closed, non-recirculating shrimp culture ponds;
3. To compare overall production performance between recirculating and closed, non-recirculating shrimp culture ponds.

Significance

Shrimp production increased rapidly from 87,831 tons worldwide in 1981 to 3,164,384 tons in 2006 (FAO, 2008). Despite continuously increasing market demand, further development and expansion is constrained by environmental concerns associated with discharge of effluents and dispersal of solid wastes to the environment. This has renewed interest in recirculating systems due to their perceived advantages, including: reduced use of water, greater control of culture environment, reduced use or non-use of antibiotics and hazardous chemicals, and close to zero discharge of effluents. Attempts have been made to develop recirculating shrimp culture systems using indoor tanks or raceways (Wyk et al. 1999) and outdoor ponds (Lin 1995; Neori et al. 1996; Shpigel and Neori 1996; Neori and Shpigel 1999; Jones et al. 2001). Commercial-scale aquaculture has become possible using these systems and practices. However, a tank- or raceway-based indoor recirculating system is technically sophisticated, economically expensive, and may be impractical for the majority of small-scale shrimp farmers in Asia. On the other hand, integrated pond-based recirculating systems require a large percentage of the farm area to culture treatment organisms such as seaweeds, bivalves, and filter-feeding fish, which limits their application. Combining shrimp pond culture with efficient waste treatment components similar to those used in indoor tank systems but with limited complexity of operation and maintenance may be a feasible alternative.

Hainan province, the only tropical area in China, is one of the major shrimp production areas in China. The environmental impact of shrimp culture has become a serious concern. Thus, we propose to test a pond-based recirculating system at Haoshideng Shrimp Farm in Hainan province to eliminate effluent discharge and use solid wastes as fertilizer for coconut trees.

Quantified Anticipated Benefits

Whiteleg shrimp (*Litopeneaus vannamei*) is the most important shrimp species cultured throughout the region. Testing and demonstration of the proposed pond-based recirculating system will lead to further development, fine tuning and extension of recirculating systems which are suitable to the majority of small-scale shrimp farms in Asia. This will reduce environmental impacts of intensive shrimp culture and improve its sustainability. Since shrimp imports are dominated by the U.S., better knowledge of sustainable shrimp culture will benefit NGOs like World Wildlife

Fund, as well as private citizens and markets concerned with reducing the environmental footprint of shrimp culture.

The impacts of the study will include the improved water quality and reduced waste discharge to the environment from the pond-based recirculating shrimp culture system. Quantitative impacts are the percent reduction in solid waste and the measured increase in water quality in the experimental ponds. Deliverables for this study will include a fact sheet on study results and presentation of results at regional farmer meetings.

Research Design & Activity Plan

Location: Ponds at Haoshideng Shrimp Farm, Hainan Province, China, and laboratory analyses at Hainan University.

Methods—Pond research

- Facility: four 0.2-h earthen ponds lined with plastic, and two sets of water treatment components, each consisting of the following equipment:
  - a screen drum filter, 200 mesh per inch, 0.6 m width, 8 m perimeter
  - a foam fractionating unit (concrete tank) equipped with 6 motors (0.75 kw) for water movement and air bulb formation, and
  - a bio-filter consisting of a concrete tank (2x3x1 m) containing porous pebbles and plastic beads with diameter of 3-5 cm as media
- Culture period: 100 days for two rounds.
- Test species: whiteleg shrimp
- Stocking density: 100 pcs/m^2
- Nutrient inputs: commercial shrimp feed
- Water management: Maintain water depth of 1 – 1.2 m in ponds by weekly topping up.
- Sampling schedule**:**
  - Water quality in ponds: standard CRSP protocols, biweekly water quality sampling and monthly diel analysis at various depths.
  - Water quality in treatment components: standard CRSP protocols, biweekly water quality sampling from inlets and outlets of the screen drum, fractionating unit and biofilter.
  - Backflush sludge: composite samples from each backflushing and foam water collection, biweekly, to analyze moisture, TN, and TP (APHA, 1998).
  - Shrimp growth: body weight for a sample of shrimp biweekly
  - Feed: will be applied at rates determined from company feeding tables, with monthly analyses for moisture, TN, and TP.
  - Nutrient balance: will be calculated from initial and final nutrient estimates. Water budget will be calculated as water lost to seepage or evaporation, as well as loss at harvest. The number and average weight of all shrimp will be determined at stocking and harvest, and survival rate calculated from these values.
- **Statistical design, null hypothesis, statistical analysis:**
  The four shrimp ponds will be randomly divided into treatment and control groups, with two ponds in each group. Unfortunately, both ponds and water facilities are limited, limiting the number of replicates and, therefore, the overall robustness of this study. Water in ponds of the treatment group will flow through the screen drum filter, foam fractionating unit and biofilter before recirculating back to the ponds. Water in shrimp ponds in control group will not be recirculated or exchanged throughout the growing period. The data will be analyzed using one way ANOVA. End results may be more descriptive in detail and require further validation, depending on the level of change noted.

  Null hypotheses: treatment and control ponds will not be significantly different in water quality and growth performance of shrimp.

Schedule

1 October 2009 to 29 September 2011. Report submission: no later than 29 September 2011.

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DEVELOPMENT OF INDOOR RECIRCULATING CULTURE SYSTEMS FOR INTENSIVE SHRIMP PRODUCTION IN CHINA

Production System Design & Best Management Alternatives/Experiment/09BMA05UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA) — James Diana
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Objectives

1. To develop water quality control technology for intensive culturing of healthy shrimp indoors.
2. To monitor main water quality parameters, especially nitrogen and phosphorus.
3. To investigate the change of micro-organisms and develop technology for disease control.
4. To investigate lethal mechanisms of the toxic cyanobacteria and their metabolites (microcystins) on shrimp *Litopenaeus vannamei*.

Significance

Shrimp is a favored aquatic product around the world since it has high protein, low fat and is rich in nutrition. The majority of marine shrimp have a wide range of adaptability to salinity and can be cultured in salt, brackish, or fresh water. China's shrimp farming industry has made remarkable achievements in the last two decades. In 1993, shrimp farming was severely damaged by outbreak of epidemic diseases, but it recovered, and shrimp production increased significantly. This increase was caused by several new technologies, such as the replacement of cultured species, structural transformation of the pond, and disinfection of rearing water.

In recent years, culturing shrimp has been widely developed in Shanghai and adjacent provinces. Traditional aquaculture models are still being applied widely in China, which means high density, high input, high yield, and high water exchange rate, with much drug use and high consumption of energy. These traditional models will not prevent the outbreak of diseases and cause water pollution with discharging of wastewater rich in nitrogen, phosphorus, and organic matter to the surrounding rivers or lakes. The damaged water ecosystems then cause disease outbreaks, which in turn threaten human health and food safety.

Due to thermal conditions, it is difficult to conduct shrimp farming throughout the year in many areas. Indoor intensive aquaculture has been developed in recent years, which has characteristics such as high-density, high input, high yield, no drug use, and low wastewater discharge. Several facilities and materials are combined, such as bio-filters, ozone or UV treatment, and foam separation. The main advantages of indoor intensive aquaculture are: (1) the culture process can be controlled more easily compared to outdoor farming, which is affected by climate or environment change; (2) water consumption is low since recycling systems use limited water exchange (less than 10% per day); and (3) little wastewater is discharged, which means that indoor aquaculture should be an environmentally friendly aquaculture model.

Intensive fish farming has a long history in many countries (Sung-Koo et al. 2000). Production by a Danish aquaculture company was from 100-300 kg/m^3. Although there is noticeable gap between China and other developed countries in facilities and techniques (Chen 1998), indoor intensive aquaculture has also been explored around China (Ying 2001). Water treatment equipment and technologies have been developed and successful systems have been introduced to culturists. Indoor intensive aquaculture technologies have been used in culturing abalone, Atlantic turbot, and flounder in Shandong, Liaoning, and other provinces (Chang-fa 2002).

Indoor intensive aquaculture has been developed world-wide. Recycling intensive shrimp farming has succeeded in Hawai'i, Florida, Texas, and other places, and may produce approximately 5-10 kg shrimp per cubic meter of water in three months. In indoor intensive shrimp aquaculture, the most important thing is to control water quality and micro-organisms within desirable levels. Combined technologies such as ozone or UV treatment, biological filtration, and sedimentation can be used to maintain water quality.

Microcystins (MCs) are secondary metabolites of toxic cyanobacteria, which often cause discoloration of the water, accumulate at the surface in discrete scums, and sometimes cause a strong smell (Carmichael 1992; Paerl et al. 2001). MCs are found world-wide in fresh water, brackish water, and marine environments and blooms of cyanobacteria often occur in eutrophic freshwater bodies (Chorus and Bartram 1999, Falconer 2001). MCs belong to a family of extremely toxic compounds and are responsible for significant health hazards to aquatic animals and even humans (Falconer 2001, Best et al. 2003). Massive fish and shrimps kills have occasionally been related to severe cyanobacterial blooms (Li et al. 2003, Chen et al. 2007). Many of these mortality events have been attributed to indirect effects such as oxygen depletion or increased ammonia concentration.

Microcystins have led to mortalities in wild and domestic animals worldwide (Yokoyama and Park 2002, Xie 2006). Moreover, freshwater fish and mussels are not only damaged by MCs, but also bio-accumulate them (Yokoyama 2003, Anderson et al. 1993). Damage such as liver tumors can also arise from long-term exposure to low level of MCs (Ueno et al. 1996; Codd et al. 2005).When people have contact with contaminated water and food, the toxins may cause problems such as nausea or liver damage. The incidence of primary liver cancer in some areas of China has been correlated to presence of MCs in drinking water (Ueno et al. 1996; Codd et al. 2005). Toxic cyanobacteria blooms are a great concern for shrimp farmers when the bloom occurs during late stages of shrimp culture, since it usually causes major shrimp mortality. However, there are very few documented reports on mechanisms of shrimp mortality caused by cyanobacteria blooms. These blooms present major issues to outdoor shrimp culture, but are not a problem with indoor recirculating culture. We plan to investigate the conditions in indoor and outdoor culture that may be associated with cyanobacterial blooms.

Our team has conducted considerable research on indoor intensive shrimp aquaculture and obtained some valuable data (Zang et al. 2003). Further research is necessary to better develop technology for water quality control, micro-organism outbreaks, and high levels of microcystins.

Quantified Anticipated Benefits:

Benefits of this study include determining the best combination of water control technologies and their relationship to microbial production in indoor aquaculture. Once again, indoor shrimp culture is envisioned by many as the future for the U.S., and a fresh evaluation of water control methodology will add to the options available to U.S farmers. Deliverables include training of at least six farmers on improved water quality management, and development of protocols that can be transferred to other aquaculture facilities.

Research Design & Activity Plan

Locations: Ponds at Shanghai Bluesea Aquatech Co., Ltd, Zhuanghang Town, Fengxian District, Shanghai, China. Laboratory analyses at Shanghai Ocean University.

Methods

- Ponds: 12 indoor raceway ponds with the size of 50m(L)×11m(W)×1.5m(H) will be used for the experiments.
- Facility: combined water quality treatment techniques will be used in each pond, and the facilities are as follows.

- a piece of canvas (30m×1.70m) to divide the pond into two parts
- two aerators
- -20 water purifying nets (5.25m × 0.90m)
- 4 air stripping tubes

- Test species: *Litopenaeus vannamei*
- Culture Period: 4 months for 2 rounds both in 2010 and 2011
- Stocking density: 2 different densities depending on farmer's opinion
- Nutrient inputs: commercial shrimp feed
- Design of experimental groups

Group No.	facilities	density	Aquatic plant	Microbe
1	All ponds have canvas, aerators, water purifying nets and air stripping tubes	I	√	
2		I	√	
3		I		√
4		I		√
5		I	√	√
6		I	√	√
7		II	√	
8		II	√	
9		II		√
10		II		√
11		II	√	√
12		II	√	√

- Water Quality: sample biweekly and monthly diel analysis at various depths. Eight parameters will be analyzed; pH, Transparency, DO, TAN, NO_2-N, TN, TP, COD and SS.
    - Sediment: sampling frequency depends on the process of the experiment. Sediment will be collected through the drainage which is in the middle of the raceway ponds. Moisture content, density, and pH will be measured and TOC, TN, TP will be analyzed after the samples have been mixed and dried.
    - Feed: monthly analyses for moisture, TN and TP. The total input of feed will be determined by the company.
    - Shrimp Growth: body weight and length analyzed biweekly
    - Nutrient balance: will be determined by estimating the initial and final nutrient content in the ponds, nutrient loss with sediment discharge, nutrient input from feed, nutrient content in the shrimp products, and water seepage or evaporation.
    - Onsite interviews: investigate routine management, chemical use, the costs including energy, labor, and feed.
- Mass balance and dynamic simulation modeling: A mass balance model will be used to analyze system efficiency. Dynamic simulations of production by using MATLAB and POND will be used.
- Cost benefit analysis: cost and benefit will be evaluated to maximize profit of shrimp farms and considered as a factor of social sustainability, possibly compared to factors of ecosystem service dollar amounts.
- Statistical analysis: Data will be analyzed using ANOVA, t-test, correlation, and regression.
- Cyanobacteria levels will be measured in recirculating tanks and compared to outdoor flushed shrimp ponds. The water quality conditions in each system will be compared to estimate the water quality parameters associated with these algal blooms.

Schedule

1 October 2009 to 29 September 2011. Report submission: no later than 29 September 2011.

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IDENTIFYING BEST PRACTICES TO IMPROVE THE GIANT RIVER PRAWN INDUSTRY IN THAILAND

Production System Design & Best Management Alternatives / Activity / 09BMA06UM

Collaborating Institutions & Lead Investigators

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Objectives

1. Review and analyze current giant river prawn production practices and standards;
2. Assess farmers' capacity and constraints in adopting current standards or new practices;
3. Identify and agree upon best practices to improve water quality and production;
4. Identify and agree upon mechanisms by which best practices can be supported, incentivized, and communicated.

Significance:

The giant river prawn *(Macrobrachium rosenbergii)* is native to Southeast Asia, South Pacific countries, northern Oceania, and western Pacific islands (New 1982; New 2002). It is the most popular prawn species used for commercial farming and has been transported to many parts of the world including South America and China (New 2002). Recently it has been determined that there are two separate species being referred to as *M. rosenbergii* and the species that is most extensively cultured and the subject of numerous research papers is actually *M. dacqueti*. To avoid confusion, efforts are being made to retain the more familiar name (Wower and Ng 2007).

Intensive culture is popular in Thailand (Yuan et al. 2004). In a 2005, survey of 100 farmers; intensive monoculture was the primary culture system utilized (96%) (Schwantes et al. 2009). Stocking and production rates were predominantly at levels representing semi-intensive culture (Valenti and New 2000), but Thai production should be described as intensive. Some farmers (31%) stocked prawns at densities greater than 20 pcs m^{-2} and a small proportion had production greater than 5,000 kg ha^{-1} yr^{-1} (Schwantes et al. 2009). Most importantly, many aspects of production were intensive as described by Yuan et al. (2004), New (2002), and Valenti and New (2000). In 1999, 50% of feed used in prawn culture was farm made (New 2000); however by 2005, most farmers (76%) relied solely on commercially produced feed. This requires frequent water exchange, also seen in the 2005 survey, to maintain suitable water quality (New and Singholka 1985). Other practices to maintain water quality included aeration, and water treatment with lime or dolomite (Schwantes et al. 2009). The majority of individuals surveyed (90%) did not utilize any treatment prior to discharging water into public canals and waterways (Schwantes et al. 2009). This nutrient rich effluent results in eutrophication and poor water quality for multiple users (Yuan et al. 2004).

Multiple methods could be utilized to retain excess nutrients and reduce environmental impacts on small-scale farms in Thailand. These practices include polyculture, integrated culture, crop rotation, water retention ponds, and water filtration. Also, closed recycling systems with zero to little water exchange could isolate production from the surrounding environment and use nutrients produced in prawn grow out to generate other crops which have market value (Yuan et al. 2004). Polyculture systems with giant river prawn have not previously been described in Thailand, but have been practiced elsewhere with fish as well as crayfish species (New 2002). Prawns have also been integrated into rice systems in Vietnam (New 2000; Zimmerman and New 2000) and Bangladesh utilizing ditches called *ghers* (New 2000). In the 2005 survey, crop rotation, integrated culture, and polyculture techniques for the purpose of increased nutrient utilization were rare (Schwantes et al. 2009). Polyculture with white shrimp was uncommon and

experimental, and practiced for economic gain rather than improved water quality. A few individuals alternated crops and discharged water into fish ponds or other agricultural plots in an effort to reuse nutrients (Schwantes et al. 2009).

For individuals to adopt more sustainable aquaculture systems they must first distinguish that current practices produce negative environmental impacts that are also associated with poor production and disease in the culture system itself. Secondly, they must recognize a long-term economic value for reducing these impacts. In Thailand the perception of environmental problems that ultimately affect production and subsequent profits is evident on an individual, community, and national level (Schwantes et al. 2009). This is vital because an intervention to correct a problem not perceived on a local level, but externally identified, will often fail (Rogers 1995; Blanchet 2001).

In 2005, the major problems most commonly identified by respondents were seed supply (67%), disease outbreak (64%), and external pollution (37%). Approximately one third (33%) of respondents also cited low production which could be caused by the other major problems or a number of other factors. Many farmers considered impacts of external pollution to be either moderate (46%) or severe (16%). Agriculture (75.4%) and aquaculture (39.3%) were most often cited as external pollution sources, demonstrating that farmers believed the problem was upstream and caused by multiple users. External pollution could also be responsible for other major issues reported such as poor quality seed supply, increase in incidence of disease, and crop collapse (Schwantes et al. 2009).

Recognition and alteration of practices on an individual level is a start, but a larger effort is necessary for noticeable improvements in aquaculture practice. On a national level, certification programs are ideal to promote environmentally and socially sound production systems as consumers become more conscious of their purchases. New et al. (2000) stated that this recognition of responsible aquaculture should include attention to the discharge of polluted effluents into natural waterways and canals as well as written records containing stocking data, feeding rate, water quality, and other parameters as an assessment of management techniques. There are two certification programs for marine shrimp aquaculture developed by the Department of Fisheries (DOF) in Thailand. None exist specifically for prawn farming or freshwater aquaculture, however the Good Aquaculture Practice (GAP) certificate is most commonly applied to prawn operations nationwide and is issued at the farm level (MSCRI 2003). The Code of Conduct (COC) certificate encompasses the whole production line from hatchery to processing plant to achieve international quality standards and is only applicable to marine shrimp (MSCRI 2003). Farmers can request an audit from DOF and if they comply with standards receive a one year certification. Both programs predominantly stress good sanitary practices and a safe consumer product absent of chemicals and antibiotic residues (MSCRI 2003). These two programs could and should be extended to prawn culture. The GAP certification indicates that effluent must be treated to reduce environmental impact to the surrounding area, while COC stresses no impacts to ecological systems. Both programs require record keeping of relevant activities to serve as a useful guide for future improvement (MSCRI 2003).

Some farmers in the 2005 survey, specifically in Chachoengsao province, held GAP certificates, but none kept written records and only three of the six interviewed said they discharged some water into a fish pond. Since very few prawn farmers treated water after use, it is unlikely many of those who held GAP certificates did. Certification might be more effective if treatment options for effluent were specified. Many farmers in the 2005 survey requested more information on prawn farming techniques (96%) and this is an opportunity to inform them of best practices in regard to effluent. It is also important that programs include regular follow up visits to ensure the farm continues to meet standards specified in the certification as well as to offer technical support which may help farmers with minimal resources. Incentives for certification may prompt farmers to utilize these types of programs.

There are many avenues to address the major problems identified in the 2005 survey; these include bottom up initiatives that result in community empowerment and support, augmenting existing certification programs to incentivize culture practices that appeal to discerning consumers, and top down government regulations that may be effective, but may generate community backlash. We propose a workshop that could address all three of these avenues by gathering stakeholders in the giant river prawn industry and providing a venue for discussion of environmental issues and experiences in regard to alternative culture practices that result in increased water quality, improved production, and other associated environmental and economic benefits.

These efforts will likely be welcomed. While only a quarter of farmers in the 2005 survey suggested that alternative culture methods were necessary, 96% of individuals were interested in learning new techniques. Also, many were concerned with financial risks associated with material costs (41.4%), as energy prices rise many individuals might be more interested in techniques that reduce consumption and maintain a reliable level of production. Also, the giant river prawn community holds significant potential for consensus building and disseminating workshop results. In the 2005 survey, there were many examples of cooperation for the common good including communal practices in Samut Sakhon, Chachoengsao, and Chonburi, participation in local management meetings (93%), and the acquisition of information from neighbors (92.9%).

We propose a 1-3 day workshop planned in collaboration with the Thai DOF and Network of Aquaculture Centers of Asia Pacific (NACA), Regional Lead Centre in Thailand, to convene stakeholders of the giant river prawn industry. Both groups have leading roles in aquaculture research and development in Thailand. The Thai DOF has an Aquaculture Policy to increase both freshwater and coastal aquaculture production and they implement various legislation including the Enhancement and conservation of National Environmental Quality B.B. 2535 (1992) (DOF 2009). NACA is an intergovernmental organization that promotes rural development through sustainable aquaculture. NACA seeks to improve rural income, increase food production and foreign exchange earnings, and to diversify farm production. NACA specializes in education, training, and collaborative development of research, information and communication networks, and policy guidelines and associated support (NACA 2009).

Quantified Anticipated Benefits:

Ultimately, freshwater aquaculture as a whole plays an important role in Thailand. It provides quality nourishment and income opportunities to the rural poor. Employment opportunities are generated throughout the production chain including manual labor, feed supply, and product distribution (FAO 2007). This is in contrast to brackish water shrimp culture which involves high value species that are often exported along with much of their production chain (FAO 2007). Giant river prawn farming is integrated into the social fabric of rural Thailand, unlike marine shrimp production, the majority of giant river prawns are sold for local consumption and are integral to Thai cuisine (Lin and Boonyaratpalin 1988). Prawn production does not necessitate higher education and specialized training and it is a lucrative venture. In the 2005 survey average yearly income per farm was US$24,160 yr^{-1} (Schwantes et al. 2009), quite high compared to the 2007 average Thai household income of US$7,425 per year (NSO 2007).[1] In addition, support for the industry exists on the community, provincial, and national level.

In 2006, Thai production was reported to be 30,000 tons at a value of US$100,448,000, ranking third in production behind China (108,592 tons) and India (30,115 tons) (FAO 2009). The combination of intensive culture practices and lack of water treatment will have severe consequences for the industry in the future. Economically and environmentally balanced practices

[1] US dollar conversion based on an average exchange rate of 30.1576 Baht per US$ for the year 2007 (X-rates.com, 2009).

are necessary to maintain this level of production and continue providing employment and income opportunities for local people.

In Thailand, efforts to engage and empower the tight knit giant river prawn farming community through outreach have high potential for impact. This workshop will provide participants with a valuable opportunity to reach consensus on best practices that could improve water quality and prawn production, identify constraints and opportunities, and map out a strategy for moving forward efficiently and effectively. While prawn consumption is not common in the U.S., the experiences gained by the workshop and community development of culture protocols can be extended to other culture systems. We anticipate that at least 20 farmers will directly benefit by exposure to this workshop by implementing more environmentally benign production methods. The real benefit will extend far beyond the 20 participants, as 91% of all prawn farmers receive their information on new methods from their neighbors (Schwantes et al. 2009). To facilitate this information exchange, we will produce a fact sheet on best practices identified at the workshop. Additionally, from 5-10 DOF employees will gain better knowledge of prawn production through this interaction with farmers, and government policy makers will receive direct benefits by being exposed to new regulation ideas that arise from this multi-sector workshop.

Activity Plan

This workshop could be held at the Asian Institute of Technology or another institution near or within Nakhon Pathom, the province which holds the greatest density of prawn farmers and is a central location within the farming community (Schwantes et al. 2009).

Stakeholders to attend workshop:

- Farmers from major prawn producing provinces such as Nakhon Pathom, Ratchaburi, Suphanburi, and Kanchanaburi, specifically targeting the leaders of local management meetings. DOF and provincial fisheries office personnel will be utilized to identify these individuals.
- Representatives from Provincial fisheries offices.
- Representatives from the two major certification programs developed for marine shrimp aquaculture and extended to giant river prawn culture, GAP and COC.
- Representatives from Charoen Pokphand which plays a role in giant river prawn production through seed and feed production, farm extension, and marketing.
- Academic professionals associated with the CRSP, such as Liu Liping, Yuan Derun, Md. Wahab, Jim Diana, and Vicki Schwantes.

The structure of the workshop will allow ample time for discussion and consensus building. The objectives stated above will be addressed as follows.

- Review and analyze current giant river prawn production practices and standards.
  - Plenary sessions from academic professionals and Thai DOF will set the stage by providing participants with up to date information of the perceived state of affairs for giant prawn grow-out practices and status. This will include the results of the 2005 survey and developments since then.
  - Ample time will be permitted after plenary sessions to allow questions from the audience. A facilitated discussion will be planned.
- Assess farmers' capacity and constraints in adopting current standards or new practices. Representatives of the farming community from several regions will be provided with plenary sessions to summarize their perspective on the state of affairs within their region. Again, there will be time for questions and facilitated discussion.
- Identify and agree upon best practices in improve water quality and production.
- Identify and agree upon mechanisms by which best practices can be supported, incentivized, and communicated.

- Several working groups will be composed around major issues in prawn grow-out identified in the 2005 survey. These include 1) seed supply, 2) disease, and 3) external pollution. Low production will not be a theme as it may be caused by any of the previous stated issues or be a management issue.
- Each breakout session will be facilitated by staff of either DOF or NACA. Rappateurs will be designated to report out from each session to share conclusions and identify common threads.
- A final session will allow participants to create the product of the workshop—a fact sheet containing agreed upon best practices and recommendations for moving forward within existent constraints and with available resources. It will also identify options for creating a more supportive and efficient network for information sharing between researchers, support organizations, and giant river prawn farmers. This may include yearly gatherings of selected representatives from each group to revisit these best practices, assess progress, and proceed accordingly. Outcomes of these follow up meetings could be communicated from representatives to DOF and provincial fisheries extension agents and leaders of local management meetings to ensure dissemination.

Schedule

Workshop between 1 April-30 August 2010. Report submission: no later than 29 Sept. 2011.

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ASSESSMENT OF AQUAFISH CRSP DISCOVERIES

Production System Design & Best Management Alternatives/Study/09BMA07OR

Collaborating Institutions & Lead Investigators

Oregon State University (USA) — Steven Buccola, Rolf Fare

Objectives

Develop improved methods for assessing the discoveries arising from AquaFish CRSP experiments, studies, and activities, and apply the methods to demonstrate how the CRSP has produced new knowledge and human capital.

Significance

CRSPs are responsible for quantifiably demonstrating their outputs. The present Investigation seeks to provide that quantified assessment for the other Investigations in the AquaFish CRSP, treating each as a production system. A production system in an aquacultural context refers to fish development from egg to grow-out stage. The present Investigation's own production system instead is its characterization of the process under which an AquaFish CRSP experiment, study, or activity uses its financial, capital, and human resources to achieve its stated objectives. In an experiment, the process might be pond and laboratory workers' procedures for attempting to improve broodstock reproduction rates. In an outreach activity, it might be trainers' success in reaching and influencing a target population of pond managers. The Production System Design and Best Management Alternatives topic area is part of AquaFish CRSP's *Integrated Production Systems* topic area goal. Investigation No. 1's focus is on AquaFish CRSP's production of new knowledge intended to alleviate poverty and improve food security through sustainable aquacultural development and resource management.

Quantified Anticipated Benefits

Characterizing the inputs and outputs of host-country-level investigations brings two benefits to the US and host countries. The first is to provide AquaFish CRSP US and HC investigators with potentially new ways of regarding their activities, procedures, and outputs, and thus expanded ways of critiquing and interpreting their own work. The second is to provide an opportunity for both US PIs and HC investigators to communicate their work and successes to host country and U.S. scientific and policy communities. These communities are in the best position to support continued AquaFish CRSP activity and to learn from its findings. Put differently, CRSP investigations have little value unless their results are promulgated. Investigation #1 (09BMA07OR) is an important part of that promulgation.

This Investigation will produce the following deliverables: (a) quarterly and annual CRSP reports; (b) oral reports at annual AquaFish meeting; (c) a manuscript, to be submitted to a refereed journal, reporting the results of our quantitative study of AquaFish study outputs and inputs; and (d) seven case studies of AquaFish investigations, to be submitted to refereed journals or books of readings, or disseminated in other form; and (e) impact training materials and software publicly available on the worldwide web. Investigation progress will be monitored by checking on the completion of the above deliverables and of the intermediate steps listed below; on our project-country graduate students' degree completions; and on the strengths of our linkages with AquaFish and other CRSPs.

Research Design & Activity Plan

Approaches to examining research programs' discoveries have been summarized in a number of places (e.g. http://impact.cgiar.org; Xia and Buccola 2005). The first approach may broadly be defined as the case-study approach, in which quantitative or qualitative procedures are used to characterize a research project's context, process, and results, often in conjunction with estimates

of its net economic benefits (CGIAR Science Council 2008; Schimmelpfennig and Norton 2004; Gardner 1999; Norton and Alwang 1998). Even when they use quantitative methods, case studies emphasize holistic understanding and are expressed in substantial institutional detail, and thus offer useful insights to policy makers and other potential adoptees of the research findings.

Besides a quantitative approach (see just below), we plan to apply case-study methods to one investigation in each of the seven AquaFish CRSP projects. The investigations on which case studies are to be performed will be selected on the basis of purposive random sampling. In particular, at least two candidate investigations will be drawn from each project, identified according to the availability of data suitable for a case study. One of those candidates will then be chosen, by random draw methods, for the case study. To the extent possible, and to maximize complementarities between our project's two Objectives, we will prefer to use these same case-study investigations for our Investigation #2 (09TAP05OR) examinations. Especially because of the desirability of such coordination across our two Objectives, and because our impact assessment methods (outlined below) are especially suitable for experimentally or at least statistically controlled experiments, we likely will give weight to control-type studies when choosing the candidates for random selection. However, outreach-oriented activities will also be considered.

The second, quantitative approach to discovery evaluation is to draw data from each of a group of studies in order to show how research inputs like total expenditure and science person-hours have led to research outputs (e.g. Smith 1998). Methods are parametric or non-parametric, dynamic or static. They differ greatly in the proximity of the research outcome targeted. The majority focus on the type, number, and quality of the resulting publications, patents, or other intellectual property awarded to the researchers (Groot and Garcia-Valderrama 2006; Wang, Xia, and Buccola 2009). For two reasons, however, such bibliometric measures are unsuitable to most CRSP-sponsored investigations. First, CRSP projects tend to be of a highly applied nature and hence often inadequately represented in journal outlets. Second, information about CRSP outputs often is needed before the outputs are observable in the scholarly market place. In our Objective 1 quantitative assessments, we therefore will focus instead on the investigations' discovery objectives: the improved survival rate, feed conversion, water quality, or other performance indicators the investigators have targeted in their proposals.

Investigations differ widely in such immediately-targeted outputs. For example, some AquaFish CRSP investigations that target yield-improving management practices focus on weight-gain improvement while others focus on survival-rate or fertility improvement. All of these in turn are incommensurable with water quality enhancement or market development indicators. Because any cross-study assessment must be comparative, metrics must be found that will achieve those comparisons. While useful for other purposes, DTAP indicators like numbers of products and technologies developed, management practices affected, or institutions involved are inadequate for the present purpose because they do not take account of differences among studies in the fineness with which products, technologies, or institutions are measured.

Incommensurability among study output units can be solved by expressing them as ratios or percentage changes, relative either to the originally anticipated improvement, the final improvement obtained, or the state of affairs already achieved before the investigation began. As percentages, changed yield or other output expectations therefore can be compared directly with the information that other investigations – pursuing different objectives – have achieved as well. However, an acceptable study output metric must satisfy two additional requirements. First, investigations frequently progress at different rates, and assessment procedures must account for differences in the stages at which investigations will be encountered. That is possible only if the assessment method is updatable, permitting one to assess successes as a study proceeds as well as when it is concluded. Second, some research projects fail in the sense that the hypothesized improvement – enhanced oyster management practice, say – does not materialize. Such failures

do not necessarily imply that the study expenditures have been wasted, since the experimental disappointment can be valuable in pointing to more fruitful directions in subsequent research (CGIAR Science Council 2009).

Both of these problems are solved by employing a procedure for casting a research study's outputs in terms of the information the study is *expected* to generate. The expectations can be updated as the assessed study proceeds, culminating in the study's final outputs. In this way, a study's terminal expectations are the realized discoveries themselves. For example, early success of a proposed new Tilapia seed production method may boost the pond yield rates relative to those farmers presently achieve or to those the investigators had anticipated. Provided it is verifiable, that updating of yield expectations constitutes the study's provisional discovery output; and the actual yield rates finally achieved are the study's final output. If the study is failing to boost yields, its success is reflected instead in the experimental lesson learned, expressed as the narrowing of the probability distribution of likely yield outcomes. In either event, the assessment consists of comparing the probabilities of the study's discoveries with its accumulated expenditures or effort.

In order to compare study discoveries with costs, we will regard a study as a production unit, each employing resources (inputs) such as money and personnel to produce discoveries (outputs) (Buccola 2008). Comparisons will be made between a study's input-output relationships at earlier and later project stages as well as between studies at a given – for example final – research stage. In this way, we will have modeled a study's trajectory toward its own completion as well as relative to other studies. Distance function methods will be employed for this purpose (Shephard 1970; Fare and Primont 1995; Fare and Primont 2006). Distance functions, estimated either parametrically or non-parametrically, show for a group of studies how much research output has been achieved for each given set of research inputs. They allow the analyst to incorporate multiple study outputs such as fish survival rates and feed-weight conversion, or pond yields and researcher training. They also permit cross-study comparisons of the efficiency with which study resources are being used to achieve the maximum amount of one study output (e.g. pond yield) at given levels of the other outputs (e.g. training). Index numbers then can be generated enabling performance or efficiency comparisons across investigations. Such scores can be used to assess an investigation's rate of progress along its own research time path as well as relative to other CRSP investigations.

An important aspect of this modeling is the manner in which the probabilities of an investigation's output success are obtained, and how they are updated as the investigation proceeds. Well-developed methods are available for eliciting investigators' initial surmises of the likelihoods of their own discovery outputs (Stael von Holstein 1970; Bessler and Moore 1979). The methods involve casting the probability questions in the context of the study's institutional and technical environment, and incorporating imaginatively the penalty of forecasting one's discovery outcomes incorrectly. In both case and quantitative approaches, Bayesian methods are a rigorous and self-consistent way of updating such probabilities as the investigation proceeds (Schimmelpfennig and Norton 2003; Press 1989; Carlin and Louis 1996). Index-number approaches are also possible.

To summarize the Bayesian approach, let Y be the percentage improvement in a particular study output such as pond water quality, and $\mathbf{X}$ be the study's inputs such as expenditures. Let Z be the performance of the new technology examined and which is intended to improve pond water quality. The investigator's initial expectation of water quality improvement (or at an earlier stage, the water quality presently observed in the study area) is, in light of the study's current progress, updated as

$$(1) \qquad E(Y \mid Z) = E(Z \mid Y) \cdot E(Y) \;/\; E(Z)$$

where E ( ) indicates expectation. That is, after the researchers have observed performance Z of the new technology, expected pond improvement equals the expectation that experimental outcome Z would occur assuming the new technology improves pond quality by a given amount, times the pond improvement originally expected and divided by the experimental outcome Z originally expected.

The likelihood of experimental outcome Z in turn depends on study expenditures and other inputs **X**. We may represent this dependency as $Z = g(\mathbf{X}, \varepsilon)$, where ε are unanticipated research findings. Furthermore, once the experiment is complete, $E(Z)$ is a known constant. Combining these two considerations gives, at the end of the experiment,

(2) $$E\,[Y \mid g(\mathbf{X},\varepsilon)] \propto \{E[g(\mathbf{X},\varepsilon) \mid Y\,]\,E(Y)\}$$

in which ∝ signifies "is proportionate to." That is, the pond improvement expected once experimental results have been obtained is proportionate to the expectation that experimental outcome Z (a function of research inputs **X)** will be obtained given that the new technology will be pond-enhancing at a given level, times the pond enhancement originally expected.

Expression $E(Y)$ in equation (2) is the investigator's prior (baseline) pond quality expectation. $E\,[g(\mathbf{X}, \varepsilon) \mid Y]$, in contrast, is the posterior improvement expectation elicited at a midpoint, then at the termination of, the research process, reflecting the intervening experimental or other study results. Per-unit output v*alues*, such as the net profits to be gained from given increments in pond quality, can – where feasible – be obtained from published information or investigators' or others' expert judgments. Distance function analysis thus would be used to compare such research net values with research inputs. Alternatively, distance analysis can be conducted in terms of physical output measures (e.g. pond quality indicators) alone, and per-unit value measures employed subsequently to show the projects' potential economic, ecological, or health implications.

We will conduct two assessments of investigators' research outcome expectations: the first midway through this Investigation and – to the extent possible – the second at or near the Investigation's end. This will permit comparisons of actual research findings with those expected earlier. Expectations and probabilities of research outcomes will be elicited in two venues: (a) by email or telephone call to US and HC PIs, and (b) at two annual workshops conducted in conjunction with the AquaFish CRSP annual meetings (see Workplans below). All elicitation efforts will be coordinated through the project US PIs. Any purposive sampling among investigations will be carried out jointly with Investigation No. 2 so that the two Investigations will be statistically linked to one another.

Much of the data collection for the proposed quantitative study – and information-gathering for the case studies – will be carried out by HC personnel under the partial direction and compensation of the present Investigation. These individuals will be identified during the 10 December 2009 – 1 March 2010 period, culminating at the San Diego AquaFish CRSP meeting.

Schedule

Workplan for Investigation No. 1 (with expected completion dates)	
Step	**Year One**
1.	Prepare materials for First Annual Workshop. (February 2010)
2.	Summarize investigation-level outputs identified in synthesis project. Check with AquaFish project PIs for accuracy and suggestions. Adjust as appropriate. (March 2010)
3.	Carry out First Annual Workshop, 1 March 2010, as part of AquaFish CRSP/WAS annual meeting in San Diego. In conjunction with Objective 2 and US PIs, complete the identification of HC personnel who will collect in-country assessment information. (March 2010)
4.	Identify the seven investigations for which case studies will be developed, and HC personnel to assist with host-country data and information collection. (May 2010)
5.	Search literature further for methods and applications of probability scoring rules. Develop scoring-rules for eliciting investigators' research output probability distributions and for comparisons with current investigation results. (July 2010)
6.	Assemble majority of data for seven case studies. (September 2010)
	Year Two
1.	In conjunction with the project planning meeting (see Investigation #3 below, 09TAP06OR), complete trial-run collection of investigation-level study input data from US and HC PIs. (October 2010)
2.	Build input-output model. Conduct trial-run estimation of investigation input-output distance function. (November 2010)
3.	Together with US and HC PIs, collect any research input-output data found missing on basis of trial-run input-output distance function. (February 2011)
4.	Plan Second Annual Workshop, to be held in conjunction with the 2011 AquaFish CRSP annual meeting in Brazil or China. (Place and date yet to be determined by AquaFish CRSP)
5.	In cooperation with Objective No. 2, conduct Second Annual Workshop. (Place and date yet to be determined by AquaFish CRSP)
6.	Contact investigators who did not attend Second Annual Workshop. Obtain updated research output expectations and second-year investigation inputs. (July 2011)
7.	Re-estimate investigation input-output distance function. (July 2011)
8.	Complete case studies of one investigation in each AquaFish project, coordinated with Investigation #2 (09TAP05OR, impact assessment studies). (August 2011)
9.	Complete AquaFish reports (September 2011) and draft publications. Report findings at annual AquaFish meeting and at professional conferences.

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TOPIC AREA
SUSTAINABLE FEED TECHNOLOGY

❖

ALTERNATIVE FEEDS FOR FRESHWATER AQUACULTURE SPECIES IN VIETNAM

Sustainable Feed Technology/Experiment/09SFT01UC

Collaborating Institutions & Lead Investigators

University of Rhode Island (USA) — David Bengtson
Can Tho University (Vietnam) — Tran Thi Thanh Hien

Objectives

The objective of the study is the development of cost-effective alternative feeds for carnivorous freshwater species to replace or reduce the dependence on low value/trash fish.

Significance

Aquaculture of freshwater carnivorous and omnivorous fish species in Cambodia and Vietnam is highly dependent on inland fisheries of low value fish for sourcing key dietary nutrient inputs. In Cambodia, the use of low value/trash fish applies mainly to commercial-scale cage culture rather than small-scale pond culture (Heng et al. 2004). Commercial-scale cage culture in Cambodia contributes about 70% of the country's total aquaculture production (DOF 2005). The major fish species for cage culture are river catfish (*Pangasius hypophthalmus*, *P. bocourti* and *P. larnaudii*) and snakehead (*Channa micropeltes*). The main feed for pangasid catfish and snakehead is low value/trash fish. Feed conversion ratios range from 1.3 to 1.5. Fresh fish feeds are available seasonally and regionally, which has led to problems of overfeeding in times of plenty and underfeeding when feeds are scarce. There is plenty of fresh fish for feed available during the peak period of fish catch in the country, particularly from November to January. Small cyprinids are caught along the Tonle Sap River. For the rest of the year, some farmers use dried fish but others are not able to afford this input. During the peak fishing season, a large bulk of low value fish is sun-dried. This processing sometimes leads to contamination with sand and dust, which reduces the quality of the dried fish produced. Manufactured pellet feeds are expensive and imported. Only a very few producers can afford the high cost of the feeds and they are primarily used for ornamental fish.

There have been very few studies conducted on feed and feeding in Cambodia (Heng et al. 2004). There is no tradition of on-farm feed formulation that can be widely used in aquaculture systems. Pond fertilizer techniques are well understood by farmers but organic manures are scarce since they are needed for agricultural crops. The market price for farmed fish, especially in relation to the cost of feed, is a major problem. Prices are very low when fish are plentiful from capture fisheries and consumers prefer wild captured fish to cultured fish.

Heng et al. (2004) recommend cooperation on feeds and feeding technologies through research and experimentation, especially suitable feed and feeding strategies. In Vietnam, more than 70% of the fish species cultured are omnivores (Hung 2004). Catfish of the *Pangasius* and *Clarias* genera are the most important omnivores cultured in Vietnam. The omnivores are cultured in cages in the Mekong River, mainly in An Giang and Dong Thap provinces. Traditional feeding is largely based on trash fish, a protein source that is quite limited in Vietnam. The traditional feeding method is to prepare and mix ingredients on the spot and cook them to produce a wet, sticky paste. Feed conversion ratios vary from 1.5 to 2. Floating pellet feed is expensive and is not suitable for small-scale farmers who cannot afford it.

The carnivores (approximately 10% of fish species cultured) are all indigenous species with a high market value (Hung 2004). The two main species are *Channa micropeltes* and *C. striatus*, estimated at 90-95% of cultured carnivores. Low value/trash fish is the only feed source for the carnivorous fish. Low value fish are caught in reservoirs and in the Mekong River during the flood season. Farmers also use marine low value/trash fish. The feed conversion ratio is approximately 4 to 5. The pressure on the low value fish supply increases the price and makes the production system "unstable and unsustainable" (Hung 2004 p77).

Hung (2004) recommended that research is needed on:

1. Alternative feeds for carnivores to replace or reduce the dependence on trash fish
2. Identification of locally available ingredients from which home-made feed can be prepared.

In the Mekong Delta in Vietnam domesticated snakehead (*Channa micropeltes* and *C. striata*) are fed with small-sized/low value fish (of both marine and freshwater origin). In Cambodia wild giant snakeheads (*Channa micropeltes*) are generally cultured in smaller cages of less than 200 m^3. Feed represents more than 70% of the total operational cost and the main type of feed for wild giant snakehead culture in Cambodia is small-sized/low value fish of freshwater origin (So et al., 2005).

Since the beginning of this project, we have accomplished several tasks and we continue to pursue the research described in our original proposal. Specifically, the laboratory of Dr. Tran Thi Thanh Hien at Can ThoUniversity in Vietnam has:

1. Determined species composition, size and chemical composition of the main freshwater trash/low-value fish species used as feed for finfish aquaculture in the Mekong Delta of Vietnam.
2. Developed weaning methods so that small, hatchery-reared snakehead can be quickly adapted to pelleted diets. (When snakehead are collected from the wild by fishermen for aquaculture, it is difficult to impossible to get them to feed on pelleted diets in captivity; the transition must be done in the early life-stages.)

Determined that *Channa striata* snakehead survive as well on pelleted diets in which up to 50% of the fishmeal has been replaced by soybean meal as they do on pelleted diets made purely of fishmeal. On the other hand, growth is equivalent only up to the point of 30% replacement of fishmeal with soybean meal, if only the appropriate amino acids are added to the soybean diets; however, that level can be increased to 40% replacement if one also adds phytase to break down the phytin in soybean meal. The addition of taurine to the diets did nothing to increase growth above that seen at the 30% soy replacement alone.

Determined that *Channa micropeltes* snakehead survive as well on pelleted diets in which up to 50% of the fishmeal has been replaced by soybean meal as they do on pelleted diets made purely of fishmeal. On the other hand, growth is equivalent only up to the point of 40% replacement of fishmeal with soybean meal if one also adds phytase to break down the phytin in soybean meal.

Demonstrated that a mixed fishmeal, soybean meal and cassava meal diet (with phytase added) can undergo replacement with rice bran at replacement levels up to 30% with no reduction in survival or growth. Cassava is a locally produced crop that may be easier and cheaper to obtain than soybean meal.

Experiments are currently underway (completion in July) to determine:

4. Replacement of fishmeal with rice bran when a fish-solution feeding attractant and alpha-galactosidase are added to the diet

5. Replacement of trash/low-value fish diets with pelleted diets at levels of 0 (control), 25, 50 75, or 100%. This experiment is being conducted to show that at laboratory scale, much or all of the low-value fish can be eliminated from the diet.

Some of the fish that are being used in the current experiments will be grown further on the plant-based diets and a taste test of fish reared on experimental diets versus fishmeal diets will be conducted by students at Can Tho University in September of this year.

Quantified Anticipated Benefits

The results of this study will provide information on alternative diets for snakehead, especially those diets that incorporate locally available plant materials, in order to build a long-term sustainable industry. Through an economic analysis of costs of the diets (based on costs of fishmeal and plant proteins vs. trash fish) and the risks of the unavailability of trash fish in the future, the information provided from this study will allow decisions to be made about the development of feed mills for local production of diets for the snakehead industry. These experiments allow the U.S. participants in this investigation, Dr. David Bengtson and Dr. Chong Lee, to expand their studies of plant protein replacements for fishmeal from temperate to tropical species and for their graduate students to understand the differences in responses between temperate marine species and tropical freshwater species. Finally, adoption of soybean meal in diets for snakehead could expand markets for the U.S. soybean industry.

Research Design & Activity Plan

(1) Location of work: Formulation of diets will be done at the URI based on information about chemical composition of locally available plant products in Vietnam. Manufacture of the diets will be done at CTU, which has a small fish-feed mill (for sinking feed, 50-200kg/hour), as will analysis of diet composition: protein, lipid, mineral, fiber, and energy. All laboratory feeding trials will be conducted in a wet lab at Can Tho University. Trials on farms will be conducted in AnGiang or Dongthap provinces of Mekong delta by CTU researchers.

(2) Methods:
This study will comprise 4 interrelated parts:
(1) Evaluate the chemical composition of marine trashfish during this phase using the same methods that were used to determine the chemical composition of freshwater trashfish during the first phase of this project.

(2) Farm trials to demonstrate the efficacy of pelleted diets compared to trashfish diets in a small-farm setting. These trials will be conducted on farms that have produced snakehead for at least 5 years, with ponds or cages suitable for conducting the experiments, and operated by farmers who have demonstrated good record-keeping skills.

a. For *C. striata*, a farm pond of about 100-200 m^2 will be subdivided into six equal portions with non-permeable barriers. Each subdivision will be stocked with juvenile fish already trained to eat pellets, at stocking levels of 40 fish/m^2. Fish in three of the subdivisions will be fed the traditional trash fish diets commonly used at farms of this type. Fish in the other three divisions will be fed the best pelleted diet that emerges from the current phase of this project (i.e., based on fishmeal, but with the maximum acceptable addition of plant proteins). All fish will be fed ad libitum by the farmer on a daily basis. Monthly for six months, CTU researchers will visit the farm for measurements of fish growth in each subdivision (based on subsamples of fish), as well as measurements of water quality parameters in the pond. At the end of six months, all fish will be removed from the pond for total counts of fish in each subdivision as well as determination of total biomass. Designing this experiment with sufficient replication will allow statistical comparison of fish survival and growth on the two diets in a small-farm setting, so those results can be presented to farmers through extension activities.

b. For *C. micropeltes*, the same approach will be followed as for *C. striata*, except that the study will be done using the cages (approx. 10 m^3) in which this species is grown. That is, three cages will receive the traditional trash fish diet and three will receive the best pelleted diet from phase 1 of this project. All other aspects of the experiment will be the same as described above for *C. striata*.

(3) While Vietnamese farmers may accept pelleted diets, because their fish have been domesticated and can be easily weaned to pelleted diets at when young, Cambodian farmers will need more traditional diets until their native fish can be domesticated (see investigation below). We will therefore conduct experiments in the laboratory at CTU for the benefit of Cambodian farmers. It is possible that marine trash fish and even fishmeal may become more available to Cambodian farmers in the near future, while freshwater trash fish will remain available.

a. In the first laboratory experiment, we will compare 11 treatments, using similar methods to those in effect during the current phase of this project, as follows:

1. Freshwater trash fish (FTF)
2. Marine trash fish (MTF)
3. Fishmeal (FM) + soybean meal (SBM) + rice bran (RB) + cassava meal (CM) in the optimal combination as determined from experiments in the current phase of this project
4. 80% MTF + 20% RB
5. 70% MTF + 30% RB
6. 60% MTF + 40% RB
7. 50% MTF + 50% RB
8. 80% MTF + 10% RB + 10% CM
9. 70% MTF + 15% RB + 15% CM
10. 60% MTF + 20% RB + 20% CM
11. 50% MTF + 25% RB + 25% CM

b. The second laboratory experiment will be similar to the first, except that the focus will be on replacement of FTF rather than MTF. The 11 treatments are as follows:

1. FTF
2. MTF
3. FM + SBM + RB + CM in the optimal ratio, as above
4. 80% FTF + 20% RB
5. 70% FTF + 30% RB
6. 60% FTF + 40% RB
7. 50% FTF + 50% RB
8. 80% FTF + 10% RB + 10% CM
9. 70% FTF + 15% RB + 15% CM
10. 60% FTF + 20% RB + 20% CM
11. 50% FTF + 25% RB + 25% CM

The laboratory experiments will be conducted in the same manner as those conducted in Phase I of this research program. Experimental units are 500-L tanks, with three replicate tanks per treatment, and 25 fish per tank. Initial fish weight is determined from a subsample of fish at the beginning of the experiment and fish are usually in the 4-5 g range on average. Fish are fed to satiation twice a day and any uneaten food and feces are siphoned out before feeding. Amounts of food provided per replicate are recorded so that food conversion ratio (FCR) and protein efficiency ratio (PER) can be calculated at the end of the experiment. The water is maintained at 28±2ºC. Any dead fish are recorded and removed daily. Experiments last eight weeks, at the end of which each fish is measured and weighed. Data from a tank are pooled (i.e., no pseudoreplication) and only one number representing average growth per fish (specific growth rate, SGR) is used per replicate. Data analysis is by one-way ANOVA, following arc-sine square-root transformation of the proportionate data to insure normality. Tukey's HSD test is used to

determine specific differences among means once the ANOVA indicates that significant differences are present.

(4) Economics of trash fish and formulated feed
Based on the results of the laboratory experiments and the farm trials, we will conduct a simple economic analysis of the cost per kg of fish produced using the various diets in the trials. The analysis will take into account the fact that the trash fish and diets based on them have a much higher moisture content than do fishmeal, plant proteins and the diets based on them, so that food conversion ratios (FCR's) are likely to be considerably different.

Schedule

The duration of implementation of this proposed investigation will be 24 months, starting from 1 October 2009 till 29 September 2011.

Year 1 (10/1/09 – 9/30/2010)

1. Trial on farm for *Channa striata* (1 month for weaning of fish to pellets and 6 months for experiment)
2. Trial on farm for *Channa micropeltes* (1 month for weaning of fish to pellets and 6 months for experiment)
3. First laboratory feeding experiment (8 weeks duration)

Year 2 (10/1/2010 – 9/29/2011)

Second laboratory experiment (8 weeks duration)
Preparation of publications for peer-reviewed journals; dissemination of information via workshops, fact sheets, etc.

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ASSESSMENT OF INTEGRATED POND-CAGE SYSTEM FOR THE PRODUCTION OF NILE TILAPIA FOR IMPROVED LIVELIHOOD OF SMALL-SCALE FISH FARMERS IN KENYA

Sustainable Feed Technology / Experiment / 09SFT02PU

Collaborating Institutions & Lead Investigators

Purdue University (USA) Kwamena Quagrainie
Moi University (Kenya) Charles Ngugi
Ministry of Fisheries Development Sammy Macharia

Objectives

Rural pond culture in Kenya is moving from subsistence to small-scale commercial culture of fish. The aquaculture industry is transitioning from the rural subsistence enterprise to commercial profit-oriented aquaculture business. Small-scale commercial farmers are utilizing improved management practices such as stocking densities, feeding regimens, and feed nutrient to enhance their economic returns (Quagrainie et al., 2009). The current major production system is pond culture with an average size of 400m2 stocked with Nile tilapia (Oreocrhomis niloticus) and the African catfish (Clarias gariepinus).

Feeding issues appear to be one of the challenges facing Kenyan small-scale commercial farmers. Studies in Southeast Asia have suggested improvements in growth and yields of Nile Tilapia in integrated cage-cum-pond systems (Yi and Lin, 2001; Yi, Lin and Diana, 1996). The integrated system allows the open pond water to utilize cage wastes as fertilizers, generating natural food in the pond. The integrated system is environmentally friendly because less waste nutrients are released to the public water systems. Profitability from such venture is highly dependent on fish performance in the cage and static ponds. Yi and Lin (2001) concluded that an appropriate integrated cage-cum-pond system depends on appropriate stocking densities for tilapia rotation culture. The underlying hypothesis is that greater amount of wastes from increased biomass in the cages would enhance the productivity in the open ponds. The specific objectives of this study are:

1. To analyze the effects of three different stocking densities of tilapia in cages on growth and yield in an integrated cage-pond system
2. To compare alternate feeding regimens on growth and yield performance under the three different stocking densities.
3. To compare the costs of producing tilapia at the different stocking densities and feeding regimens in the integrated system
4. Conduct on-farm trials to test integrated cage-pond system technologies developed in this study and evaluate costs and benefits to local fish farmers through on-farm trials

Significance

In the recent past, integrated cage-cum- ponds culture system has been developed and practiced using combination of catfish-tilapia and tilapia-tilapia (Yi et al., 1996 and Yi, 1997a, Yi 1997b). Integrated cage-cum- ponds culture is a system in which fish are fed with artificial diets in cages suspended in ponds, while same species or others low value fish are stocked in open pond water to utilize natural foods derived from cage wastes. The technique uses the niche optimization concept for feeding; the fish in cages are fed while those in open waters are either fed at lower rates or not fed at all. Pond fish, therefore, derive their nutrients from uneaten foods from the cages or from autotrophic and heterotrophic food chains (Yi et al., 1996). The aim is to rear fish in a cage while the pond fish utilize the uneaten cage feeds and the plankton generated in the pond to satisfy the bio-energetic needs. In such practices, the nutrient utilization efficiency could reach

more than 50%, compared to about 30% in most intensive culture systems (Coche 1979). To limit competition for food, raise pond carrying capacity, increase pond fish production, higher supply of artificial feed is required. This systems, provides small-scale farmers an opportunity to use their limited resources to increase fish yield, generate more income and improve their livelihood.

Significance

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Quantified Anticipated Benefits

1. Wastes from the cages would generate natural foods for culture of filter feeding species, thereby reducing feeding cost. This is very crusial for profitability of small-scale fish farmers.
2. Adoption of such an integrated system in the US aquaculture industry will significantly reduce production cost because feed accounts for about 45 - 55% of total cost of production.
3. The integrated system offers double cropping and would increase production and, consequently revenues for small-scale fish farmers.
4. The industry currently practices monoculture of catfish in ponds with average sizes of about 10acres. Adoption of an integrated system would help the US aquaculture industry reduce production risks with diversification and polyculture.

Research Design & Activity Plan

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Impact Indicators

1. Number of Master's degrees earned as a result of scholarship support provided
2. Number of Bachelor's degrees earned by students receiving stipend assistance from the AquaFish CRSP
3. Change in understanding of cage culture and management, farm management, and others, as determined by pre- and post-trials.
4. Number of Fish farmers that will adopt technologies developed

Schedule

1. Constructing and setting up cages will take the first three months; this will also include testing them in the pond
2. Brood stock will be selected from the Sagana strain and all male fry and fingerlings produced within the first three months for both pond and cages
3. Graduate Program Scholarships: Students to be selected by the first six months, to begin studies not later than September of 2010. First academic year will be largely devoted to coursework; and research and thesis or project completed during second academic year
4. Undergraduate stipends: Will be scheduled to fit the study programs of students, beginning as early as May, 2010, and ending no later than February, 2011.
5. On-farm trials to begin immediately after research work but preparations and fish farmers selection will be done while research is in progress

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EXPANSION OF TILAPIA AND INDIGENOUS FISH AQUACULTURE IN GUYANA: OPPORTUNITIES FOR WOMEN

Sustainable Feed Technology/Study/09SFT03UA

Collaborating Institutions & Lead Investigators

University of Arizona (USA) — Kevin Fitzsimmons
Mon Repos Aquaculture Center
Office of Fisheries (Guyana) — Pamila Ramotar
Vivek Joshi

Objectives

1. To support development of small-scale aquaculture in poor rural areas, with a focus on women's groups in Trafalgar Union and Annai.
2. To support development of a regional hatchery program utilizing YY Genetically Male donated by DFID.
3. To identify and determine indigenous fishes with aquaculture potential.
4. Finalize development of a standard aquaculture feed containing locally available ingredients.

Significance

Aquaculture, and specifically tilapia aquaculture, is one of six key technologies that the Government of Guyana has identified and supported within the scope of its low carbon impact-sustainable development plan. Aquaculture producers have organized into a farmer's cooperative, the National Aquaculture Association of Guyana. With the assistance of the Ministry of Agriculture and the USAID/GTIS Programme, the farmers have developed local markets and have been able to export small quantities of tilapia. The Mon Repos Aquaculture station has worked with the farmers to provide technical assistance and training. The Anna Regina Fish Culture Station was operated in the 1990's when inferior strains of tilapia were first imported and distributed to local farmers. During the 2000's the station was inadequately funded and the fish stocks abandoned. The government wants to encourage the private sector to build a dynamic hatchery sector and plans to use the Mon Repos and Anna Regina facilities to encourage this development. The UK-DFID has provided stocks of YY supermale Nile tilapia to assist the Office of Fisheries in its efforts to provide high quality broodstocks and fingerlings for the private sector and social sector. Note that the government has already accepted the fish as a donation from the Government of the UK. Many of broodstock are already in-country and fry have been stocked at several farms. We have been asked to provide technical support to develop the breeding registry and other advice to make the best use of these resources. These fish do not represent any new genetic material. The DFID stocks have been manipulated to produce only male progeny, which reduces the opportunities for unwanted reproduction.

In the previous cycle, the AquaFish CRSP project was able to collaborate with the host country Office of Fisheries and the local US-AID team to identify and analyze several locally produced ingredients that could be economically incorporated into aquatic feeds. A primary goal was to reduce the amount of expensive fishmeal in the diet and to improve the market for the local ingredients. The specific ingredients included copra meal, palm kernel meal, brewers wastes, and poultry by-product meal. The second investigation tested the experimental diets in feeding trials, which are on-going at the time of writing this proposal. Both investigations also incorporated workshops, farm visits, and e-mail consultations to assist feed millers, farmers who wanted to develop on-farm diets, and a woman's farming cooperative interested in adding an aquaculture component to their farming efforts.

For the forthcoming proposal the Fisheries Office wants to continue the diet development as a priority. They would also like to collaborate on broodstock management and hatchery development. Through the UK Department for International Development (DFID) program has committed to provide several hundred adult broodstock from the YY Supermale populations maintained by University of Swansea in Wales. DFID will transport these fish to Guyana. The Fisheries Office requests that matching support be provided within the AquaFish CRSP program to provide advice regarding management of these broodstocks and development of the local plan for distribution of adults and fry to the domestic industry. The plan would include guidance for the Anna Regina (which also needs some restoration), the Mon Repos facility, and social groups, especially women's farming cooperatives, and private sector parties who will receive some of the fish.

The Guyana government also wishes to support rural aquaculture and efforts with the indigenous AmerInd population in the interior. One of our objectives would be to conduct a "Basics of Aquaculture" workshop for the indigenous population of fishers and farmers in the town of Annai, Region 6. Emphasis will be on use of native fishes (pacu, hasar, etc) and small-scale techniques to supplement household welfare through fish consumption and/or local sales. Training will be especially focused on women as they typically select foods for the family and frequently participate in small-scale farming activities.

Sustainability has been identified as a priority for the aquaculture producers. Utilization of local feed ingredients, minimizing the use of fishmeal, and increasing the efficiency of the feed that is input to the system are immediate targets.

Quantified Anticipated Benefits

a. To support development of small-scale aquaculture in poor rural areas.
The government wishes to support artisanal rural aquaculture in addition to commercial scale culture. We will work with the Fisheries office to conduct workshops in basic aquaculture operations in Georgetown, Annai and Anna Regina. We expect that at least 20 farmers will attend each of the three workshops. One of the workshops will be held for the women's cooperative. Women will also be invited to the other workshops as their participation will be especially important as they frequently select the foods to be consumed by the family. Women also tend to care for small livestock and a family garden, activities somewhat akin to small-scale fish culture.

b. To support development of a regional hatchery program utilizing YY genetically male tilapia donated by DFID
Broodstocks have been delivered but there is no organized breeding plan, nor distribution plan. We will collaborate with the Fisheries Office to produce a breeding plan and plan for distribution to both the commercial and social sectors. We expect that by the end of the program to have written plans and be in the process of distributing fry and fingerlings from at least three hatcheries. Distribution to women's farming cooperatives along with training and initial support for farming will be a primary concern.

c. To identify and determine indigenous fishes with aquaculture potential
To date, little if any research has been conducted to identify which native fish of Guyana are likely to have potential for use in domestic aquaculture. We will work with the Fisheries Office to prepare a list of the species that should have aquaculture potential and describe the constraints to moving these fish into domestication.

d. Finalize development of a standard aquaculture feed containing locally available ingredients
The Fisheries Office and the local fish farmers all agree that reducing the cost of practical diets would remove the major impediment to industry growth for both the small-scale growers and those interested in trading aquaculture products in international markets. We expect to produce a

diet that will cost 10% less than the currently available diet, but maintain the same tilapia growth rate, while reducing the amount of fishmeal in the diet.

Activity Plan

a. To support development of small-scale aquaculture in poor rural areas.
We will work with the Fisheries office to conduct workshops in basic aquaculture operations in Georgetown, Annai and Anna Regina. Lists of farmers and members of the National Aquaculture Association of Guyana will be used to develop the invitation list. We expect that at least 20 farmers will attend each of the three workshops. One of the workshops will be held for the women's cooperative from Trafalgar Union. The project will also provide tuition and training funds for farmers and Fisheries staff to participate in Caribbean wide short courses offered by University of West Indies and University of Guyana.

Presentation subjects:
1. Aquaculture Theory: pond design, water quality, Tilapia biology, feeding, fingerling production, grow-out, health and disease etc.)
2. Practical Aquaculture: Plankton examination, male and female Tilapia ID, Tilapia dissection, transportation, acclimatization, pond fertilization etc.
3. Feed Ingredient ID: examining local feed materials, and determining suitable ones for feed ingredients
4. Feed Formulation Theory: calculation of protein and other nutrient content, balancing of ingredients, etc.
5. Practical Feed Formulations: Preparation and mixing of ingredients, mixing, pelletizing and drying of feed.

b. To support development of a regional hatchery program utilizing YY Genetically Male tilapia donated by DFID
We will work with the Fisheries Office to prepare a breeding registry recording each of the YY strain fish that have been and will be delivered to Guyana. Each location with the breeders will be provided with a copy of the registry and encouraged maintain the record of spawns and distribution of fingerlings to growers. The government and privates hatcheries will use the breeding registry to guard against inbreeding and unplanned hybridization with other strains or species.

c. To identify and determine indigenous fishes with aquaculture potential
Using existing information from the Department of Fisheries we will start with the entire list of native fishes. We will work with the Fisheries Office to select from the list the species that should have aquaculture potential. As part of the evaluation we will review the species culture literature and share the results with the Fisheries Department. Finally we will identify and describe the constraints to moving these fish into domestication and the methods that can used to overcome the constraints.

d. Finalize development of a standard aquaculture feed containing locally available ingredients
Using diet formulation software, we will develop a growout diet for tilapia based upon the first cycle diet studies. We will attempt to further reduce costs by using more local protein sources to further reduce the amount of imported ingredients into the diet. The formulation will be shared with the all the organizations making aquaculture diets in Guyana.

Schedule:

	YR1 (mos.)			Project YR 2 (mos)			
	4-5/10	5-6/10	7-9/10	10-12/11	1-3/11	4-6/11	7-9/11
Develop breeding registry for YY Strain broodstocks	x						
Attend World Aquaculture in San Diego and visit Tucson	x						
Confirm locations for workshops and make announcements	x						
Make travel arrangements and prepare presentations		x					
Confirm attendees, finalize preparations		x					
Workshops over 10 days		x					
Complete Year One Report			x				
Present results at ISTA 9 in China						x	
Complete feeding trials with standard diet				x			
Complete list of native species and constraint list					x		
Confirm locations for workshops and announcements						x	
Hold final workshops, continue breeding registry							x
Draft final reports							x
Submit final reports							x

FEEDING AND FEED FORMULATION STRATEGIES TO REDUCE PRODUCTION COSTS OF TILAPIA CULTURE

Sustainable Feed Technology/Experiment/09SFT04NC

Collaborating Institutions & Lead Investigators

North Carolina State University (USA) — Russell Borski, Peter Ferket, Charles Stark

Central Luzon State University (Philippines) — Remedios Bolivar

Objectives

1. Compare the effect of high and lower crude protein in commercial feeds with or without pond fertilization on the grow-out performance and production costs of Nile tilapia (*O. niloticus*).
2. Evaluate feed formulation strategies that eliminate dietary inclusion of fishmeal with alternative protein sources in high and lower protein diets for Nile tilapia.
3. Evaluate dietary inclusion of nutritive protein binders and pellet processing aids on pellet durability and water stability of tilapia feeds.
4. Compare the effect on tilapia feed manufactured by extrusion and pellet processing on grow-out performance and production costs of Nile tilapia.

Significance

Approximately 35% of all feed manufactured or sold in the Philippines is for aquaculture, largely for tilapia. Feed is the most costly component of fish farming, accounting for as much as 80% of total production costs for small-scale, rural farmers in the Philippines (ADB 2005; El-Sayed 2006). Provided production efficiency is not significantly impaired, any reductions of feed costs per kg of fish marketed will increase income at several levels of Philippine society, including local suppliers of feedstuffs, feed manufacturers, allied industries, and especially tilapia farmers. Total feed costs for tilapia can be reduced through three approaches: 1) decrease the amount of feed used for grow-out of marketable fish by below satiation-level feeding along with pond fertilization strategies that promote algae growth upon which tilapia may graze; 2) decrease feed formulation costs by reducing crude protein levels, amino acid supplementation and replacing expensive fishmeal with lower cost protein sources; and 3) reduce feed manufacturing costs by pellet processing in place of the more expensive current practice of extrusion processing. The objectives of this investigation will address these three approaches to reducing feed costs for Filipino tilapia farmers.

Quantitative Feeding and Pond Fertilization Strategies:

The CRSP at CLSU has reported on research and demonstration trials about cost-saving feeding strategies for tilapia (Bolivar et al. 2006). Delaying the onset of supplemental feeding by 45-days or 75-days or feeding on alternate days or at 67% of daily satiation did not significantly reduce measurable production of marketable fish in fertilized ponds (Brown et al. 2000; Bolivar et al. 2003; Bolivar et al. 2006). These reduced feeding approaches may have been compensated by the ability of tilapia to graze upon natural foods (*i.e.* algae and other plankton) generated from the excess nutrients in the pond ecosystem. These excess nutrients likely arise from dietary crude protein and other nutrients in excess of the tilapia's true requirements as well as the primary production of natural food in ponds treated with inorganic fertilizers (Brown et al. 2000; Li et al. 2006). In the proposed studies we will examine the economic and production performance feasibility of feeding tilapia high and lower crude protein (CP) diets commonly used by Filipino farmers at 67% sub-satiation levels with or without pond fertilization of inorganic urea N. These studies will serve to demonstrate to tilapia farmers a means to reduce the production costs per kg of marketable tilapia.

Reduction in tilapia feed formulation costs:
The formulation cost of commercial diets has risen sharply with about 40% of aquaculture feed costs attributable to fishmeal that constitutes as much as 20% of feed formulation. Much of the fishmeal used in the Philippines is imported and costs are expected to continue to rise as global supplies decline and demand increases. Unlike carnivorous species, tilapia are omnivorous fishes that do not require fish in their diet, and they are an ideal group of species to recycle food by-products into high quality food protein for humans (Brown 1983). Moreover, tilapia can digest a relatively high carbohydrate diet, and effectively utilize lower-cost feed ingredients readily available in the Philippines (e.g. rice bran, copra meal, and cassava) to completely replace or significantly reduce fishmeal use (Jackson et al. 1982; NRC 1993). Indeed, various animal and plant proteins have been shown to be either partially or completely replace fishmeal in tilapia diets (Lim and Webster 2006; El-Sayed 2006). For example, we reported tilapia fed diets with up to 33% sweet potato and lactic acid-stabilized poultry carcasses did not adversely affect tilapia growth performance or consumer panel sensory indices (Middleton et al. 2000). Additionally, our current AquaFish CRSP research demonstrates that fishmeal can be replaced with poultry by-product meal, fermented poultry protein, or yeast extract protein without adversely affecting growth performance of tilapia fed pelleted feed (unpublished data). However, the use of food by-products to produce least-cost fish feed is often constrained by their poor nutrient content, digestibility, or functional properties in manufacturing feed that can withstand the rigors of pond feeding (Li et al. 2006). Few studies have addressed combinations of animal and plant protein sources as alternatives fishmeal in tilapia feed from the perspective of amino acid balance. Also, most investigations focus on the performance and nutritional characteristics of different protein sources rather than their ability to improve profit margins in tilapia production (see El-Sayed 2006). As observed with other monogastric omnivorous animal species, feeding lower protein diets supplemented with amino acids could significantly reduce excess nitrogen emission into pond water and increase profit margins by lowering feed costs for tilapia farmers (Ferket et al. 2003). In the proposed studies we will evaluate the economic, production performance feasibility, and environmental impact (pond water quality) of tilapia fed high crude protein diets with lower crude protein plus supplemental amino acids diets, with or without fishmeal.

Reduction in tilapia feed manufacturing costs:
Most commercial aquaculture feed, including those for tilapia, is manufactured and fed as floating or slow-sinking extruded pellets because it is easier for fish farmers to detect over feeding and it has good water stability and durability. However, extrusion processing costs over 3 times more than pellet processing, and it's transport costs per ton are higher because of it's lower bulk density. Preliminary studies at NCSU have shown that tank-reared tilapia are able to consume pellet-processed feed without adversely affecting growth performance efficiency. The economic and production feasibility of feeding pellet processed feed must be confirmed with pond-reared tilapia in the Philippines. However, more research must be done to improve the water stability and durability of pelleted feed for pond systems.

Pond-reared tilapia feed must have sufficiently high water stability that allows feed to be consumed by the fish and prevent nutrients from dispersing or leaching in the water, leading to poor feed conversion and performance (Leonard et al. 2002). Diet formulation, ingredient particle size, conditioning, die specs, and cooling are the major factors that influence pellet quality (Axe 2002). Proteinaceous and starch materials have the greatest influence on producing a water-stable feed, as well as the affecting the formula costs to meet nutrient specifications (Rokey and Huber 2005). However, most by-product protein meals commonly used in tilapia feed are heat-denatured proteins, which have reduced pellet-binding characteristics. In contrast, dietary inclusion of nutritive protein binders from yeast, animal, and plant sources or pelleting aids, could significantly enhance the durability of pelleted feed for tilapia. In the proposed investigation, we will evaluate the effect of dietary inclusion of various nutritive protein pellet binders and pelleting aids on the pellet durability and water stability of pelleted feed, and environmental impact. This information will then be used to formulate and manufacture pelleted tilapia feed for pond culture systems and

compare it to conventional extrusion-processed feed in terms of production efficiency and profitability.

Quantified Anticipated Benefits

1. We will establish the utility of using lower cost diets to reduce feed costs.
2. Least-cost feed formulations and feed manufacturing technologies that minimize or eliminate the inclusion of fishmeal in favor of agricultural by-products available in the Philippines will be developed. The work will provide feed manufacturers in the Philippines and USA feed formulation and manufacturing specifications developed and training material for the production of least-cost tilapia feed, while sustaining the biodiversity through reduced reliance on fishmeal from captured fisheries.
3. We will identify feed formulation and feed manufacturing factors that reduce adverse environmental impact of intensive tilapia production.
4. The activities will provide research training and educational experiences of at least five graduate and seven undergraduate students at CLSU and NCSU, as well as manufacturers of tilapia feed and their customers. An important aspect will be the synergistic experiences among CLSU students, staff, faculty, feed manufactures and tilapia farmers in the region.

Research Design & Activity Plan

Location

This investigation consists of a series of studies that will follow-up on our previous CRSP-sponsored research to reduce feed costs in the production of tilapia by feed reduction, feed formulation, and feed manufacturing strategies. Additional studies will determine the value of the least-cost feeds including several locally available feed ingredients in place of fishmeal, and develop feed manufacturing technology that will reduce the cost of feeding pond-reared tilapia. In each of these studies, growth and feed conversion will be monitored at the FAC/CLSU and economic feasibility of experimental treatments and/or strategies will be evaluated. Novel feed formulation and feed manufacturing conditions will be developed and initially tested of at NCSU and optimum treatment combinations will be validated in pond culture conditions in the Philippines. Local feed manufacturing and formulation will be coordinated with Santeh Feeds in Luzon, Philippines (Ning Pascul, Formulator).

Methods

1.The effect of high and lower crude protein in commercial feeds with or without pond fertilization on the grow-out performance and production costs of Nile tilapia

Sex-reversed fingerlings will be stocked in twelve 500 m^2 earthen ponds at a density of 4 pcs m^{-2} with 3 replicates per group. These fish will be subjected to a factorial arrangement of 2 feed formulations X 2 pond fertilization treatments. Feeds with high crude protein (32% CP) and lower crude protein with amino acids (24% CP) will be formulated to meet or exceed nutrient requirements for growing tilapia. These two dietary CP levels correspond to those currently manufactured in the Philippines and used by farmers. The fish will be fed commercial extrusion-processed feeds based at 67% satiation or 2% average body weight (ABW) of the fish stock determined by sampling fish every two weeks. Each feed treatment group will either receive basal pond fertilization or an inorganic fertilizer treatment (urea and ammonium phosphate) at a rate of 28 kg N and 5.6 kg P/ha/week. Weekly fertilization will be adjusted depending on the algae productivity of the pond water using the Secchi disc visibility reading. Feed use per pond will be recorded daily. Fish sampling will be done at monthly intervals using the cast-net method and individual weights and total length will be determined on 100 sampled fish per pond. Environmental impact of experimental treatments on water quality will be evaluated by measuring dissolved oxygen, ammonia and nitrite levels, pH, water temperature, and Secchi disc visibility. Differences in growth performance, survival rate, and feed consumption will be statistically analyzed by analysis of variance, and feed costs per kg of body weight will be estimated to assess economic feasibility. The experimental treatments are as follows:

1. Feeding of high (32%) CP extruded feed with basal inorganic pond fertilization.
2. Feeding of low (24%) CP extruded feed with basal inorganic pond fertilization.
3. Feeding of high CP extruded feed with weekly inorganic pond fertilization
4. Feeding of low CP extruded feed with weekly inorganic pond fertilization

Hypotheses: 1) Pond-reared tilapia fed low crude protein diets will have lower feed costs per kg of marketable fish than those fed higher crude protein diets, particularly when ponds are fertilized at a rate of about 28 kg N and 5.6 kg P/ha/week.

2. Feed formulation strategies that eliminates dietary inclusion of fishmeal with alternative protein sources in high and lower protein diets for Nile tilapia.
Sex-reversed fingerlings will be stocked in twelve 500 m^2 earthen ponds at a density of 4 pcs m^{-2} with 3 replicates per experimental treatment group. Ponds will be treated weekly with inorganic fertilizer (28 kg N and 5.6 kg P). Fish will be fed daily at 2% ABW with dietary treatments consisting of a factorial arrangement of 2 levels of crude protein (32% and 24% CP) and 2 dietary inclusion levels of fishmeal (0% and 10%) in place of alternative food by-products proteins commonly found in the Philippines. Protein sources considered for least-cost feed formulation include rendered protein by-product meals from the poultry and swine, yeast by-products from the brewing industry that are located in Central Luzon, locally produced plant protein sources (copra meal, seaweed meal, distiller's dried grains with solubles, pea meal), and soybean meal imported from the USA or produced by expeller processing in the Philippines. Soybean meal, upon which world protein market prices are based, will be used as the basal plant protein source because of consistency of availability and nutritional quality. All grower diets will be formulated to meet the nutrient requirement of tilapia (NRC 1993; Li et al., 2006) using least-cost linear programming. The low protein diets will be supplemented with commercially available amino acids such that they have a similar amino acid profile as the high crude protein diet. Feed use per pond will be recorded daily. Fish sampling will be done as described above. Water quality will be monitored as described above. Differences in growth performance, survival rate, and feed consumption will be statistically analyzed by analysis of variance, and feed costs per kg of body weight and overall production costs will be estimated to assess economic feasibility.

The experimental treatments are as follows:
1. Feeding of high CP extruded feed with 10% dietary inclusion of fishmeal
2. Feeding of low CP extruded feed with 10% dietary inclusion of fishmeal supplemented with amino acids
3. Feeding of high CP extruded feed without (0%) dietary inclusion of fishmeal
4. Feeding of low CP extruded feed without (0%) dietary inclusion of fishmeal supplemented with amino acids

Hypothesis: 1) Decreasing feed formulation costs by replacing fishmeal with lower-cost animal and plant by-product protein meals will have no effect on cost per kg of tilapia produced; 2) Feeding low protein diets supplemented with amino acids reduces feed costs without adverse effects on growth performance of tilapia.

3. Effect dietary inclusion of nutritive protein binders and pellet processing aids on pellet durability, water stability, and palatability of tilapia feeds.
Components of this objective will be accomplished at the NCSU educational feed mill unit and aquaculture facilities. Using least-cost linear programming, tilapia grower feed will be formulated with feed ingredients commonly available in the Philippines to meet the nutrient requirement of tilapia (NRC, 1993; Li et al., 2006). To each basal feed formulation, nutritive protein binders from microbial (yeast protein by-product), animal (gelatin), or plant sources (seaweed meal, gluten meal), and/or non-nutritive pelleting aids (azomite or calcium-lignosulfonate) will be added prior to pellet processing. All mixed feed ingredients will be finely ground (< 200 microns) prior to pelleting (CPM pellet mill, model 1112-2, 60 second steam conditioning at 90 C). After the pellets have been

cooled, they will be evaluated for pellet durability (PDI) (ASAE S269.4), 3 minutes of wet tumbling, and nutrient leaching over 6 hours. These three tests will model transport and handling, degradation in water immediately after feeding, and nutrient leaching after the pellet sinks to the bottom of the pond. Feed formulations having the highest PDI per unit cost will be evaluated for palatability using tank-reared tilapia at NCSU. Each experimental grower feed treatment will be fed at 3% of ABW to 4 replicate tanks of 50 tilapia for a period of 3 weeks, and body weight gain and feed efficiency will be measured. The formulations yielding the best pellet durability and palatability responses will be provided to a commercial feed manufacturing plant in the Philippines to manufacture feed for pond testing at the FAC and at nearby tilapia farms in Central Luzon (see study 4).

Null Hypothesis: Dietary inclusion of nutritive protein binders and pellet processing aids will increase the durability and palatability of tilapia feed.

4. Compare the effect on tilapia feed manufactured by extrusion and pellet processing on grow-out performance and production costs of Nile tilapia.

Sex-reversed fingerlings of size #22 will be stocked in twelve 500 m2 earthen ponds at 4 pcs m2 (3 replicates per group). These fish will be fed dietary treatments consisting of a factorial arrangement of 2 manufactured feed forms (floating extruded feed versus slow sinking pelleted feed) and 2 dietary inclusion levels of azomite (0 and 1%) or other binder depending on results of study 3. Dietary inclusion of azomite has been reported to increase algal growth, enhance tilapia growth and improve pellet mill efficiency (Peak Minerals – Azomite, Inc., personal communication). All grower diets will be formulated using least-cost linear programming according to the optimum feed formulation treatments determined in studies 1, 2, and 3. The fish will be fed extrusion or pellet processed feeds based on 2% of average body weight (ABW) of the fish stock determined by sampling fish every two weeks. Feed use per pond will be recorded daily. Fish sampling will be done at monthly intervals as outlined above. Water quality will be monitored weekly. Differences in growth performance, survival rate, and feed consumption will be statistically analyzed by analysis of variance, and feed costs per kg of body weight will be estimated to assess economic feasibility.

Hypothesis: 1) Pellet processed feed results in lower feed cost per kg of marketable tilapia than extrusion processed feed.

Schedule

January 2010 – September 2010:	Studies 1 and 3
October 2010 – June 2011:	Studies 2 and 4
June 2011 – September 2011:	Write extension brochure/manual and final report; conduct training workshop for tilapia feed manufacturers and farmers

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DEVELOP FEEDING STRATEGIES FOR *MORINGA OLEIFERA* AND *LEUCAENA LEUCOCEPHALA* AS PROTEIN SOURCES IN TILAPIA DIETS

Sustainable Feed Technology /Experiment/09SFT05PU

Collaborating Institutions & Lead Investigators

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Objectives

To develop feeding strategies for *Moringa oleifera* and *Leucaena leucocephala* as protein sources in tilapia diets. Specific objectives are

1. To compare feeding levels at 5, 7.5, and 10% of body weight on growth performance and feed conversion efficiency of tilapia fed diets containing sunflower seed cake, *Moringa oleifera* and *Leucaena leucocephala* as protein sources.
5. To compare alternate day feeding with daily feeding on growth performance and feed conversion efficiency of tilapia fed diets containing sunflower seed cake, *Moringa oleifera* and *Leucaena leucocephala* as protein sources.
6. To determine the digestibility of diets containing *Moringa oleifera* and *Leucaena leucocephala* as protein sources.

Significance

In Tanzania, fish farming is done in ponds, mainly by smallholder farmers and institutions, mostly using Tilapia species. One of the problems that make tilapia farming unprofitable is low productivity. The low productivity is due to imbalance of energy and protein in the fish diets commonly used by small-scale farmers. In Tanzania, farmers use naturally available feeds to feed the cultured fish. Ponds are commonly fertilized with domesticated animal droppings or tender leaves as compost manure. The most frequently used feeds are rice and maize bran, kitchen leftovers, and garden remains. These are of low quality, and fish reared on these feeds are unable to meet their maintenance and production requirements, especially for protein. This prolongs the time to reach market weight and consequently leads to production of poor-quality fish and hence, low profitability of fish farming.

For several decades, fishmeal has been used as the main source of protein in fish feeds (El-Sayed 1999). However, the limited supplies due to competition with humans and livestock and the continuously rising prices of fishmeal make it to be too expensive for small-scale fish farmers in developing countries. Consequently, efforts have been shifted to evaluating potential alternative protein sources for use in fish diets. These alternative protein sources include soybean meals, protein concentrates (Refstie et al., 1998), meat meals (Williams et al. 2003) and blood meals (Bureau et al. 1999). Soybean meal has been the focus of attention for substituting fishmeal because of its advantage in terms of protein quality, competitive price and adequate supply. However, in practice the use of soybean meals and agro-industrial by-products have not been readily adopted by small-scale fish farmers in sub-Saharan Africa because of their high price and limited supplies. There is a need to identify less expensive alternative sources of protein from locally available feed resources and to select protein sources that do not conflict with human food security interests (El-Sayed 1999; El-Saidy and Gaber, 2002). For instance, fishmeal, soybean, meat meal and blood meal are likely to be reserved for human rather than animal diets in Tanzania.

Leguminous tree leaves and their pods seem to be appropriate alternative protein sources to fishmeal and soybean (Fernandes *et al*., 1999; El-Saidy and Gaber, 2003; Richter *et al*., 2003;

Kaushik *et al*., 2004). Our previous study has indicated that *Leucaena leucocephala* leaf meal and *Moringa oleifera* leaf meal can be used to substitute soybean up to 50% as protein sources in Tilapia diets and that the use of these leaf meals can lower feed costs and hence increase the profitability of fish farming enterprises. The proposed study is designed to determine the best strategies for feeding *Leucaena leucocephala* leaf meal and *Moringa oleifera* leaf meal to fish.

Quantified Anticipated Benefits

Through this investigation feeding packages based on diets containing *Moringa oleifera* and *Leucaena leucocephala* as protein sources will be developed and adopted by small-scale fish farmers. It is expected that through the use of these diets the farmers will increase the productivity of tilapia in their ponds, thus improving their incomes by selling fish. The increased level of income will improve the purchasing power of the rural farmers for food products, thereby reducing risks of food insecurity at housed levels. Also their per capita consumption of fish will increase, and thus reduce the problem of malnutrition in rural areas.

This study is beneficial to the US aquaculture industry because it offers opportunities to explore alternative protein sources since the largest and most expensive component of fish feed is protein. Generally, animal-derived protein sources (e.g.,fishmeal, fish oil, blood meal) are expensive and advancement in the use of soybean meal in fish feed is also proving to be expensive because of demand from the biofuel industry. Opportunities therefore exist to research into the nutritional value of other protein plant sources that may be available. Even if such protein plant sources in the US are limited in supply for industrial fish feed manufacturing, they would certainly be useful for small-scale feed manufacturing if the composition, and thus the appropriate dietary inclusion rates, were known.

Research Design & Activity Plan

An experiment will be conducted to test the effects of different diets and feeding regimes on growth performance of Nile tilapia. The fish will be reared in concrete ponds and tanks. The fish will be fed on diets containing 35% crude protein, 10% fats and 18 kJ/g energy. The fish will be fed to their apparent appetite but not exceeding 10% of their body weight for a period of three months. Maize bran will be used as an energy source while Sunflower seed cake, Moringa leaf meal, Leucaena leaf meal and soybean will be used as protein sources in the diets. A total of six diets will be formulated to make cost effective diets as follows. The first diet will include only soybean meal as a protein source and this will act as a control diet (diet 1). The second diet will contain sunflower seed cake as a sole protein source (diet 2). The third, fourth and fifth diets will be formulated in such a way that sunflower seed cake, Moringa leaf meal and Leucaena leaf meal, respectively, will replace soybean at levels of 50% of the total dietary protein (Diets 3, 4 and 5, respectively). The sixth diet will contain sunflower seed cake, Moringa leaf meal and Leucaena leaf meal as protein sources at the levels of 50%, 25% and 25%, respectively, of the total dietary protein (Diets 6). The diets will serve as the treatments, and hence, a total of six treatments will be used in this study. The treatments will be replicated twice and allocated randomly to 12 concrete ponds. Body weights of fish, fork length and width will be recorded at the start of the experiment and then at monthly intervals for a period of four months (January – April 2010) (i.e. at day 30, 60, 90 and 120). Economic analysis will be performed to determine the economic advantages of the alternative feedstuffs. A partial budget analysis will be conducted to determine economic returns of tilapia fed different diets. The best and most cost effective rations from the above study will be identified and used in the second experiment to test three feeding levels (i.e. 10, 7.5 and 5% of fish body weight). In addition, two feeding regimes will be tested: daily feeding and feeding on alternate days. In this study the treatments will be the three levels of feeding and two feeding regimes, thus making a 3 x 2 factorial experiment. Each treatment combination will be replicated twice and a total of 12 ponds will be used. The treatment combinations will be allocated randomly to the ponds. Body weights of fish, fork length and width will be recorded at the start of the experiment and then at monthly intervals for a period of six months (June – November 2010) (i.e. at day 30, 60, 90, 120, 150 and 180). The amount of feed given will be recorded daily and feed

conversion ratio will be computed at the end of the experiment as the ratio between feed provided to the weight gained. Deaths of fish will be recorded as they occur during the experimental period. Water quality parameters (i.e. temperature, dissolved oxygen, pH and nitrogenous compounds (NH_4-N, NO_2-N and NO_3-N) and secchi depth) of the tanks and ponds will also be measured at weekly intervals. In addition, proximate analysis will be done to assess the nutritional quality of the fish fed different diets.

A third experiment will be conducted to determine the digestibility of the diets using the indirect method which relies on the use of an inert marker. In this study chromium (III) oxide will be used as a marker at an inclusion level of 0.5%. Digestibility will be estimated by determining the relative quantities of the marker in feeds and faeces. This experiment will be carried out at the University of Arkansas at Pine Bluff, USA.

The most cost-effective ration and feeding regime will be identified and introduced to farmers in year 2 of the project (2011). The farmers will be trained to formulate the diets. Two postgraduate students registered at Sokoine University of Agriculture will be involved in implementing this investigation under the supervision of the researchers. The first student will test the suitability and profitability of different diets. The second student will test the different feeding regimes. A local feed mill (International Tanfeeds Ltd) in Morogoro will be involved in compounding commercial diets based on the leaf meals. This company will produce and promote the leaf meal based fish diets in Tanzania. The project will sensitise farmers to plant *Moringa oleifera* and *Leucaena leucocephala* around their homes and fish ponds in order to increase the availability and make the supply of leaf meal sustainable. This will be done in year 2 of the project (2011). The project will be gender sensitive; where possible more women and youths will be recruited. It is, therefore, envisaged that the introduction of cheap good quality fish diets will bring intra-household changes in resource and income allocation, hence, bring influence on issues like gender balance in ownership and decision-making. In addition, planting of *Moringa oleifera* and *Leucaena leucocephala* trees around farmers' homes and fish ponds would simplify the availability of firewood and thus serve women labour.

Impact Indicators:
At least 70% of the project farmers use the feeds and feeding strategy developed by the end of the project.

Growth rate and body size of tilapia in farmers' ponds will be improved by 60 – 70% by the end of the project.

Income of participating households will be increased by 30% by the end of the project.

At least two M.Sc. students will graduate

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TOPIC AREA
INDIGENOUS SPECIES DEVELOPMENT

❖

DEVELOPING HATCHERY METHODS FOR THE MANGROVE OYSTER, *CRASSOSTREA CORTEZIENSIS* FOR THE PACIFIC COAST OF MEXICO

Indigenous Species Development/Study/09IND01UH

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Objectives

Culture of the mangrove oyster *Crassostrea corteziensis*, in Nayarit, Mexico is an important economic activity for this impoverished Mexican State. Four hundred tons are produced annually by small-scale, family operated farms. Traditionally seed for this form of oyster culture has been obtained from the wild through spat collection. Spat collection is generally sufficient for small-scale culture operations, but is often affected by the frequent hurricanes which are common in this part of Mexico. Additionally, recent legislation has banned further farm development based on wild spat collection as a precautionary measure to avoid over-exploitation. Hence development of reliable hatchery methods is required to continue to supply the existing oyster culture industry in Nayarit and to allow new farmers to start farms (Haws et. al. 2008). The CRSP team has also been working to begin culturing C. corteziensis to more northern areas to offer an alternative to imported C. gigas (Pacific Oyster) seed. C. *gigas* grows well in the northern Mexican States of Sinaloa and Sonora, but *C. corteziensis* is the oyster preferred by consumers when it can be obtained. The reliance on *C. gigas* is due to the lack of *C. corteziensis* seed and limited success with spat collection of this species in the Northern States. One of the current AquaFish CRSP investigations has tested the effectiveness of spat collection methods for *C. corteziensis* in Sinaloa. Variable results were obtained and while spat supply is sufficient to stock a limited number of small farms, hatchery production will be required to assure a more reliable supply (outside of the normal recruitment season) and to expand farming operations. Commercial supply of all oyster and bivalve seed has been extremely limited and sporadic in Mexico for a number of reasons. In part, this is due to the lack of well-known methods for bivalve production and because commercial operations prefer to produce shrimp postlarvae due to the high price and consistent demand. Establishment of a hatchery in an university setting will provide multiple benefits: 1) development of culture methods which are non-proprietary; 2) provide seed to community groups and small farmers who cannot otherwise obtain seed; 3) train students and faculty in methods; and 4) permit research on the basic biology of bivalve species to further improve understanding of the ecology and culture of this species. If successful, the hatchery can be used to produce other bivalve species-there is a high level of interest in further diversification of the shellfish culture industry.

Significance

The ability to produce *C. corteziensis* seed will benefit local communities and ecosystems. Most of the current and prospective oysters farmers in Sinaloa and Sonora are small-scale and operated by families or cooperatives. Women are heavily involved in oyster farming and collection. The majority of new farmers are women, including three women's cooperatives now participating in the current AquaFish investigations. Increased availablity and reliability of *C. corteziensis* seed will allow for the establishment of new farms and expansion of existing farms. Additionally, since this species is preferred for its superior flavor, shape and reputation as an aphrodisiac, small farmers working with UAS will have an advantage in the market. UAS will be the only university on the Pacific Coast of Mexico that will have the capability to train students and others in bivalve hatchery methods, which will increase the number of persons in Mexico who can support future growth of the industry. UAS will openly share and disseminate any new methods for the benefit of all (currently most hatchery technology is considered proprietary). Ecological benefits will accrue through enabling the culture of a native species instead of non-native species.

Quantified Anticipated Results

The principal benefits accruing from expanding the *C. corteziensis* industry include increased revenues for oyster farmers, alternative livelihoods for fishers (including women fishers), and the promotion of a low-impact form of aquaculture. Oysters are also a high quality, high protein food commonly consumed by coastal residents. For example, only one medium sized oyster is required to satisfy the daily protein requirements of a toddler, as well as minerals and vitamins such as zinc.

Target groups include the Autonomous University of Sinaloa (UAS, Culiacan and Mazatlan campuses), women's cooperatives (which are private businesses) that produce oysters in Santa Maria Bay, oyster grower cooperatives in Nayarit. Other universities and technical assistance providers will also benefit. CESASIN (the Committee for Aquatic Sanitation of Sinaloa), the major extension corps in the region, is a partner in this activity and will benefit from the training in shellfish methods, thus expanding their capability to provide extension assistance to the private sector.

Quantifiable benefits will include: amount of seed produced, number of students and technicians trained, development of a prototype hatchery, increased availability of information and increased interest in culture of a native species.

Metrics:
Number of institutions directly or indirectly benefiting from the training: 5
Number of individual participants in extension and technical training: estimated at 6
Number of communities benefiting from extension services: 10
Number of private businesses (including cooperatives and women's groups) benefiting from improved extension services: 12
Students involved: 3
Training modules produced: 1
CRSP newsletter articles: 1
Peer-reviewed journal article: 1
Benefits to the U.S.: work in Mexico has benefitted UHH efforts to develop native shellfish species in Hawai'i. Exchange of information and methods will continue for mutual benefit.

Activity Plan

C. corteziensis broodstock will be collected and held for conditioning (development of gametes). Spawning will be induced with thermal shock, or through use of neurotransmitters, hydrogen peroxide or addition of dense algae cultures if thermal shock is not effective. Strip spawning (manual removal of gametes) will also be tested. Gametes will be collected, fertilized and held in 200 liter tanks with filtered seawater until hatching is complete and the D-stage has been reached.

The larviculture protocols of Mazón-Suástegui (2007) y Saucedo *et al*., (2007) will be tested and modified as necessary. Larvae will be stocked into larger tanks at an initial density of 9-10/ml, with density being incrementally reduced to 3/ml at the final larval stages. Larvae will be fed using a mixture of microalgae, *Isochrysis galbana*, *Pavlova salina* y *Chaetoceros muelleri*, supplied at a density of 20-30 × 10^3 cel/mL (days 1 to 10) and 30-40 × 10^3 cel/mL (after day 11). When the larvae reach the pediveliger stage, they will be transferred to setting tanks containing spat collectors. Data will be collected at all stages of the study to determine the optimal stocking and feeding rates, track survival, as well as monitoring water quality parameters.

A cost-benefit analysis will also be conducted for both seed (settled spat) and eyed-larvae production. Dr. Quentin Fong, Resource Economist at the University of Alaska has worked with the CRSP team to conduct economic analysis in the past and will provide assistance to them for the cost-benefit analysis. In conjunction with the results from the current AquaFish investigation on spat collection methods in Bahia Santa Maria, it will be possible to determine which methods are most feasible and cost-effective in terms of providing seed to remote oyster farmers. Extension visits will also be made to oyster growing groups in Bahia Santa Maria and Nayarit to provide support to continuation of the on-going AquaFish investigations such as sanitation, depuration and relay and spat collection.

Drs. John Supan (LSU) and Maria Haws (UHH) will provide technical assistance to this work based on their extensive experience in hatchery production of a variety of bivalve species and will assist with the training and outreach components.

Statistical Analysis: Analyses will be performed using the Statistical Package for the Social Sciences Version 10.1 (SPSS 10.1). Data on survival and growth of larvae under differing tempertature and salinity regimes will be subjected to a multiway factorial analysis of variance in terms of the factors of rearing salinity, absence or presence of one, two or three food types in rearing tanks (Objective 3). In all cases, significant results will be followed by a comparison of means using the Least Significant Difference (LSD) Test. Normality and homogeneity of variance tests will be performed on raw data. Sample distributions violating assumptions will be log-transformed before analysis. Data, expressed as percentages, will be arc sine-transformed before analysis. All differences will be regarded as significant at $P < 0.05$.

Schedule

This work will begin in January 2010 with set-up of the hatchery facility. Broodstock will be collected in April 2010 from the wild. These will be examined to assure that they are free of *Perkinsus marinus*, which has appeared in Nayarit State. The larviculture trials will be conducted between May and November, 2010. Students and technicians will be trained throughout this period. Workshops will be held for interested community and industry members beginning in February 2011. The final report will be submitted in November 2011. Spat and eyed-larvae from this work will be transferred to oyster farmers in Bahia Santa Marian, Boca Camichin and other rural communities to use in grow-out trials.

Student involvement: Three undergraduate and one graduate student will be involved in this work. Other UAS students will benefit through visits and internships in the hatchery as part of their aquaculture course work.

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SUSTAINABLE SNAKEHEAD AQUACULTURE DEVELOPMENT IN THE LOWER MEKONG RIVER BASIN OF CAMBODIA AND VIETNAM

Indigenous Species Development/Study/09IND02UC

Collaborating Institutions & Lead Investigators

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Inland Fisheries Research and Development Institute (Cambodia)	So Nam
Cantho University (Vietnam)	Tran Thi Thanh Hien

Objectives

The specific objectives of this investigation are as follows:

1. To domesticate wild snakehead to address the snakehead banning issue in Cambodia in order to lift the ban on snakehead culture in Cambodia;
2. To study environment impacts, fish diseases and biosecurity of snakehead farming in Vietnam;
3. To provide recommendations for policy and best practices development of snakehead farming.

Significance

In Cambodia wild giant snakeheads (*Channa micropeltes*) are generally cultured in smaller cages of less than 200 m^3. Feed represent more than 70% of the total operational cost and the main type of feed for wild giant snakehead culture is small-sized or low valued fish, representing 60 to 100% of the total feed used depending on feeding strategies adopted by different farmers (So et al., 2005). During the dry season (October to May), the most important source of feed is freshwater small-sized or low value fish, while more marine small-sized or low value fish species are used during the rainy season (June to September) (So et al., 2005). Pangasiid catfish and hybrid clarias catfish are commonly cultured in earthen ponds in Cambodia. They are omnivorous and freshwater low value fish are used as direct feed at an average proportion of 20% for pangasiid catfish and 54% of total feed fed for hybrid clarias catfish (So et al., 2005). In the Mekong Delta in Vietnam domesticated snakehead (*Channa micropeltes*, and *C. striata*) are totally fed with marine small-sized/low value fish (mostly with marine small-sized/low value fish) (So & Prum, 2009). Pangasiid catfish (*P. hypophthalmus*) aquaculture is the biggest industry, and its production was about 2 million tons in 2007/2008. The feed for this aquaculture are both pellet feed and small-sized/low value fish. Giant freshwater prawn is carnivorous and it may depend on low value fish used as direct feed.

The government of Cambodia put a ban on snakehead farming in September 2004 and the reasons for this was the potential negative impacts on wild fish populations from wasteful snakehead seed collection and on other fish species diversity, and also potential negative effects on poor consumer groups from decreased availability of small-sized/low valued fish (So et al, 2007). The first phase Investigation #2 (07MNE01UC) revealed that nearly 200 freshwater small-sized fish species were detected in the Mekong River Basin of Cambodia and Vietnam, and these freshwater small-sized fish species, including juvenile of commercially important fish species, contribute more than 70% to total freshwater capture fisheries production. After the ban on snakehead culture in Cambodia, snakeheads have illegally been imported from the neighboring countries, particularly from Vietnam, to supply high local market demands in Cambodia. Furthermore, the study showed that freshwater small-sized fish have illegally been exported to Vietnam for feeding the significantly and commercially developed snakehead aquaculture in Vietnam. The first phase study indicated that the incentives for choosing snakehead before other fish species by tens of thousands of fish farmers are strong as it generates more than 10 times higher profits than other fish species.

Therefore, the ban does not only result in positive impacts on poor consumer groups from increased availability of freshwater small-sized fish in Cambodia, but also providing negative effects on livelihood of tens of thousands of snakehead farmers who depend on this livelihood for generating household income. In other words, these snakehead fish farmers have lost their important livelihoods and household income. Moreover, the ban also does not provide positive impacts on snakehead wild stocks as fishing pressure on wild snakehead using illegal and destructive fishing gears particularly electro-shockers has been increased for the recent years in order to supply local and external markets. . In Vietnam, the information obtained from the first phase Investigation # 2 (07MNE01UC) showed that snakehead fish have been domesticated for almost two decades in the Mekong Delta (So, 2009). Aquaculture of this domesticated snakehead fish has commonly and wisely been practiced, and recently intensified. As a result, environmental issue and outbreak of fish disease are the biggest problems, which cause high fish mortality due to poor water quality, and cause decreased income of hundred thousands of snakehead farmers in the Mekong Delta in Vietnam. As intensive snakehead aquaculture has been developed, many kinds of pathogens may cause serious diseases. The first phase Investigation # 2 (07MNE01UC) showed that some fish farmers in Cambodia have illegally imported snakehead fingerlings or broodstocks from Vietnam to continue their livelihood activity. Bringing snakehead seed and broodstocks from Vietnam may also bring diseases into Cambodia fish farms then into natural water bodies in Cambodia. As a result, wild snakehead will be infected by diseased farmed snakehead imported from Vietnam. So development of Cambodian indigenous snakehead broodstocks by domestication breeding and weaning with formulated diets, which have been developed by the first phase Investigation # 3 (07SFT01UC: Tran Thi Thanh Hien and David Bengtson), will contribute positively to socio-economic development of tens of thousands of fish farmer communities as well as protect natural aquatic ecosystems. At the same time, the development of indigenous snakeheads for aquaculture in Cambodia must be approached in a responsible manner that diminishes the chance for negative environmental, technical, and social impacts. Therefore, domestication breeding of wild snakehead in Cambodia and study of water quality as well as pathogenic agents in Vietnam is practical and necessary in order to reopen snakehead aquaculture in Cambodia and to sustain snakehead aquaculture in Vietnam. Moreover, lessons learnt from Vietnam will be carried over to Cambodia.

This proposed investigation falls into the Topic Area of Indigenous Species Development. Moreover, this investigation aligns with the Strategic Planning Framework (SPF) for Fisheries: 2009-2018 of the Cambodia's Fisheries Administration (FiA, 2009), which focuses on "The increase in aquaculture production in line with food security and export demands". The Minister of Ministry of Agriculture, Forestry and Fisheries of Cambodia, in his letter banning snakehead culture on September 3, 2004, clearly indicated that detailed impact assessment of snakehead culture, and domesticated snakehead seed and formulated feed are available, the ban will be lifted. These investigations (07MNE01UC and 07SFT01UC) have been consulted with the Ministry of Agriculture, Forestry and Fisheries (MAFF), particularly the Fisheries Administration (FiA) and the Department of Aquaculture Development. The government is not only aware of these investigations, but also very supportive to them, and the government of Cambodia (i.e. MAFF and FiA) expects that these investigations will benefit at last 20,000 fish farmers who are waiting for restarting their snakehead culture operations, with the supply of domesticated seed and artificial plant protein feed in the future. Moreover, in phase 1 a one-day inception workshop was organized on 13 June 2008 at IFReDI, Phnom Penh to provide knowledge of understanding Project details and participated by senior fisheries officers/officials and policy decision markers from the Central Fisheries Administration (FiA) in Phnom Penh (i.e. all FiA divisions and R & D centers/institutes) and from Provincial Fisheries Administration (the seven project target provinces: Kampong Cham, Prey Veng, Kandal, Phnom Penh, Kampong Chhnang, Battambang and Siem Reap province) where the Project will be implemented in, universities (i.e. Royal University of Agriculture and Prek Leap National School of Agriculture) where undergraduate and graduate thesis students come from, and NGOs (WorldFish Center, FAO, JICA-FAIEX, MRC-Aquaculture/Fisheries Projects, OXFAM America- Fisheries Project, USAID- Aquaculture

Enterprise Development Project- DAI, Spanish Aquaculture Project) who are working on aquaculture and fisheries development in Cambodia.

Quantified Anticipated Results

This research will provide information on domestication breeding, feeding and weaning of snakehead fish, especially development of Cambodia's broodstocks, in order to lift the ban on snakehead culture in Cambodia, and information on environment, fish health and bio-security in Vietnam in order to develop a long-term sustainable snakehead aquaculture industry in Cambodia and Vietnam.

1. At least 20,000 farmers in Cambodia will benefit from this Investigation by restarting their snakehead culture. According to the statistics of Fisheries Administration of Cambodia, about 20,000 farmers used to culture snakehead mostly in cages and least in ponds before the ban. When snakehead will be successfully domesticated, and formulated plant protein feed produced commercially these farmers will restart their snakehead culture as snakehead culture is significantly profitable compared to other fish species cultured in Cambodia. According to IFReDI recent study, the incentives for choosing snakehead before other fish species by fish farmers are strong, generating more than 10 times higher profits.
2. More than 100,000 snakehead farmers in Vietnam will operate environmentally friendly, healthy and sustainable aquaculture. These farmers are facing environmental and disease problems in their snakehead farming in Vietnam. Study of water quality as well as pathogenic agents in Vietnam is practical and necessary in order to sustain snakehead aquaculture operated by these farmers in Vietnam. Moreover, lessons learnt from Vietnam will be carried over to Cambodia.
3. 500 scientists, researchers, government fisheries officers/managers and policy makers, extension workers, NGO staff, and private sector working on the issues of snakehead aquaculture in Cambodia and Vietnam as well as in other Mekong riparian countries will be better informed, and have better recommended policies and strategies for sustainable snakehead aquaculture. These will be conducted through Project Inception Workshop, various stakeholder consultation workshops, and final project workshops during the period of 2 years.
4. Two undergraduate students will be supported and trained through their B.Sc./M.Sc. thesis research. Two students will be selected from the Royal University of Agriculture, Phnom Penh to get partial support to complete one B.Sc. degree and one Master degree, including thesis research: one on domestication breeding of snakehead and the other on weaning of snakehead on formulated plant protein diets.
5. At least 1,000,000 indirect beneficiaries in Cambodian and Vietnamese who consume snakehead fish in their protein diets. Snakeheads are common and popular fish, which can be seen in most of the Cambodian and Vietnamese dishes in everywhere from rural to city/town areas in both fresh and dried forms. These people will get indirect beneficiaries from reopen snakehead culture in Cambodia and sustaining snakehead culture in Vietnam.
6. Benefits to the US include improved knowledge and technology on domestication of freshwater fish species for aquaculture and improved knowledge on fish health management and biosecurity of freshwater aquaculture.

Research Design & Activity Plan

Location

All domestication breeding, feeding and weaning trials will be conducted at Freshwater Aquaculture Research and Development Center (FARDeC), Prey Veng province, Cambodia, which has many broodstock, breeding and weaning earthen ponds, and a small fish feed mill for fish pellet production. Training of FARDeC researchers and staff on snakehead domestication breeding, feeding, weaning, and wet and dry diet formulation will be done at Can Tho University (CTU), Vietnam based on information obtained from the first phase of AquaFish CRSP Investigation # 3 (07SFT01UC) led by Prof. Dr. David Bengtson, University of Rhode Island and Dr. Tran Thi Thanh Hien, Can Tho University. Alternative Feeds for Freshwater Aquaculture

Species. In addition, all environmental and fish health surveys and analyses will be conducted in Vietnam by CTU PI and researchers.

Methods
The domestication study will comprise four interrelated parts:

(a) Wild snakehead fish: Collection of and bringing adult/mature wild snakehead (*Channa striata*) from different natural water bodies into FARDeC hatchery, Cambodia.

(b) Training and technology transfer: On-the-job/site training of FARDeC researchers and staff on snakehead on breeding, weaning, feeding strategies and feed formulation techniques (feed formulation based on the optimal diet composition: protein, lipid, mineral, fiber and energy obtained from the first phase Investigation # 3, and on supplemented information from Samantary and Mohanty, 1997; Arockiaraj et al, 1999) will be conducted at Can Tho University, Vietnam.

(c) Induce spawning and weaning: After FARDeC researchers coming back from Vietnam and knowing what they are doing, they will start inducing the collected wild snakehead to spawn. At the same time they will set up live feed production ponds/tanks to produce live feed (e.g. moina, cladocerans) to wean the fish larvae up to fry stage. Afterwards fry will be fed onto freshwater small-sized fish till fingerling stage, and then fingerling will be fed onto formulated diets up to adult/mature fish (i.e. first generation snakehead fish).

(d) Follow up: Dr. Bui Minh Tam (Can Tho University) will visit FARDeC for one week in order to assist FARDeC researchers to develop snakehead breeding program and to set up breeding and weaning experiment trials. Afterwards Dr. Tran Thi Thanh Hien (Can Tho University) will visit FARDeC for one week to assist FARDeC researchers to formulate artificial diets and provide advice on feeding strategies.

The environmental impact and fish health study in Vietnam will comprise two interrelated parts:

(a) Water quality analysis: CTU researchers will collect water samples from snakehead farms in the three provinces: Can Tho, Dong Thap and An Giang in the Mekong Delta of Vietnam for at least two time per year; i.e. one in the dry season and the other in the wet season. Water quality analysis will be conducted CTU researchers at CTU laboratory to address seasonal changes.
(b) Snakehead diseases study: At the same time snakehead fish diseases will be addressed to identify diseases involved, and how different they are between the dry and wet seasons. CTU researchers will conduct the sampling of tissues of infected/sick snakehead farmed in the above three provinces for two time per year (one in the dry season and the other in the wet season), and followed by diseases diagnosis done at CTU laboratory.

Schedule
The duration of implementation of this proposed investigation will be 24 months, starting from 10/1/09 till 30 September 2011.

A. December 2009 – January 2010: The wild snakehead *Channa striata* (i.e. 30 pairs) collected from different natural water bodies to be brought into FARDeC hatchery in Cambodia for inducing spawning.
B. February 2010 (i.e. the dry season) and July 2010 (i.e. the wet season): Assessment of water quality and snakehead diseases in Vietnam to be conducted. Water and fish tissue sampling from snakehead farms will be done for 5 days each time.
C. March 2010: Training and technology transfer from CTU (Vietnam) to FARDeC (Cambodia) to be conducted at CTU, Vietnam. This activity will take 15 days.
D. May – July 2010: Inducing snakehead to spawn and weaning the larvae and fry to be trialed.

E. June 2010: The CTU researcher Dr. Bui Minh Tam to visit FARDeC to assist FARDeC researchers in inducing snakehead spawning and weaning.
F. July 2010: The other CTU researcher Dr. Tran Thi Thanh Hien to visit FARDeC to develop formulated diets and feeding strategies to wean snakehead fingerling up to adult/mature fish.
G. July 2010 – July 2011: Weaning snakehead fingerling with formulated diets to adult/mature fish (i.e. first generation of snakehead broodstocks developed) to be conducted.
H. January 2011 (i.e. the dry season) and June 2011 (i.e. the wet season): Second year assessment of water quality and identification of snakehead diseases in Vietnam to be conducted. Water and fish tissue sampling from snakehead farms will be done for 5 days each time.

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INDUCED SPAWNING AND LARVAL REARING OF THE "CHAME" *DORMITATOR LATIFRONS* IN LABORATORY CONDITIONS

Indigenous Species Development/Experiment/09IND03UH

Collaborating Institutions & Lead Investigators

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Objectives

The proposed research will be focused on the production of *chame* (Pacific Fat Sleeper, *Dormitator latifrons*) juveniles for aquaculture and research purposes. Chame is a widely distributed fish along the Pacific coast of the Americas ranging from southern California to northern Peru. Preference for chame is highly localized; in some areas it is regarded as a "trash" fish, while in others, it is prized as a traditional food and as a reliable emergency food, particularly for women and children. In Mexico, it is a valuable fisheries commodity, in part for production of fishmeal. In Ecuador, this species is widely cultured using extensive methods due to its wide demand. Under the USAID SUCCESS project, reliable and low-tech methods were developed for grow-out using feeds made from local products. Chame was demonstrated to grow well either in monoculture or in polyculture with shrimp. The ACRSP project sponsored a study of the feasibility of improving chame culture methods-this work stems from recommendations in that report. The major barrier to further development of chame as an aquaculture species is that fingerlings must be obtained from the wild, an increasingly problematic issue as its native freshwater and brackish wetlands disappear. In some areas this species has disappeared entirely, removing a key species from the ecosystem, but also impeding its development as the "new tilapia". Consequently, juvenile production of chame in laboratory conditions will have a significant impact on the expansion of chame culture in commercial settings as it is already recognized a viable species for aquaculture diversification, pending proven success in the larval rearing. Additionally, the ability to produce chame fingerlings will help reduce fingerling catch in the wild. Furthermore, the results of this research will facilitate the development of captive stocks of gobies for basic scientific studies such as those being proposed for endangered and threatened Hawaiian gobies (by Clemson University and St. Cloud University in cooperation with the PACRC). The main goals of this proposal are the following: 1) attempt hormonally induced reproduction by outlining the viability of the utilization of newer spawning techniques, such as the slow release of LHRHa implants in females and LHRHa injections to achieve spermiation in males; 2) fertilization and egg incubation at different salinities to evaluate hatching success; 3) a series of trials with larvae offered live food as exogenous starter diets will be performed. Among these organisms provided will be microalgae, protozoan and rotifers at different concentrations; 4) a series of microparticulate diets will be formulated and used as initial feeds and feeds aimed at weaning juveniles. This strategy will allow comparison of the utilization of different live organisms versus artificial diets for the controlled feeding in chame larvae/juveniles.

Significance

At present, medium-scale commercial aquaculture in Ecuador, as well as initial experiences of chame culture in Mexico, are conducted with wild caught juvenile fish. There is also interest in this fish in Nicaragua, where freshwater fishes such as tilapia are currently fetching higher prices than cultured shrimp. Therefore, the goal of this proposed work is to a production of juveniles under laboratory conditions and minimize the dependency on wild fish supply. Available

information indicates that in Ecuador, chame aquaculture has continuously decreased over the last eight years due to the shortage of juvenile fish since controlled propagation has not been achieved. Research in this area was largely abandoned over ten years ago. For Mexico, there is a steadily demand on the central and the southern Pacific Coast. Also, as surveyed by the authors, there are already fish farmers interested in acquiring laboratory produced juveniles for commercial aquaculture in Oaxaca State. In addition, the species is not considered for protection under Mexican laws, and controlled juvenile production will provide a considerable benefit for the diversification of fish culture in Mexico.

Quantified Anticipated Benefits

Anticipated benefits include: lessening of dependence of wild caught juveniles for grow-out in aquaculture facilities, increased utilization of a highly desirable species; diversification alternatives to tilapia and shrimp culture; development and application of an appropriate reproduction and larval rearing methods; and development of a new source of income for local communities of farmers.

Target groups for this work include: aquaculture extension workers and researchers in Pacific Mexico and Ecuador; key private sector representatives; fish growers in Sinaloa, Oaxaca and other Mexican southern states; Universidad Autónoma de Sinaloa (UAS, Culiacan and Mazatlan Campuses). Groups benefiting in Ecuador include Ecocostas, an NGO dedicated to conservation and sustainable development for Latin America and potentially many fish growers in the Manabi and Esmeraldas Province coastal areas. There are also groups interested in culturing chame in Nicaragua; results will be shared with the CRSP partner in Nicaragua, CIDEA/UCA.

Quantifiable benefits will include: controlled reproduction in captivity and larval/juvenile rearing methods development for the target species and possibly for Dormitator maculatus, a similar species in Atlantic coastal areas. This work will benefit the U.S. by informing research taking place at UHH where 5 native species of threatened goby fishes to develop culture methods.

Metrics: This study will contribute towards institutional strengthening by providing training for faculty and undergraduate and graduate students from Facultad de Ciencias del Mar Universidad Autónoma de Sinaloa (FACIMAR-UAS) on various aspects of fish reproduction, larval feeding, live food production, and diet formulation, biochemical analyses. In addition, the development of methods that will provide chame juveniles required for self-sustaining and commercial aquaculture will potentially contribute to the artificial propagation techniques of other gobiiod species. The success of this project will be measured based on: 1) determination of an adequate live food for *D. latifrons* that results in improved survival within 96-120 hours after yolk sack absorption; 2) successful tests with several larval diets for *D. latifrons* that result in improved growth performance and survival that will be then recommended for practical production of chame juveniles; 3) two to three linkages with other organization in the host country will be accomplished; 4) two to three technical reports and/or peer-reviewed journal articles, one or two CRSP newsletter articles will be published, also two Master and one PhD degree and two undergraduate thesis will be produced; and 5) six to eight students and technicians will be trained on various aspects of fish reproduction, larval feeding and live food production techniques.

Research Design & Activity Plan

Objective 1: Induced spawning and spermiation using synthetic analogues of luteinizing hormone releasing hormone (LHRHa)

Broodstock fish will be collected and transported and acclimated at FACIMAR-UAS. They will be fed with a combination of 60% floating pellets (32% protein 8% lipids) and 40% sinking pellets (35% protein 10% lipid). Fish will be classified and separated by gender and size within 2 weeks of arrival to FACIMAR-UAS. Fish of both genders will be tagged using PIT-Tags (Passive Integrated Transponder tag, Biomark®). Fish with visible signs of gonad maturation such as swollen

abdomen, significant individual weight gain and changes in coloration on males and females, both in the papilla and the abdomen (Bonifaz et al, 1985; Estuardo Campoverde, pers. comm.), will be separated and monitored by gonad biopsies using plastic catheters. The oocytes will be examined for size and nucleus position after clearing with an Ybag solution (Rodriguez-Gutierrez, 1992). For year one, mature females (n= 5 at least) will be divided four experimental groups to evaluate the spawning efficiency after LHRH administration either by implantation or injections,compared to a control group, in a similar fashion to bullseye puffer *Sphoeroides annulatus* (Duncan et al., 2003). For males, sperm quality issues are noticeable given that in most cases, milt collected can show very low sperm motility; either after hormone injection or with testicle removal and maceration from fish (Estuardo Campoverde, pers. comm.). Therefore, sperm release and quality will be evaluated after injections of LHRHa at different concentrations per body weight (μg Kg^{-1}). Sperm quality evaluation as spermatocrit, sperm concentration and sperm activation efficiency will follow hormonal treatments. For year two, the same procedures will be used in fish already in captivity (both male and female) and compared with the results obtained from wild broodstock collected in the second year.

Objective 2. Effect of water salinity on fertilization, egg incubation and hatching success.
This experiment will be conducted to establish the effect of water salinity on fertilization efficiency of gametes, given that chame migrates to brackish water for spawning under natural conditions (Bonifaz et al., 1985) and the amphidromy of larvae and juveniles was demonstrated in chame and other gobies (McDowall, 2009). For this objective, batches of eggs (5 g) will be fertilized with 0.1 ml of sperm using water of different salinities that will be gradually increased from freshwater to 35 parts per thousand (ppt) and incubated in triplicate in 1.5 litter containers using 1 litter of 5μm filtered UV-sterilized water to a specific salinity. After estimation of fertilization efficiency, embryos will be incubated in a 3 litter volume cylindrical containers with constant aeration. Todd (1975) described hatching event and following swimming behaviour of *D. latifrons* but no data was provided of time of hatching. At the regular 2-4 hour intervals after fertilization, container will be check for hatching rate and presence of normal and abnormal larvae within each salinity treatment.

Objective 3: Effect of water salinity, food type and availability on larval survival and growth after yolk sack absorption.
The onset of exogenous feeding in fish larvae is considered one of the bottlenecks in the aquaculture industry, this is no exception for chame where the main obstacle to production of chame juveniles is precisely the optimization of the onset of exogenous feeding. Personal communications from at least four Ecuadorian researchers and producers with relevant practical experiences, from as early as 1982 to 2009, indicate that within a few hours after yolk sack absorption, there is 100% mortality of the larvae, suggesting that the onset of exogenous feeding has not been successful. Based on previous experiences, it is possible that chame larvae must be provided with microzooplankton, for an accelerated growth and survival as easier prey to catch the prey and increased acceptance due to their size (5 to 100 μm) (Chuan-Lima et al 2003), for later usage of rotifers and *Artemia* nauplii (Garcia-Ortega, 2009). The source of microzooplankton can be either by the green-water technique, or free protozoans and copepod nauplii (Olivotto et al, 2008) culture. Another potential source of live food can be provided by benthic organisms grown attached to a specific substrate as a biofilm, where larvae can obtain food when foraging from a substrate rather than catching free-swimming prey, as evaluated for marine shrimp larval and juveniles rearing and freshwater fish (Moss and Moss 2004; Keshavanath et al 2001). Several personal communications from fisherman and researchers both in Ecuador and México, indicate that small chames have been observed foraging on aquatic vegetation; also chame adults prefer detritus as primary food (Yañes-Arancibia and Diaz-Gonzalez, 1977); there is a possibility that chame larvae and juvenile already develop this feeding habit. Thus, detritus production in laboratory settings, either as a food source for chame or nourishment for free swimming protozoans will be explored. For live food production, the laboratory at FACIMAR-UAS has over 10 years of experience producing 16 species of microalgae, rotifers and indirectly protozoans;

conducting physiological studies on the production of live food at different salinities and temperatures. For this project during the first year, chame larvae will be transferred to plastic containers conical and cylindrical, transparent and black (2-4 L volume) at same water salinities from hatching tanks (Objective 2) and offered either as single food source or a combination of two to three of the proposed feeds in a series of feeding trials. Over the two year duration the following feeding treatments will be carried evaluated: (1) Two microalgae species *Isochrysis* sp and *Dunaliella* sp. at a minimum of 50,000 cell/ml as controls, (2) Green-water originated in 250 L tanks at different salinities stocked with tilapia (*Oreochromis* sp) (3) strips (15x2.5 cm size) of shade cloth (90% blocking) incubated in 250 L tanks at different salinities stocked with tilapia (*Orechromis* sp) for biofilm conditioning, (4) a combination of a liquid microencapsulated diet, EZ-larva 10-50 μm and microparticulate MPz < 70μm, (5) free swimming protozoans, (6) organic detritus and bioflocs produced in our laboratory (7) rotifers *Brachionus rotundiformis* both non-enriched and enriched with a commercial product to increase HUFA content (Aqua Grow – DHA, ABN Products®) (8) micropowder *Spirulina* <20 μm (Mackay Marine®) and (9) a solution of the rotifer enrichment product Aqua Grow – DHA (ABN Products®). At the end of the experiment, growth performance will be evaluated in terms of the final individual body weight, survival (%), specific growth rate (SGR, %) and weight gain (%) within 120 h after yolk sack absorption. Fish larvae samples will also be fixed throughout the experiments for gut content analysis in term of number of particles or organisms per dietary treatment (Rocha et al, 2008). During year 1, we proposed to conduct the experiments in small volume containers at controlled temperature in our lab, for year two our plan of work will be expanded for the most effective single or combined feeding treatments in terms of survival of at least 120h after yolk sack absorption at larger tanks (20 and 250 L) in an outdoor facility located at FACIMAR-UAS.

Objective 4. Studies on the utilization of artificial diets for weaning of chame larvae
In Columbus laboratory at Ohio State University, a complimentary experiment with formulated diets will be performed by Konrad Dabrowski and his graduate student. The feeding experiment will be conducted in a flow-through system consisting of 24 aquaria (3 tanks/dietary treatment) supplied with aeration. Water quality will be monitored throughout the larval rearing process. Temperature (26-28°C) and dissolved oxygen (5-6 mg/L) will be determined on a daily basis with weekly measurements of total ammonia-nitrogen and pH. Within two days after yolk absorption, chame larvae will be randomly distributed at a density of 100 larvae/aquarium and fed at a restricted ration up to 90% satiation for 2-4 weeks. Alternatively, live rotifers *Brachionus plicatilis* and *Artemia* nauplii will be offered in sequence as initial food and then 7 or 14 day old larvae/juveniles will be weaned to formulated diets. This technique has been used successfully with white bass (*Morone chrysops*) larvae of the approximately 2.5 mm initial size (Kwasek et al. 2009). At the beginning of the experiment with weaning diets, i.e. transition from live to formulated feeds, samples of 10 larvae/juvenile will be weighed. Larvae will be fed 4 diets: (1) a commercial diet, (2) an experimental casein-gelatin based diet with maca meal as attractant, (3) an experimental diet based on freeze-dried preparation of fish muscle, (4) freshly hatched brine shrimp nauplii. Both experimental diets will be formulated based on our previous experience and will be isonitrogenous (protein requirement: 55% for most larval fish, Dabrowski 1986). At the end of the experiment, growth performance will be evaluated in terms of final individual body weight, survival (%), specific growth rate (SGR, %) and weight gain (%). Fish from each dietary treatment will also be sampled for proximate body analysis (water, protein, lipid, ash) if the size at the termination of the rearing period will permit (at least 0.5 g individual weight).

Statistical Analysis: Analyses will be performed using the Statistical Package for the Social Sciences Version 10.1 (SPSS 10.1). Data on hormonal induction efficiency (spawning and spermiation) by administration mode or dosage and sperm quality parameters (objective 1), fertilization efficiency, hatching percentage and incidence of abnormal larvae per salinity (objective 2) and weaning trials for data on growth and proximate composition (Objective 4) will be subjected to one-way analysis of variance (ANOVA); larval growth performance and survival will be subjected to a multiway factorial analysis of variance in terms of the factors of rearing

salinity, absence or presence of one, two or three food types in rearing tanks (Objective 3). In all cases, significant results will be followed by a comparison of means using the Least Significant Difference (LSD) Test. Normality and homogeneity of variance tests will be performed on raw data. Sample distributions violating assumptions will be log-transformed before analysis. Data, expressed as percentages, will be arc sine-transformed before analysis. All differences will be regarded as significant at $P < 0.05$.

Schedule

Broodstock collection, gonad evaluation and hormone induction trials: January 2010-July 2010. Gamete quality determination, fertilization trials at different salinities, lipid analysis: July 2010-October 2010 and July 2011-September 2011. First feeding trails (small-scale), preparation of manuscript- July 2011-September 2011. Weaning experiments and feeding experiments. Biochemical analysis of diets and fish tissues-to optimize lipid class and fatty acid profiles- June 2010-April 2011. Collection of data on growth and survival, synthesis of data and preparation of manuscripts and fact sheets and final reports-May 2011 – September 2011.

Student Involvement:

Two UAS Masters, one PhD (OSU) and two undergraduate degree students working on their senior theses. Also, two more undergraduate students will collaborate as professional social services workers to fulfill UAS requirements to obtain their degree.

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STOCK ASSESSMENT OF "CHAME" *DORMITATOR LATIFRONS* IN NAYARIT AND SOUTH OF SINALOA MÉXICO

Indigenous Species Development/Study/09IND04UH

Collaborating Institutions & Lead Investigators

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Objectives

This work will assess the population dynamics of chame (*Dormitator latifrons*) in three rivers and associated coastal; Presido and Baluarte rivers in the south of Sinaloa and San Pedro River in Nayarit, México. The coastal lagoons associated with these rivers are the Agua Brava and Huizache-Caimanero. Information obtained from this study will allow researchers and regulators to determine whether there are critical issues associated with the fishery, which is for both food and for production of fishmeal, and begin to develop management recommendations for this unregulated, but important fishery.

Significance

The chame is a widely distributed fish along the Pacific Coast of the Americas. In many areas, such as the large coastal lagoons of Mexico, it is a heavily fished resource. It is also a developing species in aquaculture with the potential to become the "new tilapia" due to its favorable culture characteristics and high quality flesh. In other areas throughout Latin America, it is threatened or has disappeared in areas where wetlands are being destroyed, a trend which continues. It is also a fish that is heavily relied upon by vulnerable segments of the population (women, children, the very poor) as an emergency food source when other protein sources, including other fish, are not obtainable. In the Mexican states of Sinaloa and Nayarit, this species is found in coastal lagoons and estuaries where the intensity of fishing varies considerably. Given that this fish is being developed for aquaculture, and due to the continued threats to coastal wetlands, it is necessary to develop a database of information its abundance and population dynamics, as well as seasonal and temporal variability of these parameters.

This study will yield valuable information that can contribute to improved management of this fisheries resource and yield insights into its basic biology and ecology. The chame has been fished somewhat intensively in coastal lagoons, primarily to manufacture fishmeal. There is concern that if this practice continues, and if aquaculture of this species spurs its popularity as an edible product, that current fisheries management regulations are inadequate, or in some cases, non-existent, to protect the species. Dr. Guillermo Rodriguez, who will lead this study, was responsible for earlier studies of the blue crab fishery in Sinaloa, which was unregulated at the time of the study (1990's). His research and work with government institutions led to establishment of national fishing regulations for crab which have since helped maintain this resource and establish maximum sustainable yields for the fishery. This study on chame will be used to develop similar regulations, and the team will work with the responsible government agencies to begin considering including chame as a regulated fisheries species. Data analysis will employ standard methods for stock assessment, including size structure and otolith analysis for age estimation, the von Bertalanfy model for growth rates; gonodosomatic index (GSI) to determine gonad maturity and seasonality of spawning, and natural mortality to be estimated according to the Ricther y Efanov model (Sparre and Venema, 1997).

Quantified Anticipated Benefits

Fisheries information to improve management of a new aquaculture species, and a traditional fisheries species. Information will also be provided to local fishing communities on this fish and the researchers will develop guidelines in conjunction with government agencies for regulation of this species.

Target groups for this work include: Universidad Autónoma de Sinaloa (UAS, Culiacan and Mazatlan Campuses); local fishers in Nayarit and Sinaloa; and government agencies (State and Federal) responsible for fisheries management.

Quantifiable benefits will include:
Basic fisheries data and guidelines for a new species.

Metrics:
Number of institutions directly or indirectly benefiting from the training: 2
Number of individual participants in extension and technical training: estimated at 25
Number of communities benefiting from extension services: 6
Number of cooperatives (which are private businesses), individual businesses or community groups benefiting from improved extension services: 4
Students involved: 2
Training modules produced: 0
CRSP newsletter articles: 1
Peer-reviewed journal article: 1
Benefits to the U.S.: will inform research at UHH on goby species biology and culture

Research Design & Activity Plan

This work will focus on obtaining basic information on the density, abundance and other population parameters for the chame (Dormitator latifrons), an unregulated fisheries species. This species will be studied in three large rivers and coastal lagoons in Sinaloa and Nayarit States. Sampling will take place on a monthly basis in several sites for each river/lagoon. Data such as abundance, total length, standard length, weight, gonad weight, gonad maturity and fecundity will be obtained. Extraction and examination of otoliths will determine whether age can be determined using this method. Dr. Guillermo Rodriguez will work with his colleague, Dr. Gustavo Rodriguez, who is conducting the chame spawning and rearing trials to share information obtained from each study and to coordinate field work. Analysis of the collected data will permit estimation of the population density, growth rates, reproductive cycle, size at first sexual maturity, mortality rate and will allow for development of a population dynamics model for use in evaluating various fisheries scenarios.

Schedule

This work will begin in January 2010 with duration of 12 months. Completion of data analysis and reporting will then conclude in February 2009.

Student involvement: two graduate students and an estimated 25 undergraduate students (those taking fisheries biology classes) will be involved in this research.

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CONSOLIDATION OF NATIVE SPECIES AQUACULTURE IN SOUTHEASTERN MEXICO: CONTINUATION OF A SELECTIVE BREEDING PROGRAM FOR NATIVE CICHLIDS AND SNOOK AQUACULTURE.

Indigenous Species Development/Experiment/09IND05UA

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Objectives

1. To obtain an F_3 generation of *P. splendida* and *C. urophthalmus*, using traditional breeding.
2. To provide quality native cichlid broodstock of *P. splendida* and *C. urophthalmus.*
3. To obtain broodstock from wild and hatchery-reared snook juveniles.
4. To evaluate spawning of Mexican snook in captivity.
5. To identify native plankton used as feeds during early development of snooks.
6. To determine gene expression of enzymatic activity in different life stages of common snook and fat snook.

Significance

The selective breeding program for the native species Tenhuayaca (*P. splendida*) and Castarrica (*C. urophthalmus*) supported by the A&F CRSP in the Implementation Plan (2007-2009) was initiated using wild Castarrica and Tenhuayaca broodstock. From these fish, the first generation (F1) of selected fish has been obtained for these two species. This is a historic step in native cichlid aquaculture in the Americas. For the first years of work, we were able to combine the efforts of the A&F CRSP project and the Secretariat of Agricultural Development for the State of Tabasco (SEDAFOP). It is well known that genetic improvement in aquaculture can increase phenotypic characteristics of fish from one generation to the next, but this process is significantly higher during the first rounds of selection. Therefore, we expect that a minimum of 10% increase in yield can be achieved in the first generations. These actions can significantly improve the production of high quality fingerlings and have a favorable impact on more than 5,000 subsistence farmers and medium-scale producers. Well-supported aquacultural practices can help secure good quality food products in the near future, especially in the proposed site of study where a large portion of the population is composed of extremely poor peasants. The continuation of this selective breeding program will provide quality fingerlings to a growing number of fish producers that are requesting the development of alternative culture techniques that involve native species. The culture of native species of fish is important from an economic and a conservation standpoint at a time when the local and foreign demand has imposed great pressures on their natural populations (Mendoza, 1988).

Regarding snooks, in the Tropical Aquaculture Laboratory (UJAT) we have made significant progress understanding the reproductive cycle of the common snook (*Centropomus undecimalis*) and the fat snook (*C. parallelus*) under A&F CRSP financial support. So far we have been able of inducing spawning and producing larvae for both species. We also have determined the time and quantities at which different enzymes participate during digestion along early development. However, survival of snook fry has been very low and production of live feeds has been a limiting

factor. Despite these setbacks, progress has been made in several directions. For example: a) UJAT has consolidated the infrastructure at the Marine Aquaculture Laboratory thanks to CRSP support and the enormous interest aroused on marine fish aquaculture in the region; b) the protocol for controlled reproduction in captivity has been developed and implemented; c) larvae can be produced in massive amounts and transition to commercial food is feasible; d) important information regarding digestive enzymes on snooks has been generated making progress towards elaboration of specific diets for snooks; e) groups of snook broodstock for *C. undecimalis*, *C. parallelus* and *C. poeyi* have been kept in captivity for as long as two years, allowing facilitation of spawning trials; f) during the "second international symposium on snook biology and culture" partly supported by A&F CRSP we created the "International Network for the Biology and Conservation of Snooks" which incorporated researchers from USA, Mexico and Brazil and will incorporate scientists from central America as well. This event allowed a major leap forward bringing together the information generated to date regarding snook biology and aquaculture.

From the recommendations generated in the symposium several major research lines for snook aquaculture include the selection of broodstock groups produced in captivity (selective breeding); mass production of live feeds specific for snooks; development of specific artificial feeds; generation of protocols for weaning of fingerlings; evaluation of economic feasibility of snook culture; and production of fingerlings for sustainable management purposes (from wild broodstock). Based on this, we propose to address the first three topics recommended to generate key information required to strengthen snook aquaculture. The amount of interest generated around snook culture is such that several fishermen associations and fish farmers are waiting for the technological package to initiate snook aquaculture or restocking.

Quantified Anticipated Benefits

The establishment of good quality broodstock treatments, their distribution to local hatcheries, and the implementation of intensive masculinization programs are basic steps for sustainable aquaculture. These actions can significantly improve the production of high quality fingerlings and have a favorable impact on more than 5,000 subsistence farmers and medium-scale producers. Advancement in snook fingerling production will allow supporting the commercial fishery by restocking coastal lagoons and rivers. In the long term, these actions will help fishermen comprised in 262 associations in Tabasco that rely on eventual or permanent snook caught.

Research Design & Activity Plan

(a) Continuation of a Selective Breeding Program for the Native Cichlids Tenhuayaca, *P. splendida*, and Castarrica, *C. urophthalmus*, supporting Sustainable Aquaculture in Central America.

1. **Location of work:** Tabasco, Mexico.
2. **Methods:** One graduate student from UJAT will be recruited to work on the project. The investigation will be his (her) M.S. project.

Experiment 1. Selective Breeding Program for Tenhuayaca (*Petenia splendida*) and Castarrica, (*Cichlasoma urophthalmus*) using Total Length and Condition Factor.

Site: Reproduction trials will be conducted at the Tropical Aquaculture Laboratory (UJAT) and progeny testing trials will be performed at the "Mariano Matamoros" Hatchery, Teapa, Tabasco, Mexico. Groups of broodstock will also be kept at UJAT as a backup.

Experiment/Hypothesis 1. Both groups will show same growth performance.

***Test species*:** Tenhuayaca (*Petenia splendida*) and Castarrica, (*Cichlasoma urophthalmus*).

***General methods*:** This study will be composed of two groups of broodstock for fry production and growth comparisons for each species: Group 1. Control group (Fingerlings produced from wild broodstock collected from Tabasco and Chiapas); Group 2. F1 CRSP line (A&F CRSP project). The first group of broodstock for fry production and growth comparisons will be obtained from the wild broodstock collected from Tabasco and Chiapas and currently used in the laboratory of Aquaculture. Female selection will be based on the best total length measurements, and male selection will be performed using individuals with the best condition factor. Each selected broodstock group will be placed in 2.5m-diameter tanks. Each tank will contain 9 females and 2 males/tank, fish will be stocked at a sex ratio of 3:1 female:male in five spawning tanks. Fry to be used for grow-out trials will be collected from spawning tanks and stocked in grow-out hapas at a density of 1000 fish/m2. To eliminate age variability, fish stocked in a single pond will have a maximum difference of seven days of age. Fish will be grown for two months in these hapas.

Growth Performance. Five hundred fingerlings will be collected from the grow-out hapas and moved into three 2 x 1 x 1.2 floating cages with one-inch mesh size. This procedure will be repeated five times to assure five groups of fry. Fish will be grown for three more months.

Line Selection. After three months of growth; fish will be collected and measured. All fish will be divided in three groups using weight as the selection variable: 1) Fry which are 33% above the median value, 2) fry which are 33% around the median value, and 3) fry which are 33% below the median value. Group 1 will be reserved for follow-up studies, and group 2 will be used for line selection. All fish in group 3 will be discarded. From group 2 (of each replicate), fish will be stocked in 1,000 m2 earthen ponds and grown-out for 3 months. At the end of the grow-out phase, 900 females and 100 males with the highest length will be selected and placed (separated by sex) in 1,000 m2 earthen ponds. After three months of growth, fish will be selected to produce the F2 generation. Males will be selected based on highest condition factor, and females will be selected based on highest length.

***Sampling schedule*:** Fish in each replicate will be sampled monthly during the six-month period of experimentation, total length and weight will be measured from a subsample of 30 fish in each replicate. At the end, all fish will be measured and weighed.

***Feeding regimes and water management*:** Fish will be fed five times a day providing a daily ration of 5% of the estimated biomass. Feeding charts will be constructed from samplings performed every four weeks. Ten percent of the water in the ponds were hapas and cages are located will be replaced at least once a week.

Endpoints and statistical analysis: The experimental design consider for this experiment is a complete randomized design. The response variables (Length, Weight and mean number of fry per female) will be tested to determine if the assumptions for parametric analysis are met; if so, contrasts will be performed using ANOVA, otherwise data will be analysed using a Kruskall-Wallis test.

Laboratory and Pond Facility. The State government officials responsible for the Mariano Matamoros Hatchery have set aside four concrete ponds (200 m^2), four concrete ponds (1,000 m^2), and four grow-out earthen ponds (2,000 m^2) for UJAT's line selection investigation. If needed, more ponds can be used at the hatchery.

Universidad Juárez Autónoma de Tabasco (DACB). Ten spawning tanks (2.5 m diameter), 50 net cages (1 m^3) for fry grow-out, three grow-out ponds (200 m^2).

Universidad Juárez Autónoma de Tabasco (DACA). Two grow-out ponds (50 m^2), 20 net cages (1 m^3) for grow-out.

***Final Sampling*:** The following variables will be sampled: Initial weight and length, survival, final weight and final length. The following values will be estimated: Growth rate, condition factor and food conversion factor. This methodology will be repeated in 2011 to obtain the F_3 generation, using the F_2 group as the starting stock.

Schedule (a):

	YR1 (mos.)			Project YR 2 (mos)			
	4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
System setup, wild juvenile capture; broodstock selection	x						
Spawning and fry selection	x	x	x				
Grow-out trials, Broodstock selection (F2)			x	x	x		
Spawning and fry selection					x	x	
Grow-out trials, Broodstock selection (F3)						x	x
Data analysis and preparation of reports and publications							x

(b) Snook Aquaculture

Experiment/Hypothesis 1. Establishment of Common snook (*C. undecimalis*) and fat snook (*C. parallelus*) broodstock groups from wild and hatchery juveniles will perform equally.
The experimental protocols described below are generally based on work with snooks of Alvarez-Lajonchere et al. (2001, 2002), Neidig et al. (2000), Alves et al. (2006), and Vidal et al. (unpublished data from our laboratory).

***Location of work*:** Snook research facility in the coastal county of Centla, in the fishermen community of Jalapita, Tabasco. This facility is a rural, low budget project initiated by UJAT researchers and fishermen from "Cooperativa Pesquera San Ramón" (UJAT-CPSR) and partly supported by A&F CRSP.

***General methods*:** Two lineages will be developed, one initiated from wild juveniles captured in the Mecoacán lagoon and the Gonzalez River. The other one will be obtained from induced spawnings of wild broodstock kept in captivity since 2008. From this group, female maturity will be confirmed by observing the location of the oocyte´s germinal vesicle and by measuring egg diameter before they are transferred to holding tanks (males are not expected to be a problem). Spawning will be induced using GnRHa implants (Argent Labs). The buoyant eggs will be collected and stocked at 50 eggs/l in 1000-L incubation tanks.

Feeding regimes and water management: Larvae will be fed *ad libitum* providing microalgae, rotifers, artemia nauplii and artemia metanauplii. Weaning will be initiated on day 30 post hatching and finished on day 60 following Cerqueira, personal communication). After this, fish will be fed providing a daily ration of 2% of the estimated biomass. Feeding charts will be constructed from samplings performed every four weeks. One hundred percent of the water in the tanks will be replaced every two days.

***Sampling schedule*:** Fish in each tank will be sampled monthly during the entire study; total length and weight will be measured from a subsample of 30 fish in each tank. At the end, all fish will be measured and weighed.

***Endpoints and statistical analysis*:** The response variables (total length and weight) will be tested to determine if the assumptions for parametric analysis are met; if so, contrasts will be performed using ANOVA, otherwise data will be analyzed using a Kruskall-Wallis test. Survival to first feeding and at the end of the experiment will be compared among groups by Chi square test using contingency tables.

Schedule (b):

	YR1 (mos.)				Project YR 2 (mos)			
	12/09	4-6/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
System setup, wild juvenile capture; broodstock selection		x						
Spawning and fry selection		x	x	x				
Data analysis and preparation of reports and publications								x

(c) Experiment/Hypothesis 2. Mexican snook broodstock (*C. poeyi*) responds to GnRH implants releasing good quality eggs.
The experimental protocols described below are generally based on work with snooks of Alvarez-Lajonchere et al. (2001, 2002), Neidig et al. (2000), Alves et al. (2006).

***Location of work*:** snook research facility in the coastal county of Centla, in the fishermen community of Jalapita, Tabasco. This facility is a rural, low budget project initiated by UJAT researchers and fishermen from "Cooperativa Pesquera San Ramón" (UJAT-CPSR) and partly supported by A&F CRSP.

***General methods*:** Wild broodstock will be collected during the natural spawning season (June-September) and initially maintained in the laboratory in 25 m3 holding tanks. Female maturity will be confirmed by observing the location of the oocyte´s germinal vesicle and by measuring egg diameter before they are transferred to holding tanks (males are not expected to be a problem). At least 20 adults will be collected (15 females and 5 males). Spawning will be induced using GnRHa implants (Argent Labs). The buoyant eggs will be collected and stocked at 50 eggs/l in 1000-L incubation tanks.

***Treatments and replications*:** Females will be implanted with pelleted vehicle (no GnRHa), 100 μg GnRHa pellet/fish, or 200 μg GnRHa/fish pellet. All males will be implanted with 100 μg GnRHa/male pellets. Females will be monitored for maturation and ovulation. Sperm activation will be evaluated in males under microscopic examination. The incidence of ovulated females per replicate will be monitored. Lack of ovulation in any of the two females in a replicate will be considered a "negative-result" and will be recorded. A "positive-result" replication will be considered as one where eggs are produced regardless of their number or quality.

***Water management*:** Marine water (35 ppt) will be used in all tanks, 80% water will be replaced every other day. Water pH, dissolved oxygen, and temperature will be monitored daily.
Sampling schedule: After implantation, spawning tanks will be monitored for embryo presence every 2 hours.

***Endpoints and statistical analysis*:** Negative- and positive-result replicates for each treatment will be assigned a score of 0 or 1, respectively, and analyzed by non-parametric Kruskal-Wallis ANOVA followed by separation of mean treatment scores using Dunn's post-test. For positive-result replications, egg size and number will be analyzed by 1-way nested ANOVA (tank nested into treatment) and mean treatment values will be analyzed using Tukey's HSD. Egg quality will be assessed by determining rates of fertilization, hatching, and survival to first feeding; these results will be compared among treatments by Chi square test using contingency tables.

Schedule (c):

		YR1 (mos.)			Project YR 2 (mos)			
		4-5/10	4-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
System setup, broodstock collection		x	x					
Spawning trials			x	x				
System setup, broodstock collection							x	
Spawning trials								x
Data analysis and preparation of reports and Publications								x

(d) Study. Identification of native plankton for snook feeding.
***Location of work*:** Spawning grounds for *C. undecimalis* and *C. parallelus* Tabasco, Mexico.

***General methods*:** Phyto- and zooplankton will be collected from snook spawning grounds at the nearby Gonzalez River mouth. Plankton nets will be hauled for ten minutes using 25 feet-long boats at low speed. Samples will be fixed in buffered 4% formalin and analyzed under microscope. Snook larvae will be collected and dissected for stomach content. Identified species of plankton using both methods will be crossed to identify prey preferences.

Schedule (d):

		YR1 (mos.)			Project YR 2 (mos)			
		4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
Sample collection		x	x					
Plankton identification				x	x			
System setup, sample collection						x	x	
Plankton identification								x
Data analysis and preparation of reports and publications								x

***(e) Study*. Determination of gene expression of digestive enzymes during different life stages in common snook (*Centropomus undecimalis*) and fat snook (*C. parallelus*).**
Location of work: Tropical aquaculture laboratory facilities (UJAT).

***General methods*:** Wild larvae, juveniles and adults will be collected in such quantity that allows a minimum of 150 mg of stomach, intestine and pancreatic tissues. Sampling will be conducted after 12 hours of starvation for larvae and 48 hours for juveniles and adults. Fish will be sacrificed using a cold shock using iced water. Tissues will be collected, washed with distilled water, submerged in RNase inhibitor (RNA Later, Ambion, AM7020, Austin, TX, USA) and preserved until processing under liquid nitrogen.

***RNA extraction*.** Total RNA extraction will be conducted according the TRIZOL protocol (Invitrogen, Life Technologies SKU# 15596-018, California, USA). After this, RNA will be treated with DNase I (Deoxyribonuclease I, Amplification Grade, Invitrogen Cat. No. 18068-015 USA, Alameda, CA, USA) to eliminate genomic DNA. Retro-transcription will be conducted using the commercial kit Improm II (Promega, A3800, Wisconsin, USA).

***Primer design*.** Primers for trypsin, pepsin, lipase and amylase will be designed using gene sequences from other fish species – such as codfish (*Gadus morhua*), Atlantic salmon (*Salmo salar*) and black cod (*Paranotothenia magellanica*) registered in www.ncbi.nhl.nih.gov. For sequence analysis, multiple alignments, primer design, sequence assemblage we will use http://align.genome.jp/. Best amplification temperatures will be selected visualizing bands under ethidium bromide agarose gels. Bands will be recovered using the kit GENE CLEAN SPIN KIT (BIO 101 INC, California, USA) and then sent to Macrogen Inc. Korea for sequencing.

cDNA amplification: Amplification of cDNA will be conducted using the Thermocycler Icycler (BIO- RAD Mod. ICYCLER, California, USA) with temperature gradient and optimizing alignment temperature and Mg2+ concentration. PCR reactions volumes will be 50 μl, having 50 pmol of sense and antisense primers, 1 μl of cDNA, 0.5 U of Taq-polymerase (Invitrogen), 100μM of dNTP and 1 X o reaction buffer (Invitrogen): conditions for reactions will be: 30s at 95°C; 35 cycles (1 min each) at 95°C; 1:30s at 60°C; 2 min at 72°C; 7 min at 72°C; 4°C ∞. cDNA purity will be measured using a biophotometer (Eppendorf, Mod. 22331) having a double chain DNA as standard. Amplification products will be separated using agarose electrophoresis (A5054 Sigma-Aldrich, Missouri, USA) and then analyzed under a photodocumenter (Gel-Pro transiluminator, Mod. C-62, California, USA). DNA recovery will be conducted cutting the bands of interest with a sterilized scalpel, for purification, we will use the protocol for the kit GENE CLEAN SPIN KIT (BIO 101, California, USA). Amplified segments for PCR will be cloned according with the protocol for the kit TOPO TA CLONING (Invitrogen n° K4550-40, California, USA) utilizing E. coli Top 10F'competent cells and the plasmid pCR 2.1 as vector. Once cloned, plasmids will be obtained from the cells using the kit RPM (BIO 101 INC, California, USA). Samples will be sent for sequencing and homologies in PCR sequences bank.

***Quantitative PCR (real time)*:** Quantification of mRNA using real time PCR will be conducted using the protocol recommended by Applied Biosystems User Guides for Taqman®. This procedure will be conducted using a real time Thermocycler (Applied Biosystems, Abi Prism® 7000 Sequence Detection System, 4330087, California, USA). PCR reactions will be conducted using plates with 96 wells, under the following conditions: 1 cycle at 50°C for 2 min; 1 cycle at 95°C for 10 min; 40 cycles a 95°C for 15 sec; and 60°C for 1 min. Serial dilutions (0, 10, 100, 1,000, 10,000, 100,000 y 1´000,000) of the plasmid containing the gene inserts (50 μg ml-1) and the gene 18S rRNA (Applied Biosystems) will be used as endogenous control. For recognizing gene expression, reactions corresponding to unknown samples (M1D0-M16D30) will be conducted using cDNA with an approximate concentration of 1000 μg ml-1, of TaqMan® Universal PCR Master Mix (4331348 USA, CA) and the probe Taqman (4331348, Custom Taqman(R) Gene Expression Assay Service (TRYTG2007-TTD, USA, CA) specific for the genes found. Calculations will be conducted following the protocol User Bulletin #2 de ABI PRISM 7700 Sequence Detection System. Standard curves will be calculated using a linear regression model using threshold fluorescence values (Ct, Threshold cycle) and the log of the number of copies obtained (log Co) from the serial dilution analysis. The number of copies (Co) from unknown samples will be calculated as follows: [(CT-b value) m-1] where b= Y intercept and m = standard curve slope. The normalized Co value for trypsine for each sample will be determined diving Co from each gene between 18S Co´s. Each normalized sample will be divided by the calibrator (sample with the lowest expression). Anova tests will be conducted using normalized values for Co to determine significant differences for gene expression in the samples.

***Similarity analysis*:** Similarity analysis will be conducted contrasting the obtained sequences against known sequences from other species. Sequences will be obtained from GenBank/EMBL/DDBJ using the "SDSC Biology Workbench" system online. Several species will be used as references for first selection analysis. Sequence alignment will be determined calculating the percent of similarity and a dendogram will be constructed.

Schedule (e):

	YR1 (mos.)				**Project YR 2 (mos)**			
		4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
Sample collection		x	x					
Sample processing			x	x	x			
Gene identification						x	x	
Similarity Analysis								x
Data analysis and preparation of reports and publications								x

DEVELOPMENT AND DIVERSIFICATION OF SPECIES FOR AQUACULTURE IN GHANA

Indigenous Species Development/Experiment/09IND06PU

Collaborating Institutions & Lead Investigators

Virginia Polytechnic Institute & State University (USA) — Emmanuel A. Frimpong
Kwame Nkrumah University of Science & Technology (Ghana) — Nelson W. Agbo, Stephen Amisah

Introduction

Sub-Saharan Africa has abundant land and water resources, but these have not been tapped to increase aquaculture production significantly in global terms. Therefore, the Word Bank and its partners have sharpened focus on commercial aquaculture development in the region (World Bank 2007). Recent analyses of conditions needed for adoption and sustainability of growth of African aquaculture (Jamu and Ayinla 2003; World Bank 2007) have identified about a dozen factors some of which are: (1) perception of the value of fish as food and for generating income, (2) land ownership, ability to rent, or secure access to common property water resources, (3) increases in production intensities and efficiencies, (4) knowledge of technologies suited to available resources and conditions, (5) a widening of the range of production systems, (6) developing management technologies for indigenous species that target local niche markets, (7) putting more emphasis on marketing and processing of high value products, (8) institutional support (e.g., research and development, extension, supply of seed), (9) promotion of research on how aquaculture can respond to changing macroeconomic policies, and (10) acceleration of the disengagement of government from activities that can be best done by the private sector.

The foregoing factors are listed in the order that in our opinion roughly reflects both the inevitable and increasing need for involvement of public institutions at every step of the development process. Sub-Saharan Africa and, in particular, Ghana aquaculture development may have stagnated not because of a lack of involvement of public institutions in the past but because the roles of these institutions have not been applied in proportion to the needs. The World Bank's (2007) diagnosis of the problems of past failed aquaculture development programs in sub-Saharan Africa can be summarized as public institutions operating mostly at levels (1) - (3), where the private sector or public-private partnerships may do equally well with stronger public sector involvement at the higher levels of need. Jamu and Ayinla (2003) emphasized addressing problems from the perspective of production systems, culture species, marketing, and policy. In this proposed work, our focus will be on production systems and culture species. Jamu and Ayinla (2007) noted a relative lack of public sector research and development attention to alternative culture systems (e.g., cage culture) in Africa and recommended increased attention to alternative production systems while striving to increase intensity and production from the traditional earthen ponds. Likewise, the authors identified progress made in Nigeria and Egypt in the production of species other than the tilapias as dictated by local demands for those alternative species, leading to their recommendation of expansion of production of high-demand indigenous species for niche markets.

Aquaculture development should balance the quest for economic growth with biodiversity conservation and environmental impact concerns. "The challenge of sustainable aquaculture is to contribute to national objectives for economic development and food security while simultaneously addressing poverty reductions and environmental protection" (World Bank 2007). The development of alternative species with emphasis on indigenes provides guarantees against potential biodiversity degradation that could result from unbridled spread of aquaculture species.

In fact the USAID sees culture of indigenous species of high local demand as direct biodiversity conservation activity because this takes pressure off wild stocks (USAID 2005). Numerous opportunities exist for development of new species and expansion of the variety of production systems in Ghana. As a business model, diversification of species and systems provides a safety net and access to new markets for investors. Adoption of alternative productions systems should be dictated by economic and ecological considerations if the alternatives do not present clear relative disadvantages of environmental impacts.

The proposed work consists of two complementary investigations: Investigation #2 consists of literature studies and experiments that will lead to better understanding and improved and streamlined culture of three indigenous species (African bony-tongue *Heterotis niloticus*, a Claloteid catfish *Chrysichthys maurus*, and the African snakehead *Parachanna obscura*) that are not currently cultured on a commercial scale in Ghana. Together, these two investigations will produce and extend valuable insight not currently available to farmers, the private sector of Ghana, or government institutions. We expect the results to contribute to diversification and rapid acceleration of aquaculture development in Ghana and the sub-region.

Objectives

- Develop a profile of the ecological (trophic habits and habitat requirements) and life-history traits (growth, sites and mode of reproduction) and native distributions of *H. niloticus*, *C. maurus*, and *P. obscura*.
7. Conduct experiments to evaluate growth and feed conversion of *H. niloticus*, *C. maurus*, and *P. obscura* on formulated diets.
8. Conduct training in advanced experimental design, data management, and analysis for master's level students, AFCRSP project staff, and extension personnel.
9. Train current and prospective farmers on vital aspects of the culture of new species.

Significance

Selection of species for aquaculture development depends mainly on whether the purpose is commercial or subsistence (O'Bryen and Lee 2007). In Ghana, as in many parts of sub-Saharan Africa, the tilapias and the African catfish Clarias gariepinus were the main focus of development efforts in the early stages of aquaculture for both subsistence and economic purposes. However, there is a clear trend toward diversification on farmers' own initiatives. During the PIs recent [January 2009] tour of aquaculture facilities in Ghana, and results of currently ending AquaFish CRSP studies, it has become apparent that a dozen or more species of native fishes are being cultured besides the traditional tilapias and catfishes. Among these 'non-traditional' species, the African bony-tongue *Heterotis niloticus*, various species of mudfish *Chrysichthys* sp., and the African snakehead *Parachanna obscura* predominate. Farmers are eager to explain how they obtained seed from the wild and how the various species performed on their farms. Such anecdotal information is spurring the adoption of these species by other farmers. However, significant knowledge gaps exist because these species have not been studied well. For example, no one has yet determined exactly how farmers obtain fingerlings from nearby rivers and whether this is a sustainable practice, although we know that fingerlings for all species are currently available only from the wild.

The fact that farmers in Ghana are attempting to grow so many new species on their farms suggest that two of the major criteria to justify investing in the development of these species for aquaculture (O'Bryen and Lee 2007) are at least partly met: 1) the species being cultured must be important in the nutrition of farmers' families and local markets, and 2) supplies of these species from the wild are not sufficient to meet local demands. Other criteria that should be verified include 3) that these species possess life-history, trophic, and other ecological traits that make it feasible and economical for mass seed production and grow-out in ponds, and 4) minimal environmental risk is posed by these species in the localities where they are being cultured and where the culture of the species are likely to spread. Some scattered studies exist on these species,

including their native distributions (Paugy et al. 2003), economic importance (Dankwa et al. 1999), life-history and feeding habits, nutritional value, and use and performance as aquaculture species, especially in Nigeria. However, there can be significant regional variation in the response of these species to culture conditions. At least in the case of C. maurus, preliminary literature search suggests that virtually nothing is known or has been documented about the ecology of the species (e.g., see http://www.fishbase.org/Summary/SpeciesSummary.php?id=2441) in spite of the fact that the species could attain 510mm TL) almost twice the size of the relatively better studied and sometimes sympatric *C. auratus* (Paugy et al. 2003). Comprehensive literature reviews and experimental studies under conditions similar to the culture environment in Ghana would form the basis for developing appropriate technical guidelines for seed production and pond culture of these species in Ghana. Additionally, results would provide vital input for future economic analyses of mass production of seed and grow-out feasibility as well as markets for products of these emerging species.

Quantified Anticipated Benefits

- Increase in the number of well researched and viable freshwater aquaculture species in Ghana from 2-5.

10. Documented and accessible information on all known aspects of culture of *H. niloticus*, *C. maurus*, and *P. obscura*.
11. At least 15 students, project staff, and extension personnel trained in advanced experimental design and data management and analysis that would improve research capacity of HC in experimental aquaculture.
12. At least 20 farmers and 5 extension personnel trained in the culture techniques of *H. niloticus*, *C. maurus*, and *P. obscura*.
13. In the long-term, widespread and profitable culture of new indigenous species in Ghana with potential to spread improved culture practices of these species to other countries in the sub-region where those species are native.
14. The expected results would provide insights into diversification and competitiveness of US aquaculture development given that catfish, the largest US aquaculture industry, is facing strong competition from catfish imports from China and Vietnam.

Research Design & Activity Plan

Location

The study will be conducted in the Ashanti region of Ghana where working relationships have been established with many farmers through ongoing AquaFish CRSP projects. Experimental work will be conducted on Kwame Nkrumah University of Science and Technology Aquaculture farm and laboratory facilities, which include earthen ponds (hapas), aquaria, fiberglass, and concrete tanks. These studies are designed for execution at the KNUST with intertwined objectives of indigenous species development, renovation and productive employment of existing research facilities, and formal and informal training of students, extension personnel and staff.

Methods

Comprehensive literature reviews on H. niloticus, C. maurus, and P. Obscura will begin on all aspects of biology and culture of each of these species immediately at the start of this project. Online and print library facilities of Virginia Tech University will be accessible free of charge. Local and regional sources of published (e.g. undergraduate theses in regional universities), government department monographs and reports and anecdotal (including from farmers currently trying out the species) information about these species will be sought and integrated into secondary data analysis. This study will provide baseline data for identification and prioritization of research gaps for long-term development oriented research on the respective species.

The African bony-tongue *H. niloticus*, the Claloteid catfish *C. maurus*, and the African snakehead *P. obscura* will be obtained from local water bodies and/or fish farms that already have them. All of the fishes are endemic and indigenous species that have been in the rivers and streams across water bodies in Ghana for centuries, and undisturbed wild populations still exist in Ghana. Experiments with the species will be conducted in separate ponds to protect their genetic integrity.

Experiments
Crucial experimental studies executable in the time frame of this project will be a vital part of this investigation. Our experience indicates that careful nutritional studies are the most lacking in the region, even for the most well studied aquaculture species. It is therefore vital to establish solid nutritional baseline data which will be useful for farmers willing to brave large scale studies of the species in Ghana in their early development, and researchers interested in holding healthy brood stock for future studies on reproduction and growth in ponds.

Nutritional studies of the species will be initially on palatability/acceptability and digestibility of various (formulated) feeds using locally available ingredients to determine feed preferences, feed intake, and digestibility. The best feed(s) identified in earlier experiments for each species will be used for growth trials. Diet palatability/acceptability will be assessed subjectively by direct observation of fish behaviour and feeding responses and also by quantifying feed intake in tanks. This phase of the study will take approximately 6 weeks and will run concurrently for all three species. Digestibility trials will be conducted by using a modified settling column system similar to the Guelph system (Cho et al. 1985) for feces collection, and chromic oxide as a marker. Apparent digestibility coefficients (ADC) for the nutrients and energy of the ingredients/feeds will be calculated following the methods by (Bureau et al. 1999). Digestibility experiments will take another 4-6 weeks for each species depending on the rate of feces collection. This phase will also run concurrently for all species.

Growth experimental runs will be in hapas mounted in earthen ponds using the different formulated feeds (i.e. treatments) as identified through palatability/acceptability and digestibility trials. To evaluate their nutritive value in terms of growth, feed utilization, and body composition for the species. Experiments will be conducted under conditions suitable for each species as supported by literature reviews, and diets will meet the published nutritional requirements of each species (if available) or that of its congenerics as closely as possible. A diet with fishmeal will serve as a control in each species. Growth experiments will be conducted for 10-12 weeks.

Proximate analysis of dietary ingredients, feeds, fish and faeces will be carried out using AOAC 1990 protocols. Energy will be determined by using an Adiabatic Autobomb Calorimeter (Parr 6100, USA) with benzoic acid as a standard. Feeds will be formulated using feed ingredients locally available and meet as many of the screening criteria as possible. We anticipate that fishmeal and oilseed by-products such as; cottonseed meal, soybean meal, groundnut cake, groundnut husk, palm kernel cake and copra cake will be used as protein source and rice bran, maize bran as energy source.

A minimum of 3 experimental units (replicates) will be assigned to each diet and species combination. Because multiple hapas are mounted in each pond, randomized complete block designs with ponds serving as blocks will be employed to accommodate a large number of treatments and ranges of water quality as necessary. Subsamples in experimental units (i.e., number of individual fishes per experimental unit) will be determined by appropriate stocking densities determined through the initial trials. Juveniles of each species have a larger scope of growth and thus will be used in all experiments to provide as the greatest signals possible. All species will be obtained locally from as few different river systems as possible to reduce potential variance and confounding results due to different strains of species. Data will be analyzed

statistically using ANOVA and ANCOVA with independent contrasts; probability of type I error will be controlled at ≤ 0.10 and designs will target a power of ≥ 0.75.

Experiments and in-depth literature studies will constitute the basis of the theses of several MPhil students.

During the experimental studies in the summer of 2010, a one-week training workshop on advanced experimental design, data management and analysis will be organized in Ghana for project staff, students, and collaborating personnel of the extension services of the MOA-FI using the design of these experiments as case studies. Lessons will be given on data management using spreadsheets and statistical analyses of experimental data employing low-price and high-quality software such as Minitab and free online statistical software such as and R. This will be a vital part of student training and capacity building for Ghana aquaculture practitioners. This training will draw on the lead PIs expertise as a statistician. Upon completion of experimental studies, comparative analyses from experimental, and secondary data on H. niloticus, C. maurus, and P. Obscuraand the established aquaculture species O. niloticus and C. gariepinus) will be performed to determine some of the fundamental similarities and differences the relative promise of these non-traditional species as aquaculture species in Ghana. New finding will be disseminated in a training and workshop for farmers and extension personnel following completion of all studies.

Potential Risk of Investigation
The main risk to this investigation is if we are unable to obtain appropriate sized fingerlings and juvenile fishes at the appropriate times to run the respective experiments so that we lose time and not complete the project. To ensure this does not happen. We have identified several farmers who are currently trying the culture of these species and have been collecting fingerlings from rivers. We will use their indigenous knowledge, combined with our ecological understanding, to collect and hold sufficient numbers of each species for the entire year to ensure we have appropriate sized fishes when we need them. We have also spread the allotted time for experiments over approximately 1 year in the activity plan; although we have described experiments that should be accomplished in 6 months should everything go as planned. We know unexpected delays are inevitable and therefore additional 6 months is a large cushion to ensure that we can resolve problems that arise and still complete the project on time.

Schedule: Start date: October 1, 2009 End date: September 30, 2011

Activity/Month	O-D 09	J 10	F 10	M 10	A 10	M 10	J 10	J 10	A 10	S 10	O 10	N 10	D 10	J-S 11
Literature Reviews	x	x	x	x										
Palatability/acceptability experiments		x	x											
Digestibility experiments				x	x									
Growth experiments and proximate analyses						x	x	x	x	x	x	x	x	
Experimental design & analysis workshop							x	x						
Informational/training workshop														x
Report and student theses preparations and defenses													x	x

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TOPIC AREA
QUALITY SEEDSTOCK DEVELOPMENT

❖

NILE TILAPIA BROODSTOCK SELECTION, SEED QUALITY AND DENSITY-DEPENDENT GROWTH IN THE PHILIPPINES

Quality Seedstock Development/Experiment/09QSD01NC

Collaborating Institutions & Lead Investigators

North Carolina State University (USA)	Russell Borski
Central Luzon State University (Philippines)	Remedios Bolivar Emmanuel Vera Cruz
GIFT (Genetically Improved Farmed Tilapia) Foundation International, Inc (Philippines)	Hernando Bolivar

Objectives

1. Determine if physiological and/or behavioral responses to stress can be used in the selection of broodstock with reproductive advantage in Nile tilapia (Oreochromis niloticus).
2. Examine the effect of broodstock social condition on seed production and fingerling growout performance of tilapia.
3. Investigate the effect of stocking density on the growth, gene expression of hepatic insulin-like growth factor-I (IGF-I), and stress responsiveness of tilapia.

Significance

The quantity of Nile tilapia culture has risen significantly in the Philippines, by almost 4% annually, with a 33% increase between 1997 and 2002 (BFAR 2006 www.bfar.da.gov.ph). To support the growing tilapia industry, there is a need to provide year-round, high-quality seed that can be widely distributed at reasonable costs to tilapia farmers. This can be achieved through better broodstock quality, increased hatchery development and enhanced technologies for consistently high-quality seed production. Here, we aim to assess seed production efficiency in *O. niloticus* as a corollary of broodstock response to social stress. In the aquaculture and breeding environment, fish species such as the tilapia may develop various problems associated with physical, chemical and social stressors (Binurameeh et al. 2005; Chandroo et al. 2004), including impaired reproductive performance. Exposure to stressful conditions can reduce egg size and sperm count, cause ovarian resorption of eggs, delay ovulation, increase developmental abnormalities and reduce size and survival of offspring (Maeda and Tsukumura 2006). The effect of stress on fish is not only determined by the aversive character of the stressor but by the fish's cognitive appraisal of the stressor (Koolhaas et al. 1999). In order to optimize reproductive performance of valuable broodstock and improve seed production, stress must be limited and fish selected for based on their ability to better cope with stress. Breeding is largely driven by social behavior and an understanding or ability to predict dominance, or select breeders with reduced stress responsiveness, can improve hatchery and breeding programs.

The physiological and behavioral responses to stress may be used to select broodstock with reproductive advantage. The variable color pattern in fish may signal a behavioral strategy, enhance camouflage, improve communication, and confer reproductive advantage (Korzan et al. 2008). In *O. niloticus*, eye color is associated with social status (Volpato et al. 2003; Vera Cruz and Brown 2007). In our previous studies, eye color was found to be a predictor and consequence of social rank (Vera Cruz et al. 2009). However, no study to date has examined if eye color pattern is related to behavioral stress responses in *O. niloticus*; for instance, that associated with appetite

inhibition during isolation. Moreover, to our knowledge, no study has been done in tilapia to examine if reproductive performance and seed quality is affected by broodstock social rank and/or condition.

To seek higher incomes, farmers in the Philippines are increasingly rearing fish at higher stocking densities in cages, concrete tanks and ponds. Filipino farmers are interested in knowing the stocking densities that yield the best growth rate and minimize mortalities under more intensive culture conditions. Some have noticed significant mortalities in cages, likely due to overcrowding. It is possible that the farmers are stressing, and therefore, reducing the growth potential of fish at higher densities. At lower densities behavioral or social hierarchies may dominate and limit growth potential. Therefore, an additional aim of this investigation will test the effects of stocking density on the growth, survival, and hepatic gene expression of IGF-I, a proxy for growth in *O. niloticus* and other fishes (Picha et al. 2008), and on secretion of cortisol, a primary hormone involved in the stress response (Bonga et al. 1997).

Physical and social stressors can evoke non-specific physiological responses in fish (Barton 2002). These responses are considered adaptive to enable the fish to cope with the stressful condition and maintain its homeostatic state. If the stressor is severe or long-lasting and the fish is not capable of regaining homeostasis, then the responses themselves may become maladaptive and threaten the fish's health and well being (Barton 2002). Physiological responses to stress can be grouped as primary, which include endocrine changes such as measurable levels of IGF-I (Vera Cruz and Brown 2007) and circulating cortisol (Barcellos et al. 1999) and secondary, which includes changes in features related to metabolism (i.e hepatic phosphoenolpyruvate carboxykinase and pyruvate kinase activities and bile retention) and immune function (Binuramesh et al. 2005). Stressful condition was found to significantly increase circulating cortisol levels (Bolasina et al. 2006), hepatic phosphoenolpyruvate carboxykinase activity (Dibattista et al. 2006), and bile retention (Early et al. 2004), but it significantly decreases hepatic IGF-I levels (Vera Cruz and Brown 2007). A well-characterized physiological consequence of social stress and excessively high densities is a reduced growth rate (Sloman et al. 2000). Excessively high stocking density is a stressful condition and decreases fish growth (Björnsson 1994), increases plasma cortisol levels (Bolasina et al. 2006) and decreases survival (Sodebergg and Meade 1987). Social stress and the formation of feeding hierarchies, are also density dependent (Vera Cruz et al. 2006). Differential alterations in growth rate between dominants and subordinates are attributed more to behavioral changes (*i.e.* feeding) as transduced by physiological regulators (*i.e.* IGF-I level) but may also be due to changes in metabolism (*i.e.* hepatic phosphoenolpyruvate carboxykinase activity and bile retention) (Earley et al. 2004; Dibattista et al. 2006; Vera Cruz and Brown 2007). The growth-promoting actions of growth hormone (GH) are mediated through induction of IGF-1 (Degger et al. 2000; Picha et al. 2008). Subordinate or stressed fish is characterized by larger somatostatin-containing neurons in the hypothalamus, which leads to reduced production of pituitary GH (Hofmann and Fernald 2000). Due to this, subordination depresses hepatic IGF-I levels while dominance stimulates its production through greater secretion of pituitary growth hormone (Vera Cruz and Brown 2007). Here, we aim to assess densities that yield good growth and survival while simultaneously evaluating the use of IGF-I and cortisol as markers of growth and stress, respectively. An assessment of hepatic IGF-I mRNA in these studies will further validate its usage as a field indicator of growth status in tilapia (Vera Cruz et al., 2006; see Picha et al. 2008). Cortisol will be evaluated as an index of stress that could prove useful as a tool to evaluate poor environmental condition. Building biotechnology capacity in the Philippines and development of these bioindicators can expedite the evaluation of environmental parameters that best promote growth (or limit stress) in tilapia, with limited need for long and costly growout trials.

Quantified Anticipated Benefits

1. We will establish if physiological and behavioral responses to stress in tilapia can be used in selecting broodstock with reproductive advantage. Results could be used in future

selective breeding programs for the development of tilapia lines with reduced stress responsiveness and increased tolerance to the various breeding environments.
2. Hatchery operators in the Philippines, the U.S., and other countries could gain practical methods for screening tilapia broodstock (appetite and eye color) with low stress responsiveness and higher fecundity.
3. The work will provide research training and educational experiences to two graduate and two undergraduate students at the Central Luzon State University in the Philippines.
4. This investigation will provide information on the stocking densities that produce the highest tilapia yield (growth and survival) under more intensive culture conditions.
5. Measures of IGF-I gene expression will allow further testing of its suitability as an indicator of growth in tilapia and cortisol as an index of poor habitat quality. Development of growth and stress biomarkers addresses a USAID high priority area of establishing suitable biotechnologies for the advancement of aquaculture and can be used to optimize environmental parameters for culture of tilapia in the Philippines, U.S., and other countries.
6. The research will provide better management technologies to fish farmers, hatchery and nursery operators in the Philippines.

Research Design & Activity Plan

Location

This investigation consists of a series of four studies, which will be carried out at the Central Luzon State University (CLSU) and North Carolina State University (NCSU).

Methods

1. The influence of duration of behavioral stress response on social dominance in tilapia

This study aims to investigate whether the outcomes of competition for social dominance among *O. niloticus* individuals can be predicted by evaluating the duration of appetite inhibition after transfer to isolation. In addition, it also investigates if eye color pattern (ECP) is related to the duration of behavioral stress response such as appetite inhibition. The concept is to enable the selection of those broodstock that show dominance and hence will have and convey reproductive advantages. Physical and behavioral markers such as eye color pattern (ECP) and appetite, respectively, are features that could be easily assessed by hatchery operators in selecting the best mating pairs for seed production.

Forty all male tilapia of similar sizes, will be individually weighed and isolated at random and introduced to aquaria (1 fish per aquarium) for ten days. The time before first acceptance of food will be monitored for each fish. These data (i.e. weight and duration of inhibition of feeding) will be used for the assignment of the opposing fish, in which the two opposing fish will have similar weights and one of the opponent fish should have longer period of appetite suppression than the other. During the isolation period, the ECP of the fish will also be measured (based on Volpato et al. 2003). The fish will be fed, once a day, at 1% of the body weight. Immediately after the isolation period the fish will be paired. To ensure that there is no familiarity with home location, fish in a pair will be introduced to a new aquarium. The period from time of the introduction of the fish up to the time of first agonistic attack will be recorded. The total number of agonistic attacks during the interaction will be recorded along with changes in ECPs. We also will monitor the duration of social interaction before establishment of social status. Twenty-four hours after the establishment of social hierarchy, the ECPs and individual body weight of the fish will be measured. All fish will then be fed to satiation once daily and after 14 days of pairing, ECP and body weight of each fish will be measured. Ten dominant and subordinate fish will be collected for quantification of hepatic IGF-I according to our previously described methods (Vera Cruz et al. 2006). The fish specific growth rate (SGR) will be calculated to assess whether subordination reduces the growth rate and hepatic IGF gene expression (IGF-I mRNA levels). Social stress is known to reduce growth rate in both dominant and subordinate fish, but lower growth rate observed in subordinates can be attributed to changes in metabolism (i.e. higher hepatic phosphoenolpyruvate carboxy kinase activity and bile retention) (Vera Cruz and Brown 2007;

Dibattista et al. 2006; Early et al. 2004). Frequency difference will be analyzed using Binomial test. Linear relationships of aggression, eye color pattern, and duration of social interaction and social response will be assessed using linear regression and Pearson correlation coefficient. Differences in growth and IGF-I mRNA expression among groups will be analyzed using Student's-t-test.

Null Hypothesis: There is no effect of social response to stress, measured by appetite suppression duration and ECP, on social rank and specific growth rate and IGF gene expression of Nile tilapia.

2. Effect of broodfish potential social condition on seed production of Nile tilapia

Two social groups of broodstock fish (i.e. potential dominant and subordinate) will be evaluated for seed production yield in two breeding cycles in net enclosures during the wet (July) and dry (April) seasons. There will be two treatments in this study: potential dominant broodstock and potential subordinate broodstock. Potential social condition of the breeders will be assessed using physiological and/or behavioral stress responses (based on the results of study 1). Breeding will be done in hapas installed in ponds. The sex ratio will be maintained at 1:3 male:female and fish densities at 4 fish m^{-2}, that typically used for breeding tilapia. Eggs from mouthbrooding females and fry will be collected after 14 days from initial stocking of the breeders. Egg quality in terms of size, shape and color will be recorded. Eggs will be incubated artificially to the swim-up fry stage and included with fry counts. Total fry numbers will be regarded as an index of seed production by each treatment. Water quality will be monitored throughout the experiment to ensure rearing consistency across groups. Each treatment (social group) will be carried out in triplicate. Differences in mean fry yield will be analyzed by Student's-t-test.

Null Hypothesis: There is no effect of broodstock social condition/group on fry yield, and egg quality in terms of egg size, color and shape.

3. Effect of social condition of broodfish on the grow-out performance of Nile tilapia fingerlings

The objective of this study is to compare the growth performance of Nile tilapia fingerlings produced from two social groups; potential dominant and potential subordinate broodstock. Sex-reversed male fingerlings (0.35 g) from the two social groups raised in hapas from the fry stage will be stocked in 500 m^2 ponds at a density of 4 fish m^{-2}, in triplicate. Growth (length and weight) will be monitored under controlled conditions at monthly intervals (subsampling 50 fish) over the four-month growout cycle. Fish will be fed daily using a progression of starter and growout feeds (Bolivar et al. 2006). Fish will be harvested after 4 months for total biomass, number, and survivorship determinations. Weights and lengths will also be obtained from 100 randomly selected fish. Differences in growth parameters among fish produced from different social classes of broodstock will be assessed by Student's t-test.

Null Hypothesis: There is no effect of broodstock social condition/group on growout performance variables in tilapia.

4. Effect of stocking density on growth, stress responsiveness, and IGF-I gene expression of Nile tilapia in hapas and tanks

This experiment assesses the effects of stocking density on *O. niloticus* growth and survival, hepatic IGF-I gene expression and circulating cortisol levels, the latter to evaluate potential stress responses associated with specific densities. We will employ densities that fall within and exceed the range most commonly used in more intensive cage and hapa culture in the Philippines (El Sayed 2006): (a) 2.5 kg m^{-3}; (b) 5 kg m^{-3}; (c) 10 kg m^{-3} and (c) 15 kg m^{-3}. All-male sex reversed tilapia (~50 g) will be maintained in triplicate in net enclosures or hapas installed in ponds under the three densities. Fish will be maintained for a period of one month. The fish will be fed twice a day at 2% of the body weight. Fish mean weight will be obtained during the start of the experiment, after 2 weeks, and after 1 month. During monitoring of fish weight, the number of surviving fish will be determined and 6 sample fish will be collected for quantification of hepatic IGF-I according to our previously described methods (Vera Cruz et al. 2006). At the end of the study fish will be rapidly captured, sedated and blood drawn from 8 fish per treatment-replicate for the quantification of plasma cortisol levels (Dean et al. 2003). Cortisol increases in

tilapia during stress, and its measure should help establish whether density-dependent growth inhibition might result from stress (Dean et al. 2003). Water quality (weekly) and dissolved oxygen (biweekly) will be monitored. Oxygen levels will be maintained at > 4 ppm in ponds through water exchange if necessary. Parallel studies will be conducted in tanks at NCSU to establish whether density-dependent responses occur similarly in tanks, including in closed-recirculating systems used for tilapia culture in the USA. For semi-intensive tank studies we will use a higher range of densities of 5, 10 and 30 kg m^{-3} with supplemental pump driven aeration. Standard water quality parameters and dissolved oxygen will be measured throughout the studies. Hepatic IGF mRNA will be quantified in the host country and at NCSU and cortisol at NCSU according to our previously described procedures (Dean et al. 2003; Vera Cruz et al. 2006). Differences in growth, survival, IGF-I mRNA, and cortisol will be analyzed by one-way ANOVA.

Null Hypothesis: Stocking density does not alter growth performance, hepatic IGF-I mRNA, or cortisol levels in tilapia

Schedule

January 2010 – June 2010 – Studies 1 and 2
June 2010 – December 2010 - Studies 2 and 4
January 2011 - June 2011 – Studies 3 and 4
July 2011 – September 2011 – Complete analyses, write technical report and CRSP final report

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SUSTAINABLE INTEGRATED TILAPIA AQUACULTURE: AQUAPONICS AND EVALUATION OF FINGERLING QUALITY IN TABASCO, MEXICO

Quality Seedstock Development/Experiment/09QSD02UA

Collaborating Institutions & Lead Investigators

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Objectives

1. To build three demonstration aquaculture – agriculture units in indigenous communities.
2. To evaluate the success of local farmers adopting multi-use concepts to grow fish and plant crops.
3. To provide an enterprise model documenting the cost – benefits of the integrated system.
4. To compare at least five different tilapia strains used in Southeastern Mexico.
5. To provide a protocol for tilapia strain evaluation based on growth and economic variables.
6. To provide objective information for farmers to help decide which strains produce best results.

Significance

Conservation and multiple use of water has become an important practice, even in parts of the world with large natural water resources. Adopting water conservation principals, however, requires a strong cultural education component. In this regard, multiple institutions must cooperate with the common goal of sharing information, ideas, and local cultural practices in which to develop water re-use practices. The sharing of cultural knowledge and development of best management practices is necessary to establish community support as well as monitoring protocols needed for long-term success. Water conservation efforts are readily adopted, especially in developing and at risk regions of the world, because of the demonstrated economic and environmental benefits. One area in which a greater level of cooperation and social-economic development can be achieved through water re-use efforts is in integrated aquaculture.

The effluents from aquaculture have been shown to contain the necessary ratios and amounts of nutrients for many crop plants (Rakocy et al. 1993). Thus, significant economic and environmental benefits can be achieved by linking aquaculture and crop irrigation, as the environmental pollution from aquaculture is converted to a valuable source of fertilizers. This translates to a value-added process by which the nutrient laden effluents are converted to profitable plant biomass. A specific case has been identified for the proposed project with which to demonstrate the concepts of implementing water re-use concepts in indigenous local communities through the cooperation of multiple institutions and rural farmers. The Universidad Juarez Autonoma de Tabasco (UJAT) has already developed a partnership in aquaculture with several indigenous communities during the Condor-Eagle Project jointly supported by the Aquaculture CRSP and Heifer International. The proposed project will augment past efforts towards community based aquaculture, with the development and implementation of integrated agriculture- aquaculture practices. This project will provide a unique outlook on how water re-use in aquaculture-agriculture systems facilitate social-economic development. Determining the degree to which the system improves household income is an especially important aspect of adoption.

On the other hand; fingerling quality has become a significant concern among tilapia farmers in Southeastern Mexico during recent years. The problem goes to the basics, since several fingerling vendors are introducing fish at a lower price; however, there is no evidence that farmers are buying good quality fish, neither the effectiveness of the masculinization treatment used. Members of the Association of Tilapia Producers of Tabasco have expressed their concern to the personnel of the Tropical Aquaculture Laboratory (UJAT) regarding bad quality fingerlings. This low-quality product is mainly perceived as low growth and low survival. There are also concerns that the "purity" of the line sold is not trustable. Some fingerling retailers assure they are selling "GIFT", "YY males", "Chitralada", or Rocky Mountain" strains besides the local lines produced either by the State government ("Tabasco" line -supported through two consecutive A-CRSP projects-) or some private hatcheries ("Stirling").

In Latin America, broodstock and seed supply have been identified as one of the major constraints to production increases. In the 2001 expert panel meeting organized by the PD/A CRSP, inadequate availability and quality of fry (and broodstock) were listed as a researchable priority. Part of the problem was solved by supporting a line selection program that allowed the formation of the "Tabasco line" that supports the fry production in the State Hatchery "Mariano Matamoros". This is still an ongoing project supported mainly by the Tabasco Government and UJAT. However, the production of this hatchery is primarily used for restocking lagoons or ponds were the farmers do not require single sex populations (the government does not produce masculinized fingerlings). Some private farms have acquired the "Tabasco line" and they sell the masculinized fish. In the region, tilapia culture has become the principal aquacultural activity. Unfortunately, the introduction of different lineages of unknown origin and the lack of growth performance information has created disappointment and uncertainty. It is important to define a strategy to produce reliable information despite the origin of the fish. It is possible that the strains are originals, but the environmental conditions under which they were created may not favor performance under climatic conditions for Central America.

To help farmers in Southeastern Mexico solve these speculations, we propose to conduct an objective, unbiased experiment to contrast growth performance, time to reach market size (300 gr), survival, total biomass and cost of production. With this information in hand, farmers will have information to base their decisions and purchase the fingerlings based either in cost of production or growth performance.

Quantified Anticipated Benefits:

The communities with the demonstration projects will have access to fresh fish and nutrient enriched water that will be easily delivered to vegetable gardens. Effluents that are currently discharged to a local river will be diverted to irrigate local crops. This will increase food reserves and economic stability in the rural communities. We also expect that there will be improvements in household welfare and reduction of overall poverty.

Several graduate students will also be supported as part of this work. Students will take part in and contribute to a multi-disciplinary study linking water re-use, integrated aquaculture, and social-economic development. Upon completion of the community based project, these students will be well equipped to continue investigations not only in aquaculture, but in community development programs throughout the world.

Community leaders will be consulted regarding the manner in which the project will be managed after the system is constructed. Researchers will also work with the community leaders to establish data collection procedures. The long-term ties with the communities, developed through this project will be useful for establishing a readily accessible database in which to eventually contribute data from other development sites around the world.

Tilapia producers in Southeastern Mexico will have access to objective information that will support their decisions to purchase tilapia fingerlings. In Tabasco there are at least 5,000 subsistence farmers and medium-scale producers that will benefit from this information. We will also work with extension professionals from state and federal fisheries departments to share the findings and extend this information to the hatcheries and farmers.

The YY technology is also specifically intended to produce only male fish. The expectation with the YY fish is that the male fish grow more rapidly with a better feed conversion ratio. This serves to improve profitability and has the added benefit that the opportunity for escaped fish to form feral populations is greatly reduced.

Outreach will include presentations at local aqua-farmers meetings and a workshop on campus for the hatchery professionals in the state. Results will also be posted on the UJAT Aquaculture Website. Even rural farmers are increasingly able to access web based information. Special efforts will be made to provide outreach to women and the least educated farmers. One of the female aquaculture graduate students from UJAT is a native of these communities and speaks the local dialect . She has already offered to assist with the training and extending invitations to women in the community.

The potential benefits to the US include reduction in poverty in the indigenous community, reducing the potential for economic migration and an improvement in the food safety of vegetables and fish that might eventually make the way to US consumers.

Research Design & Activity Plan

(a) Demonstration and Evaluation of an Integrated Aquaculture — Agriculture System for Indigenous Farmers in Tabasco, Mexico

1. Location of work: Tabasco, Mexico
2. Methods - Experiment.

Two graduate students from UJAT will be recruited to work on the project as part of their M.S. projects. One will supervise the installation, initial operation of the system, and monitoring of community involvement. The second student will focus on the enterprise budget and evaluation of changes in household income. One of the communities already has a small aquaculture operation in place. The water from this site is currently being discharged into a river. However, as part of the proposed project, the effluent will be redirected to an adjacent plot which will be fenced and cultivated. Irrigation using a modified drip system will be installed to deliver effluent containing suspended and dissolved solids from the aquaculture tanks. Similar integrated systems will be developed in other rural communities in the area. The systems will be stocked with either, native cichlids, alligator gar, or tilapia, depending on the local preferences and availability of fingerlings from the UJAT hatchery.

Economic data will be collected by conducting a survey of the farmers involved. Information will be evaluated as a perceived benefit of the integrated systems to the farmers' source of income. The ease of set-up and maintenance will also be evaluated in line with the success of the operation. Long term data on costs and benefits of the operation will be input into an enterprise budget. These results will be documented in both M.S. theses, in reports for the AquaFish CRSP, and the peer reviewed literature.

Schedule (a)

	YR1 (mos.)			Project YR 2 (mos)			
	4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
Meet with community leaders to finalize location of aquaculture and irrigation aspects	x						
Purchase equipment and begin installations	x						
Stock tanks and prepare growing system	x						
Begin data collection	x						
Begin vegetable harvests		x					
Begin fish harvests		x					
Continue surveys of involved farmers		x					
Prepare year one report			x				
Begin second year of operation				x			
Continue data collection and growing fish and vegetables				x	x	x	x
Prepare final reports							x

(b) Evaluation of Different Tilapia Strains used in Southeastern Mexico and Incorporation of a Pure GIFT Line as Reference to Determine Quality of Tilapia Fingerlings.
Objective 1: To compare at least five different tilapia strains used in Southeastern Mexico.

Experiment/Hypothesis 1. All strains will show same growth performance.

Test species: Nile tilapia (*Oreochromis niloticus*).

General methods: Fingerlings will be purchased anonymously from different hatcheries and/or retailers. Target size will be one inch (total length; TL). Fish will be obtained (February-March, 2010) allowing only one week of difference between batches. However if differences in TL are observed, initial length of the batch will be blocked in the statistical analysis. Fish will be maintained in mosquito-mesh hapas for one month to allow acclimation to pond conditions and determine if the batch is disease-free. To do this, a batch of fish will be sampled for most common bacterial infections (*Streptococcus, Trichodina, Columnaris,* or *Aeromonas*), ich disease (*Ichthyophthirius multifilis*) and parasites. Samples will be taken and analysed by the personnel of the Aquatic Sanitation Laboratory (UJAT). Once fish have been screened and acclimated, all strains will be used for experimentation.

Nucleus Breeding Center for GIFT Tilapia
World Fish has offered to assist UJAT to become a nucleus breeding center for GIFT in Eastern Mexico. The operational plan will be to bring 30 individual fish from each of the eight parental lines of the GIFT program from other parts of Mexico to Villahermosa, Tabasco. These lines would be maintained at UJAT and used to creat the GIFT fish for the evaluation and later used to provide fingerlings to the commercial industry either as fingerlings or as broodlines for the hatchery sector.

Treatments and replications: Five thousand fingerlings will be obtained anonymously from five different commercial hatcheries, the fish from the GIFT line (5,000) will be obtained from the Nucleus Breeding Center, and the fish from the Tabasco line (A-CRSP supported) will be obtained from the Mariano Matamoros Hatchery. The experiment will consist of seven

treatments (lines). Three thousand fish from each line will be randomly selected and placed in 2x1x1.2 mosquito mesh hapas, at a density of 1,000 fish per hapa (three replicates per strain). The remaining 2,000 fish will be used for screening diseases and parasites. Fish will be grown for two months in these hapas. After this period, 500 fish (from each hapa) will be selected based on best size and moved into three 2x1x1.2 floating cages with one inch mesh size. Fish will be grown for four more months (n=3/line; N=21).

Sampling schedule: Fish in each replicate will be sampled monthly during the six-month period of experimentation, total length and weight will be measured from a subsample of 30 fish in each replicate. At the end, all fish will be measured and weighed.

Feeding regimes and water management: Fish will be fed three times a day using 5% of total biomass. The amount of food will be adjusted monthly. Ten percent of the water in the ponds were hapas and cages are located will be replaced at least once a week.

Endpoints and statistical analysis: The experimental design contemplated for this experiment is a randomly blocked design. At least two factors are considered to be blocked (average size at the beginning of the experiment and date of initiation). We contemplate that these two factors may vary based on fingerling availability in hatcheries; therefore they should be blocked at the experimental design phase. The response variables (Length and Weight) will be tested to determine if the assumptions for parametric analysis are met; if so, contrasts will be performed using ANOVA, otherwise data will be transformed to meet the requirements. Total biomass will be compared using an ANOVA test and Survival results will be compared among treatments by Chi square test using contingency tables.

Experiment/Hypothesis 2. The best three strains will perform equally at the farm level.

Treatments and replications**:** The best three performing strains will be selected and tested in a commercial tilapia farm in Tabasco. We will sign an agreement between UJAT and a commercial farm in order to test growth performance among these three strains. Fingerlings will be obtained under A&F-CRSP project and the farm will be requested to pay all expenses related to the experiment (feeds, labor, electricity, etc.). At the end of the experiment UJAT will use all the information obtained and the farmer will be able to sell the biomass produced. The number of fingerlings to be purchased will depend on the size of the system used; an estimate of thirty thousand fish per strain will be stocked in 50 x 20 earthen ponds (three replicates per strain), at a density of 10,000 fish per pond. Fish will be grown for six months.

Laboratory and Pond Facility. The State government officials responsible for the Mariano Matamoros Hatchery have set aside four concrete ponds (200 m2), two concrete ponds (1,000 m2), and two grow-out earthen ponds (2,000 m2) for UJAT's Tilapia line comparison investigation. If needed, more ponds can be used at the hatchery.
Universidad Juárez Autónoma de Tabasco (DACB). Eighty 2x1x1.2 (2.0 m3 under water) mosquito-mesh floating cages for fry grow-out. One hundred 2x1x1.2 half-inch mesh size floating cages, and one hundred and twenty 2x1x1.2 one-inch mesh size floating cages for fingerling grow-out.

Sampling schedule**:** Fish in each replicate will be sampled monthly during the six-month period of experimentation, total length and weight will be measured from a subsample of 100 fish in each replicate.

Feeding regimes and water management: Fish will be fed three times a day using 5% of total biomass. The amount of food will be adjusted monthly. Ten percent of the water in the ponds will be replaced at least once a week.

Endpoints and statistical analysis: The response variables (Length and Weight) will be tested to determine if the assumptions for parametric analysis are met; if so, contrasts will be performed using ANOVA, otherwise a Kruskall-Wallis test will be performed. Total biomass will be compared using an ANOVA test and Survival results will be compared among treatments by Chi square test using contingency tables.

Objective 2: To provide a protocol for tilapia strain evaluation based on growth and economic variables.

Activity. Based on the experiences and results, a performance protocol for tilapia assessment will be developed and published. Using all the results obtained, a performance index will be constructed using diseases, parasites, growth, and expenses as variables in the model.

Objective 3: To provide objective information for farmers to help decide which strains produce best results

Activity. Results from the two experiments will be published in different formats. A) A technical report will be printed and made available to farmers that require the information. B) The results will be uploaded in the Biological Sciences Division (UJAT) webpage. C) Results will be presented in local, national and international meetings. D) A scientific paper will be published.

Schedule

	YR 1 (mos)			Project YR 2 (mos)			
	4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
Identify major fry retailers in Southeastern Mexico	x						
Initiate cleaning and preparation of ponds for experimentation	x						
IGIFT broodstock from state hatcery	x						
Purchase fry from different suppliers	x						
Stock tanks and prepare growing system	x						
Begin grow-out trials		x					
Begin fish harvests				x			
Prepare report				x			
Grow-out trials at the farm level					x	x	x
Workshop for farmers describing results							x
Workshop for hatchery managers describing results and process for obtaining genetic material							x
Prepare final reports							x

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DEVELOPMENT OF POLYCULTURE TECHNOLOGY FOR GIANT FRESHWATER PRAWNS (*MACROBRACHIUM ROSENBERGII*) AND MOLA (*AMBLYPHARYNGODON MOLA*)

Quality Seedstock Development/Experiment/09QSD03UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA)	James Diana
Bangladesh Agricultural University (Bangladesh)	Md. Abdul Wahab
Shanghai Ocean University (China)	Liu Liping

Objectives

1. To compare growth and production performance of manually segregated all-male giant freshwater prawns with mixed-sex and all-female culture in pond systems;
2. To evaluate the effects of adding mola at different densities on pond ecology, growth, yield, and survival of giant freshwater prawns in polyculture;
3. To investigate the effects of selective harvesting and size grading on prawn production in polyculture of all-male giant freshwater prawns and mola.

Significance:

Bangladesh is rich in inland waters, which are suitable for growth of many species of freshwater prawns including giant freshwater prawn (*Macrobrachium rosenbergii*). FAO statistics (FAO 2000) indicate that the production of farmed giant freshwater prawns in Bangladesh had reached a substantial 48,000 mt by 1998, placing the scale of its freshwater prawn farming industry second only to that of China (New 2000). Due to the importance of freshwater prawns as an export product, the government had declared prawn cultivation to be of primary industry status in an effort to boost production (DoF 2003). A recent survey showed that annual yields from extensive ponds are in the range of 300-600 kg/ha (Asaduzzaman et al. 2006a), which is low compared to neighboring countries. Thus, efforts should be made to increase freshwater prawn production in order to contribute to the national economy.

The Aquaculture CRSP worked extensively with Bangladesh Agricultural University on aquaculture issues important to that country. The location, focus, and personnel at BAU are perfect to renew this collaboration to the benefit of BAU and AFCRSP. Therefore, we propose this study to renew our collaboration.

Monosex all-male culture may be one means to increase giant freshwater prawn production. Bangladesh faces dual challenges of feeding its own people and increasing export earnings through development of new products. Culture of freshwater prawns for the export market and the small fish mola (*Amblypharyngodon mola*) in the same ponds for household consumption may be an innovative option. Mola and prawns could be cultured together, so that farmers have the opportunity to harvest small fish throughout the year, and family members can consume mola without affecting their cash crop. Mola can also improve the culture environment for prawns. Most freshwater prawn farmers face problems with oxygen deficiency, particularly during phytoplankton blooms, which are mainly due to wastes derived from high protein diet (Asaduzzaman et al. 2005). Since mola can consume excess algae, they may lower nocturnal respiration and increase oxygen levels at dawn, thus providing a good ecological balance in polyculture.

Attempts have been made to apply all-male production to crustacean culture (Sagi et al. 1997). The first attempt at monosex culture of giant freshwater prawns was done in a small-scale, intensive cage culture system (Sagi et al. 1986). All-male population production was 473 g m^{-2} in

150 days, whereas all-female and mixed populations produced 248 and 260 g m^{-2}, respectively. In a similar study conducted in Bangladesh, gross production of prawns was 710 and 594 kg ha^{-1} in all-male and mixed-sex culture systems, respectively, over 112 days (Asaduzzaman et al. 2006b).

Fujimura and Okamoto (1972) first recommended the periodic removal of larger, faster-growing animals in order to reduce competition for resources and enhance growth rates among the remaining prawns. This technology has been used in other countries such as Thailand, and could be adapted to Bangladesh as well. The size grading of nursed juvenile prawns prior to stocking has been reported to yield higher growth and higher profit. Income from the large size prawns has been found to be nine times as great as that obtained from small prawns after a short grow-out season of 97 days (Karplus et al. 1987). There was a 22% to 26% increase in weighted profit because of size grading following 135 days of grow-out (Daniels and D'Abramo 1994). The only study on size grading in the tropics was carried out during ten months in the Coconut channels of southern India, but it resulted in very low survival rates of all tested groups (< 30%). However, the largest prawns at harvest were twice as large as average prawns, and their survival was twice as high (Ranjeet and Kurup 2002). Bangladesh is ideally suited to benefit from early size grading operations at stocking, due to its long grow-out season.

Thilsted and Hassan (1993) studied the nutritional value of indigenous small fish and cultured large carps in Bangladesh and showed that the content of essential nutrients, particularly vitamin A, differed dramatically between species. Small fish species like mola was shown to be a very valuable vitamin A source. Zafri and Ahmed (1981) reported that mola contained 200 IU of vitamin A per gram of edible protein. A medium size mola has about 2.0 g edible protein in its muscles, which contain 400 IU of vitamin A. Because of high dependence on cereals for nutrients in Bangladesh, about 50% of the population suffers from hidden hunger, the deficiency of many nutrients. Deficiencies of iron, vitamin A, and iodine are very common; in 1980, the average vitamin A intake was only 1/3 of recommended values, and 82% of surveyed households got less than 50% of the recommended dietary supply of this vitamin (Zafri and Ahmed 1981). The inclusion of mola in the culture system of prawn may improve the culture environment as well as provide much need micro-nutrients to farm households.

The purpose of the proposed study is to develop a new sustainable polyculture technology for all-male giant freshwater prawns and mola to increase the average productivity of high-value prawns for export, as well as to provide highly nutritious fish for household consumption.

Quantified Anticipated Benefits

If these experiments are successful, Bangladesh will secure all-male production technology, increase prawn production dramatically, expand international export markets, and provide mola, rich in vitamin A and other micro-nutrients, for family nutrition. Initial impact will be the relative increase in production of mola and prawns in the optimal density and stocking design. Additional impact will be the increased profit predicted for export of prawns. Export to developing countries will be another benefit, along with publications, on this new practice. Giant freshwater prawns and mola are widely cultured in the region especially in West Bengal and Myanmar and recently introduced to Nepal. This study will thus provide a sustainable polyculture strategy for small-scale rural farmers in the South Asian region. It will be of interest to all NGOs involved in aquaculture outreach and household nutrition security programs throughout Bangladesh. Caritas is one example of an NGO interested in this work and having a history of cooperating with our studies. Results on sex of prawns, density of mola, and size grading of prawns on overall yield would be simple management manipulations that could be extended to small-scale farmers. We will work with Caritas to extend these concepts to women involved in fish culture, since women are the main drivers of better household nutrition.

Research Design & Activity Plan

Location: One village of Guripur Upazila, Mymensingh District (north-central), one village of Upazila of Fakirhat Upazila, Bagerhat District (south-west) , Bangladesh

Methods:

- Pond research: This study will consist of three experiments conducted in two contrasting sites in the south-west and north-central regions.
- Pond facility: Twelve 200-m^2 earthen ponds.
- Culture period: 245 days.
- Test species: Giant freshwater prawn and mola
- Stocking density: 1, 1.5 and 2 mola/m^2 size 2-3 g (depends on experiment); 2-3 juvenile prawns/m^2 (based on stakeholder's opinion)
- Nutrient inputs: regular fertilization with N & P fertilizers and commercial feed once daily in the evening at 3% body weight of prawns.
- Water management: maintain at 1.0-1.5 m depth by weekly topping up.
- Sampling schedule:
    - Water quality: standard CRSP protocol, biweekly water quality sampling and monthly diel analysis at various depths.
    - Prawn growth: monthly sampling and total harvests.
    - Partial enterprise budget: variable costs and value of crops
- Statistical design, null hypothesis, statistical analysis:

Experiment one: Comparison of growth and production performance for all-male, mixed-sex and all-female giant freshwater prawns in pond culture system
There will be three treatments in triplicate: (A) all-male; (B) mixed-sex; and (C) all-female prawns at the same stocking densities. The experiment will be conducted in a completely randomized design, and the data will be analyzed using one-way ANOVA. Experiment will be conducted at both sites in year one.
Null hypothesis: There are no effects of sex of giant freshwater prawns on growth, size structure, and production.

Experiment two: Effects of the addition of mola at different densities to giant freshwater prawn production
All prawn stockings will include all-male individuals. There will be four treatments in triplicate: (A) prawns only (control); (B) prawns plus mola at 1 fish/m^2; (C) prawns plus mola at 1.5 fish/m^2; (D) prawns plus mola at 2 fish/m^2. The experiment will be conducted in a completely randomized design, and the data will be analyzed using one-way ANOVA and linear regression. Experiment will be conducted at one site only in year two.
Null hypothesis: There are no effects of stocking density for mola on growth, size structure, and production of freshwater prawns.

Experiment three: Effects of grading and size-selective harvest for giant freshwater prawns on prawn and mola production in polyculture ponds
There will be three treatments of size graded prawn juveniles (non-graded, upper half of size distribution, and lower half of size distribution) and two levels of harvest management (with or without selective harvesting of blue claws at biweekly intervals). All ponds will be stocked with mola at the best density determined in experiment two. The experiment will be conducted in a 2 x 3 factorial design with three replicates for each of the six treatment combinations. Data will be analyzed using factorial ANOVA. Experiment will be conducted at the other site in year two.
Null hypotheses: Both size grading at stocking and selective harvesting have no effect on growth, size structure, and production of both freshwater prawns and mola.

Schedule

1 October 2009 to 29 September 2011. Report submission: no later than 29 September 2011.

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EVALUATION OF PERFORMANCE OF DIFFERENT TILAPIA SPECIES

Quality Seedstock Development/Experiment/09QSD04PU

Collaborating Institutions & Lead Investigators

University of Arkansas at Pine Bluff (USA) — Rebecca Lochmann
Sokoine University of Agriculture (Tanzania) — Sebastian Chenyambuga, Berno V. Mnembuka, Nazael Madalla

Objectives

To identify tilapia species suitable for aquaculture in different management systems. Specific objectives are

1. To compare the performance (growth rate, survival, feed conversion ratio and mature body size) of different strains of Nile tilapia (*Oreochromis niloticus*).
2. To compare the performance of five other species of tilapia under different conditions
3. To carry out economic analysis of raising the different species
4. To determine the management requirements of the best tilapia species identified under objectives one and two.
5. To train farmers on the proper methods to culture the improved tilapia species.

Significance of the study

Economic studies have demonstrated that fish farming is a viable enterprise for African producers with high gains, but minimum costs (Molnar *et al*. 1991; Lightfoot *et al*. 1996). Wijkstrom and MacPherson (1990) indicated that while large-scale and intensive aquaculture enterprises have proven to be beyond the means of most farmers in Africa, small-scale aquaculture with commercial orientation can be a profitable economic activity. In Tanzania, aquaculture has a vast but as yet untapped potential. The industry is dominated by freshwater fish farming in which small-scale farmers practice both extensive and semi-intensive fish farming. Fish ponds of an average size of 10 m x 15 m (150 m^2) are the predominant production system (URT, 1997). These ponds are usually integrated with other agricultural activities such as gardening, livestock and poultry production on small pieces of land. Although production from aquaculture accounts only for a small proportion of total fish produced at the national level, it provides vital animal protein to the population residing in areas which are located far away from the major fishery resources or where transport of fish is either difficult or too expensive. In some regions where protein intake per capita is low and where protein malnutrition prevails, the socio-economic benefit from aquaculture is high. Given the importance of aquaculture in the country, there is a need to improve fish production to complement the capture fisheries. This project is designed to improve tilapia production in ponds of small-scale fish farmers through introduction of improved management principles and better genotypes. This will ensure profitability and sustainability of aquaculture enterprises in rural areas. Two investigations will be carried out as shown below.

Aquaculture in Tanzania started in the 1950's with the pond culture of the tilapia species native to the region, including Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*Oreochromis niloticus*) and Zanzibar tilapia (*Oreochromis urolepis hornorum*) (Rice *et al*., 2006). Other species which have been used commercially in aquaculture include *O. urolepis hornorum* originating from the Wami river of north-central Tanzania and *O. karongae* native to Lake Nyasa (Lake Malawi). At the moment, more than 95% of the farmers culture Nile tilapia (*Oreochromis niloticus*) in earthen ponds under mixed-sex culture (Kaliba *et al*., 2006). Pond culture of Nile tilapia is now viewed as a possible source of livelihood for farmers residing in proximity to the urban markets of cities and towns. The emphasis of the national fisheries policy (URT, 1997) is on a semi-intensive integrated mode of fish culture, focusing on Nile tilapia. The Nile tilapia is given first priority due to their

better characteristics that include fast growth, short food chain, efficient conversion of food, high fecundity (which provides opportunity for distribution of fingerlings from farmer to farmer), tolerance to a wide range of environmental parameters, and good product quality (Hussain *et al*., 2000; Neves *et al*., 2008).

In Tanzania, fish farmers obtain fingerlings from government fry centres and fisheries institutes. Some fish farmers produce their own fingerlings and sell them to other farmers. Because of the lack of controlled breeding, most ponds in the country are yielding only small-sized tilapia and production of fish is not encouraging. This may be due to lack of pure species caused by interspecific hybridization in fingerling production centres. Another reason is high levels of inbreeding which has resulted in inbreeding depression. Primary collections of wild broodstock that were done in the past involved a small number of individuals. Consequently, most fingerling production centres maintain small populations. These are serially distributed, so the genetic problems are passed from fry centres to farmers' ponds. Quite a number of farmers feel that their fish are small due to stunted growth, and this is discouraging them from continuing with fish farming operations.

Therefore, there is a need for bio-prospecting for various species of tilapia to identify the species suitable for aquaculture in Tanzania. Because Tanzania is a region with very high natural tilapiine fish diversity (Rice *et al*. , 2006), the ability to tap into the diverse natural pool of tilapia fish genes is very important. This project will collect and evaluate the productive performance (growth rate, feed conversion ratio and market body weight) of different species of tilapia.

Research design and activities:

To achieve the first objective, strains of Nile tilapia (*Oreochromis niloticus*) will be collected from different parts of the country. At least four strains will be collected from four fry centres and evaluated for their performance in one environment. Sixty fish (approximately 20 males and 40 females) will be collected for each strain. These strains are indigenous and fortunately, undisturbed wild populations of *O. niloticus* tilapia still exist in water bodies in Tanzania. All strains will be reared and bred in separate earthen ponds under station conditions to protect their genetic integrity. The resulting fingerings will be reared in concrete ponds. The fingerlings of each strain will be cultured under one sex (males only) and mixed sexes and monitored for growth for a period of six months (July 2010 – December 2010). A total of eight ponds will be used and the strains will be allocated to the ponds randomly.

For implementation of the second objective the following Tilapia species (with their local names in brackets) will be collected and their performance evaluated on-station: *Oreochromis niloticus* (Sato), *Oreochromis jipe* (Perege), *Oreochromis placidus ruvumae* (Ruvuma Perege), *Oreochromis leucosticta* (Ngege) and *Oreochromis urolepis* (Mtera perege). These are the most prevalent Tilapia species in Tanzania. Sixty fish (approximately 20 males and 40 females) will be sampled for each species from regions where each species is concentrated. *Oreochromis niloticus* will be collected from Lake Victoria, *Oreochromis jipe* will be collected from Nyumba ya Mungu dam, *Oreochromis placidus ruvumae* will be collected from Lake Nyasa, *Oreochromis leucosticta* will be collected from Nyumba ya Mungu dam and *Oreochromis urolepis* will be collected from Mtera dam. All strains/species will be reared and bred in earthen ponds under on-station conditions. The resulting fingerings will be reared in plastic tanks and concrete ponds. In each system, the fingerlings will be cultured under one sex and mixed sexes and monitored for growth for a period of six months (January – June 2011). A total of 10 ponds will be used and the strains will be allocated to the ponds randomly. Each strain/species will be stocked separately in both tanks and ponds at a stocking density of two fingerlings/m^2. The fish will be fed on diets containing 40% protein source, 58% energy source and 2% minerals. Soybean will be used as a protein source while maize bran will be the energy source. Fish will be fed twice a day at 0900hrs and 1600hrs for 180 days. The amount of feed will be 10% of the body weight, and adjusted upwards based on the estimated weight of the biomass obtained by weighing fish sampled fortnightly. Body weights of fish, fork length and

width will be recorded at the start of the experiment and then at monthly intervals (i.e. at day 30, 60, 90, 120, 150 and 180). The amount of feed given will be recorded daily and feed conversion ratio will be computed at the end of the experiment as the ratio between feed provided to the weight gained. Deaths of fish will be recorded as they occur during the experimental period. Water quality parameters (i.e. temperature, dissolved oxygen, pH, Nitrogenous compounds (NH_4-N, NO_2-N and NO_3-N) and turbidity) of the tanks and ponds will also be measured at weekly intervals.

Economic profitability of each species will be determined through partial budgeting. The study will compare costs and returns of the five tilapias. Partial budget analysis is a simple but effective technique for assessing the profitability of new technology for new enterprises. Results of partial analysis provide the foundation for comparing the relative profitability of alternative treatments and associated risk due to changing product or input prices. The study will follow the procedure on partial budget analysis as published in the manual by the International Wheat and Maize Improvement Center (CIMMYT 1988). Marginal analysis will be used to assess relative profitability among the different species. The gross income will be taken as quantities of fish sales and fish donated and consumed by the family valued at market prices. Variable costs will be taken as disease control costs and other inputs like feeding and labour. The value of family labour will be estimated based on the prevailing labour cost for casual labourers. The most profitable species will be promoted for use by farmers (July – November 2011).

Anticipated benefits

This project will identify tilapia species with enhanced productivity and develop their management protocols. The best performing species and the management systems will be introduced to farmers for improvement of fish farming in rural areas. It is expected that fish productivity will increase in smallholder fish ponds. Thus, the rural farmers will improve their incomes by selling tilapia fish of high quality. Also their per capita consumption of fish will increase. Furthermore, the increased level of income will improve the purchasing power of the rural poor farmers for food products, thereby reducing risks of food insecurity at community and individual levels. The increased income will lead to increased ability of farmers to pay for social services such as school and medical fees.

Impact indicators

1. Number of new species of tilapia identified and introduced to farmers for culturing under small-scale condition.
2. Quantity of fish sold per year by small-scale fish farmers.
3. Number of small-scale fish farmers increased from 0 – 10 to 20 – 30 in project areas.
4. Availability of fingerlings of the new tilapia species.
5. At least two M.Sc. students will graduate.
6. Availability of extension materials used for training of fish farmers.

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TOPIC AREA
HUMAN HEALTH IMPACTS OF AQUACULTURE

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CO-MANAGEMENT AND BIVALVE SANITATION FOR BLACK COCKLES (*ANADARA* SPP.) IN NICARAGUA

Human Health Impacts of Aquaculture/Experiment/09HHI01UH

Collaborating Institutions & Lead Investigators

Pacific Aquaculture & Coastal Resources Center University of Hawai'i at Hilo (USA)	Maria Haws
Louisiana State University (USA)	John Supan
Central American University (Nicaragua)	Nelvia Hernandez Carolos Rivas LeClair

Objectives

Since 2004, the University of Rhode Island and the University of Hawai'i Hilo have been working with local partners in Nicaragua and Tanzania to develop community-based co-management systems for bivalve fisheries, an often neglected, but valuable resource. The Center for Development and Research of Aquatic Resources (CIDEA) at the Central American University (UCA) collaborated with this effort, continuing over ten years of experience developing culture methods, bivalve sanitation and fisheries management methods for the black cockle (*Anadara similis* and *A. tuberculosa*) on the Pacific Coast of Nicaragua. The black cockles are a critical resource along most of the Pacific Coasts of the Americas, and are targeted largely by women and children fishers. They are also an important emergency food for the poor. Additionally, this resource has been heavily exploited, leading to near disappearance and year-round fishing bans in some countries. Additionally, since cockles are commonly eaten raw and are taken from estuary areas known to be contaminated, much of the recent effort has focused on developing bivalve sanitation programs, including extensive water quality sampling efforts along the Nicaraguan coast by CIDEA/UCA (Crawford, et. al. 2009; Haws et. al. 2009). This work has been funded by a number of donors, including USAID under the SUCCESS program, the EU and the Government of Japan.

Since 2004, CIDEA and partners have established and tested a community-based co-management program as an alternative to the annual seasonal ban (April-July) which has no biological basis. The latter is an essentially ineffective management method, established mainly due to the inability of government agencies to enforce fishing regulations. This annual ban is also problematic since it occurs precisely at the time when finfisheries experience the lowest yield, which is when the population turns to cockles as an emergency food supply. The need to collect cockles as the only available protein source has caused the communities to come into conflict with government regulators. The co-management efforts aim to develop a science-based method to effectively manage cockle populations, while at the same time allowing limited harvest by the poor fishers who depend on this resource and find it difficult to completely stop fishing for four months each year. The co-management effort is based on the established of no-take zones within the Aserradores Estuary (a large coastal lagoon) which is heavily populated by fishers. The community voluntarily selected the no-take zones, including adding several after the initial experiment began, and compliance is voluntary, depending upon peer-pressure and awareness raising within the communities for effectiveness. The first two years of sampling no-take and fishing zones indicated a preliminary increase in cockle populations and an increase in average size in the no-take zones, with indications that a spill-over effect was

occurring outside of the no-take zones. The results were presented to the community and resource management agency with the result that the Ministry of Natural Resources (MARENA) is considering legalizing this form of management and extending it to other communities if longer-term monitoring shows that co-management does help control and increase cockle populations, and if the community can sustain its involvement. Given that this sort of management may require 3-6 years in order to be shown to be effective, this work will allow continued technical assistance and support to the Aserradores communities involved in the co-management efforts for the additional time required to conclusively demonstrate effectiveness. This work will also include an extension component to begin disseminating the results to other coastal communities which have shown interest in this form of management, as well as facilitating consideration of the results by regulators.

Additionally, since extension visits will be made for purposes of the co-management research, the extension agents will also continue to provide support to the current, on-going AquaFish work which focuses on relay and depuration of cockles in Aserradores, as well as the certification and labeling of depurated product to assure long-term sustainability of these efforts.

Specific objectives include:
1. Continue monitoring to determine cockle population densities and size distribution within and outside of the community-supported no-take zones.
2. Continue working with the Aserradores communities to support their management efforts
3. Conduct outreach to other communities to initiate similar efforts and work with government agencies to develop more science-based forms of management other than the annual four- month ban.

Significance

If the co-management continues, and if it is accepted as a legally valid form of management, over 50 coastal communities in Nicaragua that depend largely on the cockle fisheries may benefit. Firstly, by offering an alternative to the annual ban, conflicts between fishers and authorities can be avoided. Community members will also benefit from being allow to harvest limited numbers of cockles all year round, including for their personal consumption as an emergency food. This will contribute to food security in these highly food-insecure communities. Women and children will particularly benefit. Additionally, if initial trends indicating an increase in population abundance and increase in cockle size continue and are validated, this will benefit efforts to sustainably manage this important fishery. This can become a model for the rest of Latin America.

Quantified Anticipated Benefits

The Asseradores community has over 300 women with children who are dependent on the cockle resource. Additionally, at least 50 other coastal communities in Nicaragua can benefit from this.

Metrics:
Number of institutions directly or indirectly benefiting: 3
Number of individual participants in technical training: 63
Number of communities benefiting: 4
Number of women-owned businesses benefiting: 10
Number of documents produced or contributed to: 1
Students involved: 2 undergraduate
Publications: 2 (technical report and article for CRSP newsletter)
Number of new or improved products: 1

Research Design & Activity Plan

- Cockle populations will be sampled every six months at 12 sampling stations, which include three in no-take zones, three sites located 100 meters from the no-take areas, and six stations located outside the no-take buffer zones. The community members are trained in sampling methods and will participate in the sampling and will receive extension visits after each sampling so that the results can be shared.
- Statistical analysis is conducted using one-way analysis of variance (ANOVA) for population numbers inside of the no-take zones and those at some distance from the no-take zones.
- CIDEA will also facilitate community meetings to discuss issues related to management, including providing conflict resolution when necessary.
- The no-take areas are marked with signals, which will be replaced every six months, working with the community.
- CIDEA will also work with other communities to share the results and begin similar no-take zones in other communities, as well as work with the authorities to share the results, hopefully leading to legalization of community-based co-management methods.
- CIDEA is also continuing the AquaFisheries CRSP work on cockle sanitation and depuration for the next two years under new funding obtained from the EU. These results will also be reported to CRSP although CRSP is no longer funding this effort.

Schedule

This work will begin in January 2010 and terminate in October 2011. Sampling will take place every 6 months and community visits will occur on a monthly basis. CIDEA is also working on other community efforts in the Asseradores area, allowing them to make additional, regular visits outside the budget provided by CRSP.

Student involvement

One graduate student and at least 10 undergraduate students will participate in this work. Additionally, biologist Nelvia Hernandez will be funded for her coursework in the new UCA Masters degree in Integrated Coastal Management. She will also serve as an instructor for aquaculture and fisheries topics in the program.

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CAPACITY BUILDING IN AQUACULTURE, FISHERIES MANAGEMENT AND COASTAL MANAGEMENT FOR COASTAL WOMEN. WORKSHOP: "OPPORTUNITIES FOR COASTAL WOMEN IN FISHERIES, AQUACULTURE AND COASTAL MANAGEMENT"

Human Health Impacts of Aquaculture/Activity/09HHI02UH

Collaborating Institutions & Lead Investigators

Pacific Aquaculture & Coastal Resources Center University of Hawai'i at Hilo (USA)	Maria Haws
Louisiana State University (USA)	John Supan
Central American University (Nicaragua)	Nelvia Hernandez Lorena Irma Camacho

Objectives

Since 1996, a team of UAS researchers has been working in coastal communities to develop coastal management efforts which culminated in two officially adopted coastal management plans (Bahia Santa Maria and Boca de Camichin). The findings and results from the Mexico work were published as part of the ACRSP program (Haws, et. al. 2008) and integrated into peer-reviewed publications as part of the USAID SUCCESS program (Crawford et. al. 2009; Haws et. al. 2009). Since that time, the same team and a number of partners from the education, government and private sectors have continued with implementation efforts following the recommendations of the management plans. A similar effort has been in place in Nicaragua since 1998, which led to the official adoption of the management plan for the Estero Real (Royal Estuary), a watershed which drains approximately 30% of Nicaragua and parts of Honduras and is a major tributary for the trinational Gulf of Fonseca. In both nations, the primary target groups have been socially-disadvantaged groups including women, fishers, disabled and indigenous groups. Women comprise approximately 80% of the total stakeholders involved. The range of the CRSP work, including leveraged efforts and similar projects have included topics such as: fisheries co-management, development of national regulations for previously unregulated fisheries species, alternative livelihoods (aquaculture, eco-tourism, handicrafts, bakeries), large-scale water quality monitoring, aquaculture best management practices, seafood sanitation and quality and bivalve sanitation. Two major cross-cutting themes in this work are conservation and food security. Although efforts have been made to disseminate the results of these many years of work, both the research and the extension efforts, more work needs to be done in this area. Additionally, although women are active and involved at all levels, more women can be involved and their individual and collective capacity improved. This work proposes to accomplish this through holding two regional workshops, one in Nicaragua and one in Mexico, to provide a venue for exchanging lessons learned and practical methods. Women, including young girls, will be the primary audience for this work. Participants will be selected from women stakeholders who have participated actively in previous efforts and women who have not had the opportunity to become involved. Young women (ages 12-18) will also be selected in coordination with local schools as a means of involving younger women who may not have been exposed to the concepts and practices.

Specific objectives include:

1. Hold two regional workshops for women and female children to provide an opportunity to exchange lessons learned and identify future needs
2. Inclusion of young women to broaden the participation of women in the future

3. Provide training with a focus on alternative livelihoods (including aquaculture) that are specifically targeted to users of threatened natural resources (e.g mangrove wood cutters, shrimp post-larvae fishers)
4. Produce an outreach video highlighting the achievements of each nation's women in these areas. This will be shown on TV channels in both countries and distributed to institutions working with these topics.

Significance

This work will provide an opportunity to increase dissemination of past accomplishments and methods developed as part of the previous CRSP work. Involvement of women will be expanded and deepened by including new women, women's groups and younger women. It will also provide an opportunity for a south-south exchange between Nicaragua and Mexico via distribution of the materials, joint preparation and the final video production. Researchers and extension agents will also benefit by being able to work with a broader range of women to identify need needs for research, extension and training.

Quantified Anticipated Benefits

Metrics:
Number of institutions directly or indirectly benefiting: 15
Number of individual participants in technical training: 50
Number of communities benefiting: 12
Number of women-owned businesses benefitting: 10
Number of documents produced or contributed to: 2 (including the video)
Students involved: 10 graduate and 10 undergraduate
Publications: 2 (technical report and article for CRSP newsletter)
Number of new or improved products: 0

Research Design & Activity Plan

Nelvia Hernandez (Biologist/Extension Agent, Nicaragua) and Lorena Irma Camacho (Sociologist, Mexico) will lead this work and will be responsible for planning, designing and organizing the two workshops. Both have worked extensively on the CRSP and SUCCESS efforts, including related projects, and have specialized in outreach to women. Ms. Camacho also assisted Dr. Mario Carranzas in the research on gender and participation of disabled individuals in aquaculture during the ACRSP research leading to the Human Health and Aquaculture Case Studies. Drs. Haws and Supan will assist with the planning and design of the workshop training materials. Both have at least 20 years of experience working in extension and training. Haws has worked with women's groups in aquaculture and alternative livelihoods in 10 countries. The workshops will be held in rural communities (La Reforma, Bahia Santa Maria and Aserradores, Nicaragua). Transporation and other services will be provided to allow more women to attend. Since many of the stakeholders are single mothers, child care will be provided if necessary. Young women (ages 12-18) will be selected in coordination with schools, although efforts will also be made to identify and include young women who may no longer be attending school. Institutions that collaborate with CRSP will also be invited, particularly those which may be able to provide future assistance through technical assistance, medical services or social assistance. The current rural women who are involved with the CRSP efforts will also be involved in the planning and coordination of the workshop.

Schedule:
The workshop will be held in Nicaragua in June, 2010 and in Mexico in August, 2010.

Student involvement

Ten graduate students and at least 10 undergraduate students will participate in this work. Additionally, biologist Nelvia Hernandez will be funded for her coursework in the new UCA Masters degree in Integrated Coastal Management. Students in this M.S. program will be involved in the Nicaraguan workshop. The four students working on the UAS projects will also be involved in the planning and execution of the events.

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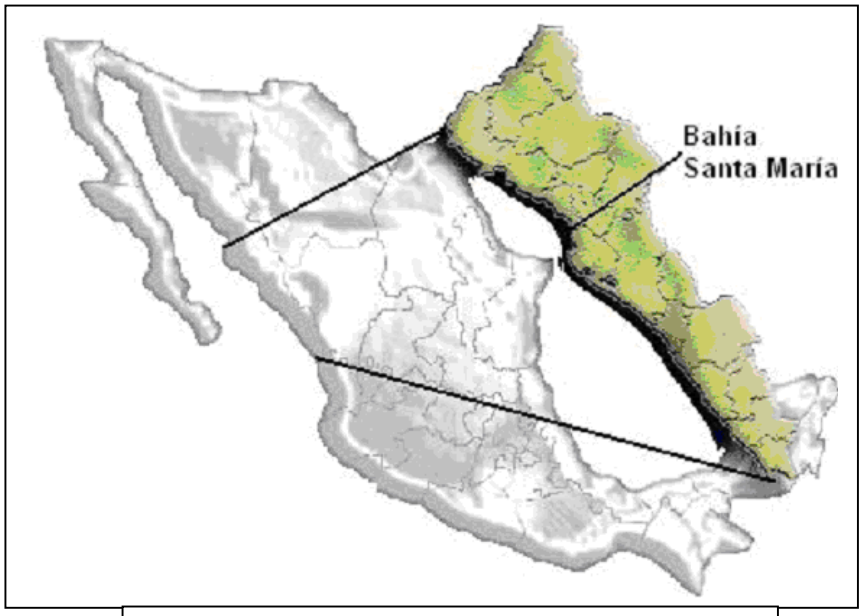
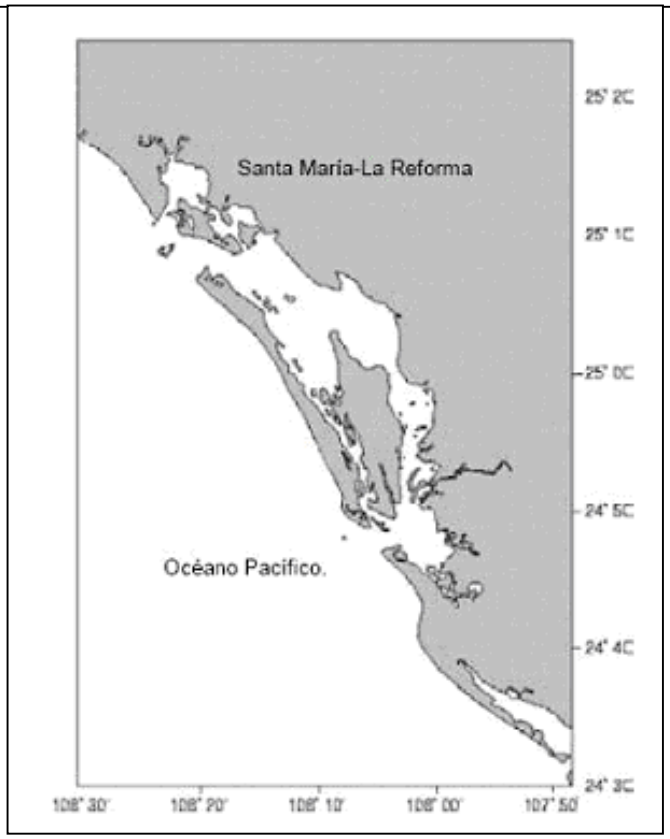
Maps

Map of Nicaragua and study sites in coastal areas

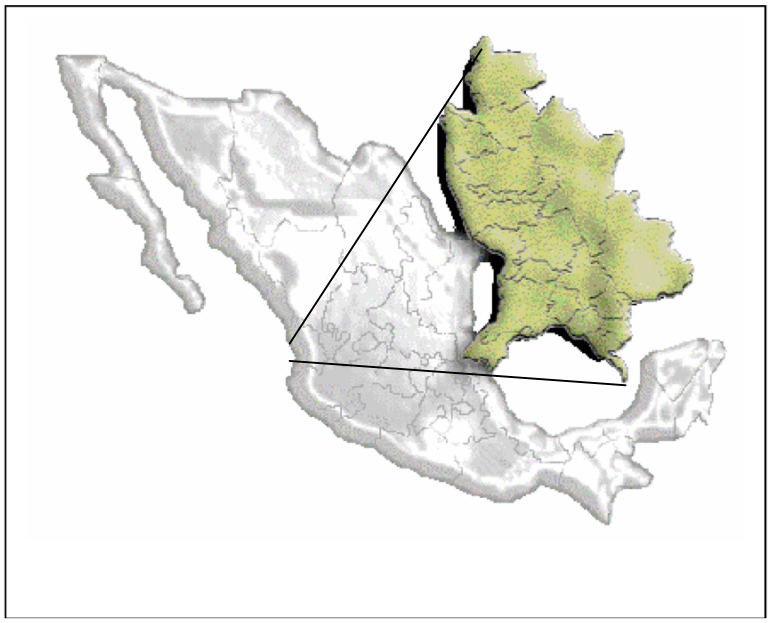
Maps

1. **Sinaloa State and Santa Maria Bay (Bahia Santa Maria)**





2. **Nayarit State, Mexico and Boca de Camichin Estuary**



TOPIC AREA
FOOD SAFETY & VALUE-ADDED PRODUCT DEVELOPMENT

❖

MAXIMIZING THE UTILIZATION OF LOW VALUE OR SMALL-SIZE FISH FOR HUMAN CONSUMPTION BY IMPROVING FOOD SAFETY AND VALUE ADDED PRODUCT DEVELOPMENT (FERMENTED FISH PASTE) THROUGH THE PROMOTION OF WOMEN'S FISH PROCESSING GROUPS/ASSOCIATIONS IN CAMBODIA

Food Safety & Value-Added Product Development/Study/09FSV01UC

Collaborating Institutions & Lead Investigators

University of Connecticut-Avery Point (USA)	Robert Pomeroy
University of Rhode Island (USA)	Chong Lee
Inland Fisheries Research & Development Institute (Cambodia)	Kao Sochivi
	Long Li

Objectives

The overall objective of this investigation is to work with women to improve and ensure food safety and value added of fermented fish paste products for local consumers and the competitive markets in Cambodia and the development of women fish processing groups/associations.

To achieve the overall objective of the investigation, the following are the specific objectives:

1. To identify and analyze the composition and natural and chemical hazard of the products.
2. To develop best practice quality and safety guideline, standardize packaging and labeling for fermented fish paste to the processor, who are primarily woman.
3. To develop an outreach program to apply the best practice guideline on quality and safety of fermented fish past products to promote the women fish processing groups/associations.
4. To disseminate the best practice guideline for quality and safety of fermented fish paste products to the provincial fisheries officers and processors.

Significance

In Cambodia, low value/trash fish is used for human consumption, particularly by the poor as it is relatively cheap and provides good sources of protein and other nutrients to humans, especially pregnant women and children. The fish is utilized for household food security and income. Artisanal processing is undertaken to make fermented fish or fish paste (*prahoc* in the Khmer language) or processed in other ways (e.g. fish sauce, *teuk trei* in the Khmer language) using different traditional processing practices. This processing is done primarily by women. This processed product is used in the household and sold in local and regional markets (Thailand, Laos, and Vietnam) and provides income to the household. Tens of thousands of the Cambodia poor, especially rice farmers, who are living hundreds of kilometers away from the main natural freshwater water bodies, come to the Tonle Sap River during December to February every year to buy low value or small-sized fish to make *prahoc*. Vietnamese traders are known to come to Cambodia to purchase both fresh and semi-processed low value/trash fish for further value-added processing in Vietnam. The increasing competition for low value/trash fish for aquaculture has reduced the supply of fish for these value-added products.

Prahoc is produced in a variety of ways depending on the raw material, but there are two main types, boneless and bony. Boneless *prahoc* is made almost exclusively from *gourami* species and

commands a high price in the restaurant trade, for export and amongst higher income consumers. *Prahoc* made from small mixed species is less valuable but is a more universally made product from the people. It is produced essentially by taking fresh fish and removing the heads and scales and intestines. The fish are salted and dried for a few days before being mixed with salt and stored in airtight ceramic vats to mature. The products are made by subsistence fishermen and others when fish are abundant as a means of storage for later consumption or as a product for sale or barter for other food stuffs.

Prahoc is perhaps the most widely consumed fish paste, but the quality of this product varies and has a short shelf-life with a number of health concerns associated with this. Due to lack of standards for most of the products and lack of inspections and controls, there is significant value loss. There are no official control services available at central level and in provinces for products intended for domestic consumption, consequent to which, health control and monitoring of production conditions are not in place at any stage of the fish production chain. The official laboratories are not in a position to perform the range of analysis required for quality checks. Health conditions during production and storage of fishery products are not in line with the requirements and fish-borne illnesses are recognized as an important public health problem. So far there are few regulations and standards related to fish and fish products. The shortage of standards addressing fish, food additives and fish feed hinders action against adulterated or contaminated food. Overcoming this would be important for achieving the goal of protecting the people against fish borne diseases (UNDSF-8; NSDP-4.45/4).

According to the results of gender implications in the study conducted by the CBCRM Learning Center in Cambodia "The Role, Needs, and Aspiration of Women in the Community Fisheries in Cambodia", in six fishing communities: "the main roles of women in fisheries related livelihood activities, the results from most of the case studies are consistent with the general understanding from the literature review. This is that women are engaged in a variety of fisheries-related livelihood activities on their own small-scale capture fisheries, gathering of aquatic plants and animals, aquaculture - and also play a supportive role in the fishing activities of their husbands. But the main responsibility of women in fisheries-related livelihoods is in the post-harvest sector, including processing and trading fish." (Keang Seng 2001; Khim et al. 2002; IFM 2007). In all study sites, women are viewed as more competent than men in marketing fish and take more responsibility in the post-harvest stage of fisheries livelihoods. In some cases, men immediately sell the fish to collectors at landing sites. Women think of this as a disadvantage because men do not usually negotiate prices or look for the best buyer and thus may not get a good price for their catch. Women's roles in fisheries are often invisible because fisheries management normally focuses only until catch and does not take the post-harvest stage into consideration. It is noted that women play a large role in the post-harvest stage, and it would not be an exaggeration to say that the need created in the post harvest stage is largely determined by the effort for catch.
Many studies described women's roles in every aspect of rural livelihoods in Cambodia, including some documentation on the traditional division of labor between men and women in agriculture. However, there has been little examination on women's roles and contribution to fisheries post-harvest sector. Understanding gender in the development of fisheries post-harvest is very important especially for their participation and contribution to improve their livelihood and food quality, safety, and food nutrition in order for the sustainable development and management of fisheries natural resources. It can also help to improve women's rights and participation in the socio-economic activities.

The results of work undertaken in Phase I show hygiene and quality of *prahoc* are the main driven factors for local and external demands. The study also showed that semi-processed products of small-size fish are also important for external markets (e.g. Thailand and Vietnam). So hygiene and quality issues should be addressed in the second phase of the project. The study of Phase I also documented traditional and modern *prahoc* processing technologies, and compared the two in order to develop Best Practices for producing *prahoc*. For phase-II, we will use this output on

best practice for *prahoc* processing method to develop the *prahoc* quality and safety guideline, standardize packaging and labeling for fish paste and apply to promote the women fish processing group/association. So based on this investigation we hope that we will have a direct and indirect effect/impact to the National Fisheries Post-Harvest Sector. The results can be used to effectively enhance human health to all consumers and processors of the fish paste in order to promote the alternative livelihood/employment of the people who depend on the fisheries, especially women in the community fisheries members/fishers/processors in order to increase their income. These activities will also help to improve women's sharing of the added value and improve the social/family economic livelihoods, and equal rights in family decision-making as many of Cambodian women have low education.

Quantified Anticipated Benefits

The investigation will provide direct and indirect benefit to different stakeholders such as:

1. The target beneficiaries are the fish processors and fish traders, who are primarily women, who would get better price for their improved quality of the product, and fermented fish paste consumers, who will get a safer product, and would be able to access better markets having complied with quality and safety requirements of these markets. The impact of the project will benefit the entire fisheries sector by improving the livelihoods of Inland and coastal fishing communities, and the women in those communities, generating better products through improved processing and packaging labeling techniques, facilitating access to new markets.
2. One student will be supported and involved in the project through thesis research.
3. The National Fisheries Post-Harvest Sector will have formal national guideline on fermented fish paste and control of the product quality, safety, values added and market.
4. 100 scientists, researchers, government fisheries managers and policy-makers, inter-government and non-government staff, extension agents, academic institutions, private sector, importer and exporters, fish farmers, fishers, fish traders, fish processors, and consumers will have a better understanding and using of *Prahoc* processing with the best practices guideline to improve the quality and safety, values added for this product and market opportunities.
5. 2000 poor households in Cambodia, including women, who rely on fermented fish paste processed products will have improvements in product quality and safety.
6. 2000 poor households in Cambodia, including women members of the households who process low value/trash fish will be better informed about potential improvements in processing practices; value-added product development opportunities; and market opportunities toward increase their income.
7. Long term indirect impact are at least one million of people will get benefit from eating healthy fermented fish paste food across the country in support of the national poverty alleviation program and improved natural resources management and development.
8. Benefits of this investigation to the US include improvements in the technology for processing, food safety and quality, packaging, and labeling of freshwater fish products.

Research Design & Activity Plan

Location

This study will be undertaken only in Cambodia as resources are limited and there is a priority need within this country for this kind of fermented fish paste products improvement and information. Survey and consultation will be undertaken in two provinces located along the Tonle Sap Greate Lake. The provinces are Siem Reap and Battambong that most important for the fermented fish paste processing and supply for the whole country and export to other neighbor countries.

Methods

The study will be comprised of the following activities:

1. Literature review of the results from the first phase with a desktop survey to better understand fermented fish paste best practice processing in Cambodia and fermented fish processing quality standard guideline.
2. Field observation, focus group discussion, and key informant interview observation using some guide question to the processors to study processing practices on the processing plant/chain and areas of fermented fish paste product and to identify problems and issues related to food safety, processing, and value-added product development.
3. Identify and analyze the composition and natural and chemical hazard of the products through getting simples from the site and then send to the accreditation laboratory to check and analysis it.
4. Consultation workshop/meetings with processors, who are primarily women, on the best practice of fermented fish paste product quality standard and safety guideline, packaging, and labeling.
5. Qualitative method will be employed in analyzing data and developing the guideline, standardize packaging and labeling of *prahoc* product. Dr Chong Lee of the University of Rhode Island, a food scientist, will assist with analysis.
6. Outreach to promote the women fermented fish paste processing group/association
7. Apply the product best practice quality safety guideline, standard packaging, labeling to improve the product quality, safety, values added, and competitive market to women processors.
8. Publishing and disseminate of the best practice quality and safety guideline, packaging, and labeling standard of the fermented fish paste product to the processor and provincial fisheries officers through research report or guideline book, newspaper/magazine article, TV/Ratio. The publications will be translated into the local Khmer language.

Schedule

The study will be comprised of the activities:

Activities	Beginning	Ending
Literature review	01/01/2010	31/01/2010
Survey & key informant interview	01/02/2010	30/04/2010
Organize the women fermented fish past group/association	01/02/2010	30/04/2010
First identify composition, quality and safety of the product before applying the guideline, packaging, and labeling standard.	01/05/2010	31/05/2010
Consultation workshop/meeting with processors	01/06/2010	30/09/2010
Summary and develop guideline, standardize packaging and labeling of fermented fish paste products	01/10/2010	30/02/2011
Apply the best practice fermented fish paste product guideline, packaging and labeling to the women group	01/12/2010	30/03/2011
Second identify composition, quality and safety of the product after applying the guideline, packaging, and labeling standard.	01/04/2011	30/06/2011
Publish and dissemination (workshop/training/TV/...)	01/05/2011	29/09/2011

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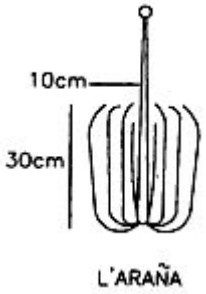
DEMONSTRATION OF SUSTAINABLE SEAWEED CULTURE, PROCESSING AND UTILIZATION IN ACEH, INDONESIA AND THE PHILIPPINES – OPPORTUNITIES FOR WOMEN TO IMPROVE HOUSEHOLD WELFARE

Food Safety & Value-Added Product Development/Activity/09FSV02NC

Collaborating Institutions & Lead Investigators

North Carolina State University (USA)	Russell Borski
University of Arizona (USA)	Kevin Fitzsimmons
Ujung Batee Aquaculture Center (Indonesia)	Hasan Hasanuddin
	Coco Kokarkin
SEAFDEC AQD (Philippines)	Evelyn Grace de Jesus-Ayson
	Maria Rovilla J. Luhan

Objectives



1. Demonstrate and train women to recognize the many advantages of utilizing seaweeds to improve family nutrition and as a potential cottage industry to improve household and community wealth.
2. Conduct a series of workshops regarding proper harvesting, handling, and drying of red seaweeds.
3. Build demonstration seaweed drying racks in three communities.
4. Conduct workshops on methods of using seaweed agar to make candy and desserts.
5. Demonstrate methods to partially process seaweed to increase its value as an industrial supply of agar and carrageenan products.

Significance

Scientists from the Philippines have been leaders in the development of red algae harvesting, culture, domestication, and processing into marketable products (Hurtado 2002; Santelices and Doty 1989). This proposed activity will build largely upon the successful transfer of technology from the SEAFDEC in the Philippines to other regions of the Philippines and the Aceh Province of Indonesia. Women were the primary beneficiaries of the earlier training in the Philippines and Indonesia. In fact, many of the world's leaders in seaweed culture are women, and women conduct many of the culture and processing activities. The farmers in Aceh, mostly women, have specifically requested that additional training be provided from the experts in the Philippines to further develop the potential for seaweed production, processing and utilization for various products.

The technical and environmental benefits of polyculture of seaweeds in shrimp and fish ponds are well documented (Ryder et al. 2004a,b; Marinho-Soriano et al. 2002; Nelson et al. 2001; Neori et al. 2000). Polyculture of seaweeds in shrimp and fish ponds has proven to be popular in several coastal communities based on our current AquaFish CRSP. Large volumes of *Gracilaria* and *Eucheuma spp.* are produced in ponds with small volumes being used for home consumption as fresh sea vegetables or for agar for cooking. However, more product is being produced than is needed for home use. We would like to assist the farmers to learn how to handle and process their raw seaweed into more valuable semi-processed forms that will be of interest to commercial agar buyers. We would also work with women to demonstrate cooking and preparations for the kitchen. Recipes and copies of the Hawai'i Sea Grant publication "The Limu Eater: A Cookbook of Hawaiian Seaweed" will be provided.

Demand is significant for agar based candy and desserts in Indonesia and the Philippines. However, a suitable grade of agar is needed before it can be made into a marketable candy. The

pharmaceutical grade agar used in microbiology demands a yet higher grade. In both cases, contamination and spoilage are the primary reasons for degradation. With the guidance of researchers and extension specialists, farmers have developed the "araña" tool for improved collection of seaweeds (Poblete and Inostroza 1987) and a method of off the ground drying on racks. The araña tool used in harvesting *Gracilaria* grown in ponds is efficient since it leaves around 25-30 % of biomass of *Gracilaria* to serve as 'seedlings' for the next cropping season. Further, it prevents the trampling of the substrate, which may inhibit the growth of *Gracilaria* in ponds. The racks are constructed of locally available components (lumber, bamboo, ropes, and fish nets) and serves to elevate the seaweed and facilitate manually turning the seaweeds. This serves to increase the rate of drying, thus reducing spoilage, and it reduces contamination from soil, shells, and rocks that occurs when the seaweed is dried on the pond bank. We would like to demonstrate to farmers in Aceh and additional locations in the Philippines how the seaweed can be partially processed to increase its value as an industrial source of agar.

Quantified Anticipated Benefits

- Women in Aceh frequently assist with pond (tambak) maintenance and harvest. To date they have also taken the lead on seaweed harvest, processing and utilization. We would like to continue to support their training so that they can use seaweeds for direct consumption, for processing into agar for cooking and candy preparation, and for the potential to sell seaweed products for the benefit of their families and themselves.

7. A series of training workshops will promote proper harvest, handling and drying of red seaweeds that should increase the price per kilo of seaweed sold.
8. Demonstration seaweed drying racks will be build in three communities.
9. Training workshops will be provided on methods of using seaweed agar to make candy and desserts, increasing local and regional demand for agar and providing in-home business option especially for women of the communities.
10. Methods to process partially seaweed to increase its value as an industrial supply of agar and carrageenan products will be demonstrated, providing farmers the capacity to produce value-added products that will increase their incomes.

Activity Plan

Location

Workshops and demonstrations will occur in communities of Aceh, Indonesia and in Palawan, Philippines

Methods

1. Continue the training of women in Aceh and the Philippines to improve understanding of the nutritional and financial benefits from seaweeds.

We will include training in nutrition and seaweed handling so that women will be able benefit from the increasing volumes of high quality seaweed produced in the shrimp tambaks. We will provide nutritional data, recipes, example products, and copies of a popular book from Hawaii. Translations or provision of a similar book in Bahasa if available will be pursued. Our team of experts composed of women will provide training, in order to follow the cultural norms of women in Aceh. In the Philippines, women will conduct most of the training as they are the experts anyway.

2. Conduct a series of workshops regarding proper harvesting, handling and drying of red seaweeds

The farmers in Aceh and several locations across the Philippines have begun to produce large quantities of red seaweeds in shrimp and milkfish ponds but still have limited market demand. We plan to teach the members in the farming community how to handle and dry the seaweed to meet the criteria of the seaweed brokers who buy product for the processors who purchase vast

quantities to turn into pharmaceutical agar. By improving the quality of the seaweed product itself, we hope to see an *increase in the price per kilo* for delivery to both markets.

We intend to conduct two workshops in Aceh, Indonesia, most likely in the Sigli and Pidie communities and one in the Philippines. These farming communities have strongly embraced the polyculture concept and have large quantities of seaweed produced from their shrimp ponds. Improving the quality for both domestic consumption and for sale to brokers and commercial processors is critical. In the Philippines, we intend to conduct a workshop in the communities of Palawan that have begun culture of seaweeds, but are producing below average quality product, due to a lack of training in proper methods of handling and drying the seaweed.

The first topic to be addressed will be the use of the araña, a harvesting tool that allows farmers to cast out and bring back the bulk of seaweed with minimal disturbance to the fish or shrimp in the pond. One of the arañas will be provided to each community. Plans will also be provided to construct them locally. After the farmers are instructed in its use, we will move onto handling the seaweed, removing epiphytes, avoiding contact with rain or freshwater, and the most advantageous methods for drying, including racks, hanging systems, and various coverings to keep rain off and to speed drying. These techniques are important and may vary depending on the value added product. Product for home use may only need to be cleaned of epiphytes before use as a vegetable or in cooking. Product for candy or dessert, will need cleaning and some drying, while industrial agar will require considerable drying.

3. Build demonstration seaweed drying racks in three communities

By building drying racks in each participating community, we hope to further improve the quality of seaweed product. We will demonstrate the drying of harvested seaweeds using elevated platforms (5 m x 10 m long) with fish net on top to facilitate aggregation of the seaweed. We will first provide drawings and photos to the local farmers in the workshop. We will work with our local partners to purchase the materials and identify a location for the demonstration rack. The rack will be constructed using the plans/drawings/photos accommodating any changes that might be necessary depending on local circumstances (dimensions, materials, etc.). The pro's and con's for utilization of various covers (plastic, metal, fiberglass, bamboo, palm fronds) will be discussed. The potential for multiple uses of the drying rack beyond seaweeds will also be described.

4. Conduct workshops on methods of using seaweed agar to make candy and desserts

The most rapid and lucrative niche market to develop is for agar products used to make candies and desserts. These can quickly contribute to household welfare by providing additional food products for the home and entrepreneurship opportunities in the community, especially for women. Within our three workshops, we will progress through the simple collection of agar from red seaweeds and then to the manufacture of simple candies and desserts. It will also describe the process of preparing more refined agar and carrageenan products that will be of interest to brokers and buyers for larger food processing and packaging firms. The processing steps and the equipment requirements will be described along with suggestions regarding where new and used equipment might be obtained.

5. Demonstrate methods to process partially seaweed to increase its value as an industrial supply of agar and carrageenan products

Agar and carrageenan are vital food ingredients with global markets in the billions of dollars per year. Farmers who can provide high quality dried and semi-refined or refined products will be able to find willing buyers, which will increase their incomes. In three follow-up workshops we

will work with our partners to teach the methods of processing dried seaweeds to chips, semi-refined and refined products. The processing steps and the equipment requirements will be described along with suggestions regarding where new and used equipment might be obtained.

Schedule:

February 2010: First Indonesian workshops on handling seaweed products and designing drying racks
February – March 2010: First drying racks constructed
June 2010: Indonesia workshops on candy/dessert production from agar and value added processing
October 2010: Presentation of results to date at Asian Fisheries Meetings in Shanghai, China
January 2011: Workshop in Palawan, Philippines on nursery management, handling, and processing of seaweed
June 2011 – Meet with farmers & agar buyers to determine value added products acceptance and market prices and degree of implementation
July – August 2011 – Draft and submit final reports

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TOPIC AREA
TECHNOLOGY ADOPTION & POLICY DEVELOPMENT

❖

AQUACULTURE & FISHERIES CRSP SPONSORSHIP OF THE NINTH INTERNATIONAL SYMPOSIUM ON TILAPIA IN AQUACULTURE TO BE HELD IN SHANGHAI, CHINA

Technology Adoption & Policy Development/Activity/09TAP01UA

Collaborating Institutions & Lead Investigators

University of Arizona (USA) — Kevin Fitzsimmons
Universidad Autonoma de Tamaulipas (Mexico) — Pablo Gonzalez Alanis

Objectives

1. To provide travel support for Dr. Gonzalez and four international contributors from other Aquaculture & Fisheries CRSP countries to attend ISTA 9.
2. To publish and print the Proceedings of the 9th ISTA. To establish an ISTA website for on-line submission of abstracts and papers and eventual e-archiving of paper and presentations in PDF formats.

Significance

The ISTA's are the premier international meetings focused directly on tilapia aquaculture and have provided one of the most important outlets for publication and discussion of the findings of Aquaculture and Aqua/Fish CRSP supported research. The CRSP has been a co-sponsor of the last five ISTA's (Fitzsimmons 1997; Fitzsimmons and Carvalho 2000; Bolivar, Mair and Fitzsimmons 2004; Contreras and Fitzsimmons 2006; Elghobashy et al., 2008). World-Fish Centre, the China Aquatic Products Processing and Marketing Association, and other sponsors will be co-hosting ISTA 9 and will be especially interested in ensuring the success of the conference. The original PD/A CRSP contributed greatly to the capacity building of aquaculture and especially tilapia production in Southeast Asia. Southeast Asia is the global center of tilapia production and research. Much of this success can be attributed to earlier CRSP activities and the ISTA 9 will highlight past achievements that led to current success.

Travel support is critical to allow scientists from developing countries to present their findings in international fora. Host country CRSP scientists benefit from the opportunity to discuss their work amongst themselves, with their US colleagues, as well as the rest of the international community. The objectives within this proposal fit the Activity description of conference organisation.

The ISTA 9 will be held in conjunction with the Ninth Asian Fisheries Society meeting to form one of the biggest aquaculture conferences held to date in China. Shanghai Ocean University has agreed to host the ISTA9 AFS9 to showcase their new campus built south of the Pudong Airport in the planned suburb community of Lingang. The ISTA 9 has been scheduled for April 2011. Several co-sponsors have already agreed to provide financial and in-kind support. These include Intervet-ScheringPlough, World Fish Centre, Tilapia International Foundation, Aquaculture without Frontiers, Global Aquaculture Alliance, and World Aquaculture Society.

Quantified Anticipated Benefits

We will provide direct financial support for at least four (and probably more) host country scientists to participate in the ISTA 9. We anticipate that several more of the various AquaFish

CRSP host country and US scientists and students will also participate. Our larger target group is the international community devoted to tilapia aquaculture. We have increased ISTA participation by about 150 persons each over the last four symposia. We expect that the meeting in China will exceed 1000 participants.

The print and on-line proceedings will quickly make the research results presented at the conference available to a wider audience. The benefits to the US are that technologies developed in many countries around the world will be made available to US farmers. Advances in certification programs, food safety and processing-packaging will improve product quality and control tilapia product prices. Environmental safeguards described and implemented will benefit American and host country citizens.

Activity Plan

Location of work: UAT and China

Methods

Drs. Fitzsimmons and Liu Liping are on the international organising committee planning the ISTA 9 symposium. A sub-committee will be formed to set the selection criteria and then determine which applicant scientists will be awarded the travel support. The selection criteria will be based on contributions of papers to the conference, past participation in Aquaculture & Fisheries CRSP projects and other available support. If partial support can be generated from other sources, the funds may be split to support additional participation.

The ISTA 9 organizing committee has been formed and includes:

Chair - Dr. Kevin Fitzsimmons
Dr. Chan Lee
Mr. Di Gang
Representative of WorldFish Center.
Representative of American Soybean Association

Schedule

	YR 1 (mos)			Project YR 2 (mos)			
	4-5/10	5-6/10	7-9/10	10-12/10	1-3/11	4-6/11	7-9/11
Select printer	x						
Begin to organize sessions	x						
Design and put up ISTA 9 website	x						
Conference organizing committee meeting at SOU – June 2010		x					
Publicize conference hotels		x					
Begin to receive abstracts				x			
Begin to receive and edit papers				x			
Select and invite scientists who will receive travel support				x			
Determine travel plans for those receiving travel support					x		
Provide travel stipend for airfare, registration, and other travel costs					x		
ISTA 9						x	
Submit final report							x
Convert all files to PDF and load to website							x
Ship half of remaining proceeding books to WAS offices in Baton Rouge LA							x

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INTERNET-BASED PODCASTING: EXTENSION MODULES FOR FARMING TILAPIA IN THE PHILIPPINES

Technology Adoption & Policy Development/Activity/09TAP02NC

Collaborating Institutions & Lead Investigators

North Carolina State University (USA)	Russell Borski
U.S. Department of Commerce, Milford CT (USA)	Christopher Brown
Central Luzon State University (Philippines)	Remedios Bolivar

Objectives

1. To build on our initial podcasting efforts by providing a complete series of podcast presentations to interested viewers (farmers, aquaculture students, etc.) to cover basic methods and current topics in a short, attractive, and readily accessible format.
2. Produce eight 5-minute tilapia-related podcasts, as the initial installment in a catalog of introductory and more advanced information on tilapia culture methodology, new production technology, cost-saving feeding practices, new publications, conferences, etc. These will be laid out on the AquaFish CRSP, Central Luzon State University CLSU) and North Carolina State University (NCSU) websites and will be fully updateable.
3. Train a student at CLSU and NCSU in podcast technology, to participate fully in the technical aspects of production of Tilapia Podcasts, and to build capacity for future podcasting in the host country. The individuals will train both in-person with project personnel and through online internet conferencing activities.
4. Build a database consisting of digitized materials found to be essential for podcasting purposes to include non-copyrighted photographs and background music – preferably representing the work of students, faculty, and farmers associated with the tilapia production community on Luzon Island in the Philippines.
5. As the layout and content of the CLSU/CRSP-based podcast website is developed and refined, efforts will be made to publicize and to promote access to it among aquatic farmers worldwide.

Significance

Podcasting is an internet-based communication method that is in the early phase of establishing popularity. In Phase I of our AquaFish CRSP, we produced and uploaded the first Tilapia Podcast to a trackable server at NCSU. It was downloaded > 100 times in the last month alone. The reaction to the initial launch of this current and cutting-edge technology at CLSU during a workshop was equally enthusiastic. CLSU recognizes this medium as an effective and low-cost means of sharing news and technical information. They correctly see it as a technologically advanced process in which CLSU is an innovator and a world leader, as opposed to a follower. The use of podcasts is not restricted to owners or users of iPods, and neither an iPod nor any other MP3 player is actually necessary for participants in and beneficiaries of podcasting. Podcasts can be accessed from desktop computers with internet access, and they are extraordinarily portable – they can be distributed on many cell phones or loaded onto "flash drives" or USB "memory sticks" and passed around among friends, including students and farmers. With a podcast, newly updated sound and/or images and video can be distributed at practically no cost to end users worldwide, and practical applications of this technology as a means of communication are clearly accelerating. At present there is almost no use of podcasting by aquaculture farmers, although the tremendous potential is clearly being recognized, particularly with the younger generation.

Our CRSP group has generated a range of practical improvements in culture methods of tilapia, some of which have increased the potential profitability for farmers. New feeding paradigms have already been widely recognized as having practical utility for Luzon area fish farmers. The essence of one such series of contributions is the reduction of production costs by using moderate

feeding strategies, without incurring any significant loss of product value or quantity (Brown et al. 2004; Bolivar et al. 2006).

The NCSU/CLSU group interacts actively with the fish-farming community. CLSU is an agricultural university and the surrounding fish culture areas are populated largely by families that have relatives and friends who have trained or are training at CLSU. The resulting relationship is an unusually healthy and trusting one – farmers welcome academic input and enjoy both extension and social components of campus life. Past activities of our project have included the production of scientific publications and fact sheets in the form of extension pamphlets, and we have also hosted training sessions and workshops at the School of Fisheries' Freshwater Aquaculture Center at CLSU. Farmers have been involved from the outset in large-scale experimentation and experimental production trials (e.g. Bolivar et al. 2006), and the first-hand involvement of farmers in research has a strongly favorable impact on the extension process. Farmers that have volunteered pond space to participate in tilapia production trials are the first to learn of technical advances, and methods that reduce costs and increase profit margins are adopted without additional extension effort. The tilapia farmers in Luzon Philippines, are an ideal group for the advancement of new extension methods. The aquaculture community in this region – the farmers, families, and CLSU fisheries people – are collectively friendly and receptive to innovative academic activities that have a focus on aquaculture.

Among recent extension efforts, our internet-based computing center at the School of Fisheries has grown increasingly popular. This center at the Freshwater Aquaculture Center is readily accessible and is heavily used by commercial farmers. Our Tilapia Podcasting Workshop was held there in early 2009, and was attended by about 35 people, many of whom were already regular visitors to the facility. For this reason, the computing center will continue to serve as the primary access site for tilapia podcasts, and we propose to involve CLSU students in production aspects of podcasts. We expect increases in both the rate and quality of new podcasts, especially so as CLSU graduate students and fisheries faculty become more involved in the technical components of their production. We also expect the networking and sharing of podcasts to grow – as available information begins to build, students and farmers will be able to download podcasts to digital phones and flash cards, to pass them around among interested user groups. Our goal is to develop a library of practical information in 5-minute components that can be distributed and shared almost effortlessly and at practically no cost in order to keep farmers technologically current. With the next phase of our project, a library of eight short tilapia-related podcast contributions will take shape through regular additions of new technological information and other announcements, in a low cost and easily-updated way. This phase of our podcasting work will keep the Luzon tilapia farming community well-informed, and very much on top of the latest technical information.

Quantified Anticipated Benefits

1. A series of 8 short, 5 minute podcasts will be created to inform the tilapia farming community of practical culture methods that include new and relatively thrifty feeding strategies and stocking schedules to reduce feed costs, without significantly compromising the performance of fish produced.
2. Two students or more from both CLSU in the Philippines and NCSU in the U.S. will be trained in production of podcasts, an emerging new extension tool.
3. Aquaculture extension podcast modules for tilapia culture will be developed for access by the world's tilapia research and farming communities.

Activity Plan

Location

Central Luzon State University in Munoz, Republic of the Philippines, will remain the focal point for elaboration of podcasts into an integrated series. One or more student from CLSU and NCSU

will be trained in the USA for the production of podcast material, in order to establish future capacity for podcasting activities.

Method

The three project investigators will collate technical information and generate a list of the most useful types of technical material to present in podcasts. These will represent a range of introductory and advanced subjects (e.g. genetically select strains of tilapia, feeding methods, culture in hapas) as well as the latest presentations from meetings of the World Aquaculture Society and its subsidiary regional groups.

The current format using narration set to still photographs and music will be elaborated to include short digital videos illustrating themes that are of importance to tilapia farmers. Relative to our initial 18-minute podcast, a shortened 5-minute format will be used for most podcasts. These will be made available to farmers and students as a series of presentations reviewing available options for effective tilapia production operations. The goal will be to build a collection of well-illustrated podcast presentations that are of practical value to students as well established farmers in the Philippines, and a series that can also serve as the basis for international exchanges of technical information.

The expansion of podcast content to include digital video clips will be facilitated both by the exchange of electronic subject material from the host country to the USA and by the initiation of podcast production activities in the Philippines. Training of Philippine personnel and podcast production (digital video and sound editing) will be done at a US institution. Podcasts will be added regularly, and the podcasts comprising this digital library will be updated as needed. Production goals will include brief and to-the-point presentations that refer interested users to greater depth elsewhere, and a comfortable visual and sonic "feel". The use of non-copyrighted music and video clips will illustrate the work and accomplishments of Luzon island area aquaculture farmers and academicians. The availability of the growing assortment of tilapia podcasts will be announced electronically near the end of our project, through appropriate aquaculture media and agencies such as the World Aquaculture Society. We will build a comprehensive and technically sound library of practical information that will encourage the refinement of tilapia culture methods in the Philippines, and one that will contribute to the international pooling of expertise on these subjects. Podcasts will be posted on CLSU, NCSU and CRSP websites for access by the research, extension and farming communities throughout the world. The number of downloads/hits on podcast modules will be monitored through the NCSU Information Technology site to obtain a preliminary assessment of its popularity and interest in podcasts. Once we have developed the podcasts modules, future work will evaluate the effectiveness of the podcasts through surveys/interviews of the farming community and farmer households.

Schedule

January - April 2010: Pick a highly computer-literate CLSU and NCSU student with aquaculture knowledge for training in tilapia podcast technology. April – September 2010: Collect digital video clips of technical tilapia production methods for incorporation into podcasts. Collect other un-copyrighted materials (music and photographs) suitable for use in podcasts.

June 2010 – August 2011: train one or more selected CLSU/NCSU students in the technical and editorial aspects of podcast production, with hands-on involvement in the development of a series of 8 podcasts, some illustrated with digital video, and each of approximately 5-minutes in length.

September 2010 – August 2011: Promote access to the complete podcast series among tilapia aquaculture end-users worldwide. Complete final report.

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DEVELOPMENT OF ALTERNATIVES TO THE USE OF FRESHWATER LOW VALUE FISH FOR AQUACULTURE IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM

Technology Adoption & Policy Development/Activity/09TAP03UC

Collaborating Institutions & Lead Investigators

University of Connecticut–Avery Point (USA)	Robert Pomeroy
Inland Fisheries Research and Development Institute (Cambodia)	Prum Somany

Objectives

The overall objective of this investigation is to transfer the alternative feeds technology to broader farmers and end-users for snakehead aquaculture in order to sustain aquatic resources in Cambodia and Vietnam.

To achieve the overall objective of the investigation, the following are the specific objectives:

1. To promote adoption of alternative feed technology through the farm adoption pilot.
2. To widen awareness and foster adoption of alternative feed to farmers in both project sites in Cambodia and Vietnam.
3. To produce an outreach document for end users in both Cambodia and Vietnam.

Significance

In the first phase of the project entitled "*Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Market*," a new alternative feed technology was developed for snakehead fish culture at Cantho University, Viet Nam. In the second phase of the project, the technology will be transferred to farmers. This new alternative feed technology will require conducting more on station pond trials and a farmer adoption pilot before the technology can be widely disseminated and transferred to the end users.

This investigation will document the result of the farmer adoption pilot and on station pond trial to compare the benefit of this new alternative feed technology to the current feed. The results will be widely disseminated to broader audiences. The adoption of this new feed will lead to reduction in the utilization of small size fish for snakehead culture in both Cambodia and Vietnam. Moreover, this investigation will lead to the establishment of effective linkages between researchers and communicators. The research result will be applied to develop appropriate technologies to disseminate technical information and to provide awareness and better understanding of the importance of low value fish, feed meal technology and feeding practices to the fish farmers which will significantly reduce dependence on capture trash fish for feed and feeding in aquaculture activities.

On the other hand, the result of this investigation will provide substantial information to policy makers to justify the use of new alternative feed technology developed by AquaFish CRSP to reopen the snakehead culture fish in Cambodia.

The Minister of Ministry of Agriculture, Forestry and Fisheries of Cambodia, in his letter banning snakehead culture on September 3, 2004, clearly indicated that detailed impact assessment of snakehead culture, and domesticated snakehead seed and formulated feed are available, the ban will be lifted. These investigations (# 2 & # 3: 09IND02UC and 09TAP03UC) have been consulted with the Ministry of Agriculture, Forestry and Fisheries (MAFF), particularly the Fisheries Administration (FiA) and the Department of Aquaculture Development. The government is not only aware of these investigations, but also very supportive to them, and the government of

Cambodia (i.e. MAFF and FiA) expects that these investigations will benefit at last 20,000 fish farmers who are waiting for restarting their snakehead culture operations, with the supply of domesticated seed and artificial plant protein feed in the future. Moreover, in phase 1 a one-day inception workshop was organized on 13 June 2008 at IFReDI, Phnom Penh to provide knowledge of understanding Project details and participated by senior fisheries officers/officials and policy decision markers from the Central Fisheries Administration (FiA) in Phnom Penh (i.e. all FiA divisions and R & D centers/institutes) and from Provincial Fisheries Administration (the seven project target provinces: Kampong Cham, Prey Veng, Kandal, Phnom Penh, Kampong Chhnang, Battambang and Siem Reap province) where the Project will be implemented in, universities (i.e. Royal University of Agriculture and Prek Leap National School of Agriculture) where undergraduate and graduate thesis students come from, and NGOs (WorldFish Center, FAO, JICA-FAIEX, MRC-Aquaculture/Fisheries Projects, OXFAM America- Fisheries Project, USAID-Aquaculture Enterprise Development Project- DAI, Spanish Aquaculture Project) who are working on aquaculture and fisheries development in Cambodia.

Quantified Anticipated Results

This investigation will provide direct and indirect benefit to different stakeholders such as: fish feed producers, 20 snakehead fish farmers for feed adoption experiments, aquaculture specialists, extension workers, and the people who live in Mekong Delta. The work will be especially important to women, children, and elders whom often involved in developing fishmeal, feeds, and fish feeding practices. This investigation will have indirect benefit to the fish consumers in the Mekong Delta from lower fish price due to the increased fish productions through appropriate information, fish feed technology, and management of fish feeding practices as well as indirectly affect to the poverty alleviation, improvement in food quality, and rural economic development in Southeast Asian country such as Cambodia and Vietnam.

Moreover, this investigation will train 50 fish feeds producers to be trainers and disseminate relevant information and appropriate technologies that developed by Aquafish CRSP project to 20,000 fish farmers (aquaculture and aquatic resource users).

The benefits of the investigation to the US are advances in extension and outreach methods to train poor fish farmers in new aquaculture technologies.

Activity Plan

The life cycle of this investigation work plan activities is 30 months and divided into two phases.

Location

The location of this investigation is in both countries Cambodia and Vietnam. However, three (3) investigation sites will be selected Kandal province in Cambodia and two (2) sites in Vietnam.

Methods

Since this is an activity type of investigation, experimental research design will be used to compare the effectiveness of the new feed developed by the AquaFish CRSP. The methods will be in form of on farm experimentation with snakehead fish farmers, outreach document, improve feeding practices, promote adoption, and change over to alternative feeds.

A total 20 of snakehead fish farmers will be selected for experimentation group for new feed technology adoption pilot. Each country 10 snakehead fish farmers will be selected for experimental group based on meeting the criterion such as 1-poor snakehead fish farmer (women household head with more children is preferred), 2-have cage or pond for snakehead fish culture, 3-willing to do snakehead fish culture with the project without changing feed, and 4-innovative and active famer. Selected farmers will be provided all pond inputs (fingerlings and feeds) for six months. All snakehead culture fish farmers will be provided a record book and they will be

required to keep daily records of all relevant information related to fish culture such as: amount of feeding and fish mortality and monthly records on fish growth rate and fish size.

Two graduate students will be supported for their research theses to determine the success and adoption of the new feed technology developed by AquaFish CRSP through the two research thesis topics on 1-the impact of snakehead culture by using the new feed technology of the selected farmer and 2- the effectiveness and level of adoption of new feed technology. These two research studies will give us substantial information for assessment and evaluation the farm trial.

Research assistants and students will monthly assistto train farmers in the use of record books and how to take all fish parameter measurements. These assistants will periodically conduct site visits to ensure protocol is being followed and is consistent among farms involved in the pilot project.

Schedule

1. Phase 1, (9 months) January 01 to September 30, 2010: Set up on Farm Feed Adoption Experimentation.
   a. Select exact sites for targeted farmer adoption pilot in both countries.
   b. Make a preliminary assessment of potential problems of those farmers.
   c. Provide pond/cage inputs and fingerlings and logbook
   d. Provide training for log book use and fish parameter measurements
   e. Schedule follow-up site visits

2. Phase 2: (12 months) October 01, 2010 to September 30, 2011: Design and Implementation of Information/Communication Plan for Technology Adoption.
   a. Follow up activities and record keeping.
   b. Develop report on the progress of the farm adoption pilot.
   c. Produce prototype multimedia messages and training materials according to local Information/Communication Plan.
   d. Implement local Information/Communication Plan in project sites.
   e. Prepare final report.

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HARNESSING THE OPPORTUNITIES AND OVERCOMING CONSTRAINTS TO WIDESPREAD ADOPTION OF CAGE AQUACULTURE IN GHANA

Technology Adoption & Policy Development/Study/09TAP04PU

Collaborating Institutions & Lead Investigators

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Introduction

Sub-Saharan Africa has abundant land and water resources, but these have not been tapped to increase aquaculture production significantly in global terms. Therefore, the Word Bank and its partners have sharpened focus on commercial aquaculture development in the region (World Bank 2007). Recent analyses of conditions needed for adoption and sustainability of growth of African aquaculture (Jamu and Ayinla 2003; World Bank 2007) have identified about a dozen factors some of which are: (1) perception of the value of fish as food and for generating income, (2) land ownership, ability to rent, or secure access to common property water resources, (3) increases in production intensities and efficiencies, (4) knowledge of technologies suited to available resources and conditions, (5) a widening of the range of production systems, (6) developing management technologies for indigenous species that target local niche markets, (7) putting more emphasis on marketing and processing of high value products, (8) institutional support (e.g., research and development, extension, supply of seed), (9) promotion of research on how aquaculture can respond to changing macroeconomic policies, and (10) acceleration of the disengagement of government from activities that can be best done by the private sector.

The foregoing factors are listed in the order that in our opinion roughly reflects both the inevitable and increasing need for involvement of public institutions at every step of the development process. Sub-Saharan Africa and, in particular, Ghana aquaculture development may have stagnated not because of a lack of involvement of public institutions in the past but because the roles of these institutions have not been applied in proportion to the needs. The World Bank's (2007) diagnosis of the problems of past failed aquaculture development programs in sub-Saharan Africa can be summarized as public institutions operating mostly at levels (1) - (3), where the private sector or public-private partnerships may do equally well with stronger public sector involvement at the higher levels of need. Jamu and Ayinla (2003) emphasized addressing problems from the perspective of production systems, culture species, marketing, and policy. In this proposed work, our focus will be on production systems and culture species. Jamu and Ayinla (2007) noted a relative lack of public sector research and development attention to alternative culture systems (e.g., cage culture) in Africa and recommended increased attention to alternative production systems while striving to increase intensity and production from the traditional earthen ponds. Likewise, the authors identified progress made in Nigeria and Egypt in the production of species other than the tilapias as dictated by local demands for those alternative species, leading to their recommendation of expansion of production of high-demand indigenous species for niche markets.

Aquaculture development should balance the quest for economic growth with biodiversity conservation and environmental impact concerns. "The challenge of sustainable aquaculture is to contribute to national objectives for economic development and food security while simultaneously addressing poverty reductions and environmental protection" (World Bank 2007). The development of alternative species with emphasis on indigenes provides guarantees against potential biodiversity degradation that could result from unbridled spread of aquaculture species. In fact the USAID sees culture of indigenous species of high local demand as direct biodiversity

conservation activity because this takes pressure off wild stocks (USAID 2005). Numerous opportunities exist for development of new species and expansion of the variety of production systems in Ghana. As a business model, diversification of species and systems provides a safety net and access to new markets for investors. Adoption of alternative productions systems should be dictated by economic and ecological considerations if the alternatives do not present clear relative disadvantages of environmental impacts.

The proposed work consists of two complementary investigations: Investigation #1 is a study of the opportunities and challenges to the adoption of cage culture as an alternative production system in Ghana. Together, these two investigations will produce and extend valuable insight not currently available to farmers, the private sector of Ghana, or government institutions. We expect the results to contribute to diversification and rapid acceleration of aquaculture development in Ghana and the sub-region.

Objectives

1. Identify the main constraints to cage aquaculture in Ghana
2. Examine opportunities that may be exploited to encourage cage aquaculture development
3. Conduct training needs assessment for cage aquaculture farming
4. Provide awareness and targeted training for potential and current cage fish farmers

Quantified Anticipated Benefits

1. A clear and accessible policy-relevant document on the strengths, weaknesses, opportunities, and threats (SWOT) analysis of cage culture in Ghana.
2. Informed and targeted recommendations to policy makers and the private sector on opportunities for acceleration of profitable cage aquaculture in Ghana.
3. A non-technical brochure for dissemination of cage culture information to prospective adopters of the technology.
4. At least 20 current and prospective fish farmers trained in cage culture to take advantage of vast open water resources in the country.
5. In the long-term, increases in the adoption of cage culture at least 100% above current levels following policy changes.
6. Cage culture in the US has not received much attention. Results from the study, especially SWOT analysis will provide insights into strategies for adopting cage culture in regions of the US where there are large private water bodies.

Significance

Fish is the main source of animal protein in most Ghanaian diets and accounts for about 60% of the protein intake of the people. Conventional fish farming started in Ghana in 1950 as an initiative of the colonial powers. This initiative remained morbid until in the early 1980s, when a nationwide campaign by the then military government resulted in a rush into fish culture. Consequently, the first experimental fish farm was established in the Upper West Region in 1985. During 1982-1985 the number of fish ponds increased from 578 to 1390. In 1986 the number rose to 1400 covering an average surface area of 685 m^2 at the beginning of 1994, fish production from artificial waters was estimated as 500t involving 1,000 farmers in 1997, the Fisheries Sub-Sector Capacity Building Project estimated 3330 ponds with a total pond area of 242.7 ha with yields of 700t/year. A mid-term evaluation in 1998 put the yield figures at 1000kg/ha/yr. Since the 1990s there has been a steady increase in the number and of fish ponds and fish farmers, with some venturing into cage culture. The overall contribution of aquaculture alone to the economy of Ghana has not been separated from the contribution of fisheries. Livelihood opportunities are usually those related to marine and inland capture fisheries. Recent studies by the AquaFish CRSP have established the economic profitability of tilapia farming in rural Ghana. Training in some aspects of fish farming and outreach activities by AquaFish CRSP in partnership with the Ministry of Fisheries has generated interest in fish farming.

Cage culture was introduced on a trial basis in the 1980s when a momentum for aquaculture development grew and the need for aquaculture research received government recognition as part of national development plans (Masser 1988). Multilateral and bilateral donors increased technical assistance, and aquaculture started to develop more solidly. Recently, the general development policies of several African countries have been changed to recognize aquaculture as an independent sector (FAO 2001). Cage culture is an emerging activity in Ghana although there are currently only a few in the country. The country offers a considerable scope for the commercial-scale development of freshwater cage culture, especially in the Volta Lake and Lake Bosumtwi. To encourage more people into fish farming and provide alternative livelihoods in the face of dwindling capture fisheries, the government of Ghana has allocated 1% of the total surface area of the Volta Lake (the world's largest man-made lake found in the Eastern Region of Ghana) for cage culture of fish. To put things in perspective, 1% of the area of Volta Lake corresponds to the area of a square with a side of approximately 10km− a vast amount of surface water resource available for cage culture. For reasons that remain fairly obscure, not many individuals or corporations have taken advantage of this opportunity and there are only two main cage aquaculture ventures on the Volta, despite the ever growing demand for tilapia and other freshwater food fish. The main commercial ventures are Crystal Lake Fish Ltd. and Tropo Farms Ltd. both located on the Volta Lake. Established in the 1990s, Crystal Lake Fish Ltd. grows indigenous tilapia, *Oreochromis niloticus* in ponds and concrete tanks. Tropo Farms on the other hand, has been pond farming for 6 years till 2005 when they developed a pilot scale cage site on the Volta Lake near the Akosombo dam. Tropo Farms grows the indigenous *O. niloticus* as well.

The FAO regional technical workshop on cage culture in Africa (FAO 2004) identified numerous potential constraints to cage aquaculture, including occupational risks and significant skill requirement. The workshop concluded that

> "*This makes entry for the poor difficult, and they will require much support if they are to succeed. Larger enterprises have the resources that allow them to make mistakes, learn, survive, and ultimately thrive. But unless they engage the local community through quality employment, supply enterprises, and possibly out-grower schemes, they are likely to encounter resistance and in some cases conflict. Fishers in particular may perceive their livelihood to be threatened*."

Obviously, having significant national water resources set aside for cage culture is an important first step, but national development policy for cage culture should be cognizant of other complex and interacting set of constraints. Other major constraints to aquaculture development are feed and seed availability, quality, and cost as well as cage design and construction and financing (FAO 2004). Observations and interviews during the 2008 National Best Fish Farmers survey in Ghana revealed that there is a lack of knowledge and training in cage aquaculture and the lack of extruded feeds (S. Amisah, pers. comm.). Also, banks and financial institutions are skeptical of investing in cage aquaculture ventures. In 2005, a Ministry of Fisheries was created to develop and advance fisheries and aquaculture in Ghana and a new draft aquaculture policy was in place. Unfortunately the Ministry has again been placed under the Ministry of Agriculture in 2009 by a new government. It is unclear how this has affected cage culture initiatives and there is a need to assess this impact. The slow adoption of cage culture in Ghana appears to be a problem with both the public and private sectors and with individual/subsistent and business enterprises. A comprehensive study is needed to inform policy makers and move cage culture past its current sluggish growth.

Research Design & Activity Plan

Location

Study will be conducted in Ghana by Ghanaian and US experts on the Volta Lake and communities in the Eastern Region and the Lake Bosumtwi and communities in the Ashanti region.

Methods
Interviews, structured questionnaires, and participatory appraisals will be employed to target government and civil institutions, current and prospective cage farmers and their communities. We plan to draw from diverse perspectives including policy makers, banks and private investors, current aquaculture enterprises, and inhabitants of communities in the vicinity of the Volta and Bosumtwi Lakes. Including all relevant stakeholders will ensure that future policies address the economic, social and environmental objectives of these stakeholders. The concerns of resource-poor farmers who have been the target of cage culture policy but have not taken advantage of available water resources will be foremost so that this study's contribution to poverty reduction, food security, competitiveness of farm enterprises, and sustainable resource use will be significant.

At the beginning of this study, a strong partnership with Ghana's Ministry of Agriculture Fisheries Directorate (MOA-FI) will be established through communication of the goal of this study and its timeline in writing to the Ministry. The PIs will personally contact the minister of agriculture to request the identification of a government liaison to the project. This individual will be the primary link between the project and the MOA-FI. A similar partnership arrangement will be sought with the FAO regional office in Accra, Ghana. These partnerships are expected to provide a more structured input and direction from the government and institutions that would be the first users of the research outcome from a policy standpoint. Specific activity components will include:

1. Schedule desk studies and interviews with representatives of MOA-FI to obtain details of the government's policy for cage culture and clarify the objective of the policy. A clearly stated policy objective or end state is required for SWOT analysis (Zang et al. 2007). The government will 'own' the result of this project by being involved in the definition of the objective.
2. Schedule interviews with five representative major agricultural lenders/banks to evaluate levels of awareness, interest, and concerns about cage culture in Ghana.
3. Tour and interview entrepreneurs in the aquaculture business, especially those who have tried cage culture. The two established cage culture businesses on the Volta Lake, Crystal Lake Fish Ltd. and Tropo Farms Ltd., will be the primary target of these interviews to obtain an in-depth understanding of the practitioners' challenges and opportunities.
4. Design and administer questionnaires and focal group meetings in communities of the Volta and Bosumtwi Lakes. Target will include both people already employed in fish farming and those who might enter fish farming, including men and women in all aspects of culture and capture fishing and trade. A sample size of at least 30 will be targeted at each site for questionnaires and 4-8 group size in 2-3 focal groups at each of the two sites.
5. Analyze data from diverse sources and integrate responses in a SWOT analysis framework to identify alternative strategies to improve or convert weaknesses to strength and mitigate threats or map threats unto opportunities for cage culture.
6. Organize an informational meeting with stakeholders and a basic training workshop in areas of need that are identified for current and prospective cage farmers through the SWOT analysis. The partnerships that will be established at the beginning of this study with the MOFI and FAO regional office and other relevant institutions will be harnessed in designing the most efficient training programs that minimize duplication of institutional efforts within Ghana to develop cage culture. At the information meeting and workshop, various technical and non-technical documents resulting from this project will be distributed to the appropriate entities.

Potential Risk of Investigation
The main risk of implementing this investigation is a potential disconnect between government policy objectives and the project objectives. That could lead to research activities that the government would be nonchalant about or even oppose. We have included explicit statements

about early inclusion of the government through the ministry of agriculture in the definition of objective that will guide the whole study. We will also keep the government involved through a liaison up to the end of the study and participation in workshops and training programs.

Schedule: Start date: October 1, 2009 End date: September 30, 2011

Activity/Month	O-D 09	J 10	F 10	M 10	A 10	M 10	J 10	J 10	A 10	S 10	O 10	N 10	D 10	J-S 11
Interviews, Survey Design and Pre-tests	x													
Survey pretests and refinements		x	x	x										
Survey administration				x	x	x	x	x	x					
Data analysis										x	x	x	x	
HC Training Workshop														x
Reports & Distribution													x	x

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ASSESSMENT OF AQUAFISH CRSP TECHNOLOGY ADOPTION AND IMPACT

Technology Adoption & Policy Development/Study/09TAP05OR

Collaborating Institutions & Lead Investigators

Montana State University (USA) John Antle

Objectives

1. Further develop "minimum data" (MD) methods and software for assessing the adoption and economic, environmental, and health impacts of agricultural technologies.
2. Train AquaFish CRSP project personnel to use MD methods and software in current and possible future investigations.
3. Collaborate with AquaFish CRSP project personnel to assess impacts of selected technologies, using sustainability indicators such as fish farm and trader income, environmental quality, human health, gender, and other social outcomes.

Significance

There is a growing demand for assessment of economic, environmental, health, gender, and other social impacts of agricultural technologies, yet doing so is often infeasible due to the time and resource demands of methods involving spatially-explicit data and complex models. Moreover, most impact assessment methods depend on process-based models and therefore cannot address gender and other social impacts. This investigation will extend recent methodological developments in research on ecosystem services, to develop *parsimonious* methods for impact assessment that can be implemented at reasonable cost, yet can also be sufficiently accurate to inform policy ad technology assessment. These methods are based on population-level statistical data, and therefore can address environmental impacts as well as human health, gender, and other social impacts. Research, training, and outreach activities have impact only if disseminated and adopted by downstream decision makers. Quantifiable project impacts (addressed in the present Investigation) thus must be distinguished from research discovery (addressed in Investigation # 1, 09BMA07OR). Impacts will be evaluated in the present using indicators such as farm income, water quality, human health, and gender impacts to the extent practicable given available data. The Technology Adoption and Policy Development topic area under which this objective falls is part of the AquaFish CRSP's *People, Livelihoods, and Ecosystem Interrelationships* topic area goal.

Quantified Anticipated Benefits

This investigation will provide at least three types of benefits to US and host countries and the larger scientific community. First, US and host country personnel will receive training in the use of impact assessment methods, and will be provided with software tools they can use in current and future projects to carry out impact assessments. Second, impact assessments will be implemented for selected investigations from current (2009 – 2011) AquaFish investigations. Third, the further development and refinement of impact assessment methods will be of general scientific value, and will benefit other ongoing projects that will also be using the methods and tools developed here (see Leveraged Activities).

This Investigation will produce the following deliverables: a report on the impact assessment methods; training materials and software developed for the project; papers suitable for publication reporting the methods and findings of the assessments. Progress on the Investigation will be monitored through quarterly and annual reports, presentations at annual AquaFish meetings. Outputs to be monitored are: (a) completion of the intermediate steps listed below; (b) refereed journal articles and other reports, (c) project-country graduate student involvement, (d) strengths of linkages with AquaFish and other CRSPs.

Leveraged Activities

The minimum-data methods and software that will be the basis for this investigation are already being disseminated and utilized in projects around the world. Current or recent collaborations include:

- A project on adaptation to climate change in East Africa, in collaboration with the International Potato Center (CIP), funded by the German government (GTZ).
- The OASIS drylands project managed by ICARDA, funded by USAID (completed in September 2009).
- The Agricultural Policy program at the Gates Foundation, which is using the Tradeoff Analysis concept in its development of impact assessment tools for projects it funds, and is planning to use the TOA-MD methods and software to evaluate impacts of projects it is funding. There may also be the opportunity to link training carried out under this project to training of investigators from Gates-funded projects.
- Projects in West Africa on pest management, being coordinated by the Integrated Plant Protection Center at Oregon State University.
- A project on endemic ruminant livestock breeds in West Africa, coordinated by the International Livestock Research Institute (ILRI).
- The Long Term Agricultural Research Site being developed at Montana State University, funded by USDA.

These projects have either already participated in training and use TOA-MD methods and tools, or have expressed an interest in doing so in the future. These training sessions could be coordinated with AquaFish training. In addition, more than 100 institutions have downloaded TOA-MD software and many are using it in ongoing projects. The AFCRP project can contribute indirectly to these activities and also benefit from the ongoing program to develop and disseminate these methods and software tools.

Finally, it is anticipated that future research programs at CGIAR centers and future USAID CRSP projects will benefit from the methods and tools developed in this project.

Research Design & Activity Plan

This Investigation will utilize both *ex ante* and *ex post* impact assessment methods to evaluate the potential adoption of AquaFish CRSP technologies and their impacts. AquaFish projects describe a wide array of possible impacts, both on-farm and off-farm. The on-farm benefits range from on-farm improvements in productivity and on-farm sustainability, farm income, and improved health and well-being of farm household members. Off-farm impacts include reductions in adverse effects of aquaculture systems on water quality and food safety, and improvements in the well-being of consumers of fish products due to increased availability, quality and safety. A combination of *ex ante* and *ex post* methods is appropriate because adoption is an ongoing-process that will continue after the projects are completed. Thus, *ex post* assessment will be carried out in cases where technologies have already been widely disseminated and adopted, whereas a combination of *ex ante* and *ex post* methods will be used in cases where further future adoption and impacts are likely to occur.

Assessing all of these potential impacts would be daunting even if the assessment had been planned at the outset of AquaFish CRSP projects and incorporated into the research design and data collection. Because impact assessment now sought by the AquaFish CRSP is mostly after-the-fact, and subject to substantial time and budget constraints, it is anticipated that it will be possible to assess some but not all of the technologies, and some but not all of the impacts.

The most significant constraint to the assessment of AquaFish CRSP impacts is data. Inevitably, when impact assessment is not designed into projects from the outset, data needed for impact assessment is lacking and difficult to obtain after-the-fact. It is remarkable that most impact

assessment methods are designed as if data and other resources are costless and unconstrained, whereas the reality is normally closer to the situation encountered in this investigation. The methods proposed for the present investigation – referred to henceforth as "minimum-data" (MD) methods – are designed to facilitate impact assessment when time and data are significantly constrained. In addition to being useful for AquaFish CRSP, these methods should be valuable in impact assessments in many other programs where time, data, and other resources face significant limitations. Another advantage of these methods is that they can be learned and used by scientific teams at much lower cost that more complex, "full data" (FD) methods of impact assessment. Validation studies carried out thus far have shown these methods are sufficiently reliable for technology impact assessment and policy design, in the sense that they can approximate results from FD analyses (Antle and Valdivia 2006; Antle et al. 2009). Nevertheless, the reliability of both MD and FD methods remains an important topic for research on impact assessment methods.

A New Approach to Impact Assessment: Minimum-Data Tradeoff Analysis (TOA-MD)
A suite of methods has been developed for impact assessment of agricultural technologies (e.g., Alston, Norton and Pardey 1995). A good example of these methods is the IPM CRSP Global Theme Initiative on Impact Assessment. This initiative proposes to apply a common set of methods across regional IPM CRSP projects that establish linkages among data, methods, and impacts at various geographic scales and on different types of outcomes. The methods include ones that all regional sites will be expected to implement as well as more specialized methods for in-depth assessment of specific aspects of the IPM CRSP program. These methods involve quantitative and qualitative analysis of technology adoption, and estimation of market-level economic impacts on producers and consumers. Specialized in-depth assessments of poverty, environmental, and nutritional impacts of IPM packages also will be undertaken. Importantly, these methods include the systematic collection of data, in collaboration with research projects, over a 5-year project cycle, training of collaborating scientists, and utilization of common data sets collected in the previous 5-year funding cycle.

There are a number of important differences between what the IPM CRSP Impact Assessment will do over a 5-year project cycle and what is being proposed here for the AquaFish CRSP in a two-year project. In addition to the shorter time horizon and smaller resource commitment, a crucial difference is that the AquaFish assessment is after-the-fact, meaning that comparable data cannot be collected for the AquaFish assessment. Another important difference between the two CRSPS is that the IPM CRSP is evaluating a suite of technologies that are more similar than the range of technologies being investigated in the AquaFish CRSP, thus facilitating the use of a common approach across regional projects. Finally, within the two-year time frame of the AquaFish assessment, a specialized in-depth assessments of poverty, environmental and nutritional impacts comparable to what the IPM CRSP plans is not feasible

This investigation proposes an alternative methodology that will be referred to as "minimum-data tradeoff analysis" (TOA-MD). This methodology utilizes two recent methodological developments in impact assessment. First, it will utilize the conceptual model underlying the development of "Tradeoff Analysis" (TOA). TOA is an approach to participatory integrated assessment of agricultural systems designed to quantify economic, environmental and human health impacts of agricultural technologies and policies (Antle et al. 1998; Stoorvogel et al. 2004). TOA can be implemented using software designed to integrate spatial data, bio-physical process-based simulation models, and economic simulation models. TOA can be used to assess impacts on poverty and sustainability (e.g., Antle and Stoorvogel 2008), but is data-intensive and its use requires a highly-trained multi-disciplinary scientific team (Antle and Stoorvogel 2006). Such applications would be similar to the specialized in-depth assessments being carried out by the IPM CRSP impact assessment initiative.

Second, the TOA-MD approach proposed here will build upon the full-data TOA approach by incorporating the MD methods developed by Antle and Valdivia (2006) for analysis of ecosystem

services associated with agricultural systems (for applications, see Immerzeel, Stoorvogel and Antle 2008, Nalukenge, Antle and Stoorvogel 2009, Claessens, Stoorvogel and Antle 2009; Stoorvogel et al. 2009). The MD approach utilizes existing data on productivity, costs and returns to simulate the rate of adoption of technologies, and impacts of adoption on farm income and provision of ecosystem services, in a spatially-heterogeneous producer population. An important feature of the approach is that producers are assumed to be heterogeneous with each adoption domain, with their heterogeneity characterized using data measuring the spatial variability in productivity. Thus, the analysis produces a predicted adoption rate in each adoption domain, and then allows impacts to be estimated based on this adoption rate. This approach provides a more reasonable approximation to adoption behavior and impact than conventional methods based on "representative farm" models, which are unable to predict adoption rates and which must extrapolate average impacts from one "representative farm" to the population.

The MD adoption analysis can then be linked to analysis of other environmental, health, gender, and other social impacts to the extent that suitable data are available. Recent research by the PI shows that it is possible to substantially reduce data requirements for environmental impact assessment by using the MD approach. Moreover, the statistical approach taken to population-level impact assessment makes possible analysis of health, gender, and other social impacts that cannot be addressed using conventional impact assessment methods that use process-based models. The adoption analysis can be linked to market surplus analysis to estimate impacts on producer and consumer economic welfare, similar to what is planned for the IPM CRSP, to the extent that suitable data are available. Data templates and software have been developed for implementation of the MD technology adoption model and have been utilized in the Soil Management CRSP and other on-going research programs at CGIAR Centers. These tools provide a useful foundation for data collection in collaboration with AquaFish project personnel (see the training plan below).

As noted above, the MD impact assessment methods being developed are suitable for evaluation of age, gender and other social impacts of technologies. For example, an aquaculture technology that improves protein availability to farm households may have differential impacts on the health and nutrition of children or women. If those differences can be measured in the sub-populations of households not using and using the technology, in terms of the mean and variance of nutritional status in those sub-populations, these parameters can be used to incorporate nutritional impacts of the technology into the impact assessment. The impact assessment team will: (1) train AquaFish CRSP collaborators how to utilize this methodology; (2) work with collaborators to identify any gender impacts of technologies; and (3) incorporate any such data and analyses into the assessments carried out.

The MD modeling approach is currently implemented for analysis of technology adoption and ecosystem service supply. It is available in an Excel spreadsheet which incorporates documentation, a user guide, sheets for data entry, and a graphical user interface to run the model and manage model output (e.g., adoption rates, changes in farm income, and supply of ecosystem services). For AquaFish CRSP, this Excel model will be expanded to include sheets for incorporation of other environmental impacts (e.g., off-farm water quality) and human health and gender impacts. This TOA-MD model will be designed to output simulation results in the form of tradeoff curves which show, in a two-dimensional format, the combinations of outcomes (e.g., farm income, environmental impacts, human health impacts, and gender impacts) that are associated with a range of prospective rates of technology adoption.

The rates of technology adoption in the analysis are based on profitability of the technologies, other possible constraints on adoption such as financial, and any other positive incentives provided to farmers such as payments for ecosystem services. The structure of the model also allows the user to evaluate a baseline adoption rate that could be achieved under existing conditions, and how much additional adoption could be induced if there were changes in

economic conditions or additional financial incentives provided. The model will also output data in files that can be used to display results on maps and in tabular form.

TOA-MD Training and Implementation

The MD model has been disseminated for use in the Soil Management CRSP and projects managed by CGIAR centers through a series of workshops. The same approach is planned for the AquaFish CRSP, using two workshops held in conjunction with the CRSP annual meetings as well as in a project planning meeting discussed below under Investigation #3 (09TAP06OR). In the first annual workshop planned for the 2010 annual meeting, the methods and software will be introduced to US PIs and HC investigators. We will seek as much as possible to apply the impact assessments to the same investigations as are used for the case studies. Those investigations will be selected on the basis of purposive (stratified) random sampling, as explained on page 7. PIs will be asked to identify one member of their investigation team to lead the impact assessment activity (impact assessment leader – IAL). Subsequently, a meeting will be held for these IALs, as discussed in Investigation #3 (09TAP06OR) below. In addition, PIs will be encouraged to select personnel from other investigations who could become IALs in future CRSP or other research projects. After this planning meeting, the IALs will assemble data needed to implement the assessment. In a Second Annual Workshop, held in conjunction with the next CRSP annual meeting in 2011, each project will present their data and their preliminary analysis, and the impact assessment team will work with them to finalize the analysis.

Workplan for Investigation No. 2 (with expected completion dates)	
Step	Year One
1.	Prepare TOA-MD software for use. Task 1. Add data sheets to model to incorporate environmental and health impacts. (February 2010) Task 2. Update documentation. (June 2010) Task 3. Program and test TOA-MD model in Excel. (September 2010)
2.	Review AquaFish CRSP projects and document technologies under development. (September 2010)
3.	Prepare materials for First Annual Workshop at the CRSP Annual Meeting in San Diego. (February 2010)
4.	Carry out the First Annual Workshop at the annual meeting in 2010, identify investigations for assessment and impact assessment leaders (IALs) for each. (March 2010)
5.	Provide technical support to IALs as they collect data and implement analysis. (September 2010)
6.	Draft reports and publications on methodology and each technology assessment. Task 1. Methodology report. Task 2. Technology reports. (September 2010)
	Year Two
1.	Plan impact assessment aspects of Second Annual Workshop, 2011 AquaFish Annual Meeting.
2.	Continue Steps 5 and 6 from Year 1 (October 2010 – April 2011)
3.	Prepare and conduct the Second Annual Workshop at the 2011 Annual Meeting. (April 2011)
4..	Assist collaborators to carry out TOA-MD analysis and market surplus analysis for each technology, as feasible. Task 1. Complete TOA-MD analysis. (August 2011) Task 2. Complete market surplus analysis. (August 2011)
5.	Complete reports and draft publications. (September 2011)
6.	Present findings at CRSP Annual Meeting (April or June, 2011)
7.	Report methods and results at a professional meeting such as the Agricultural and Applied Economics Association. (August 2011)

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PROJECT PLANNING MEETING ON AQUAFISH TECHNOLOGY DISCOVERY AND IMPACT ASSESSMENT

Technology Adoption & Policy Development / Activity / 09TAP06OR
Production

Collaborating Institutions & Lead Investigators

Montana State University (USA)	John Antle
Oregon State University (USA)	Steve Buccola

Objectives

Train host-country personnel in methods of assessing technology discoveries and impacts.

Significance

Much of the data collection – and many of the insights – associated with the proposed project will be generated under our direction by the other seven AquaFish projects' host-country investigators. Because this assessment work requires technical skill and judgment, it is essential that all participants agree how to conduct it, and to allow comparisons of results across projects and investigations. Furthermore, determining best practices will allow host-country investigators to conduct future aquacultural technology assessments.

Some of this discussion will take place at the two Annual Workshops we will hold in conjunction with the AquaFish Annual Meetings, and in the course of our investigation site visits. For the HC personnel who will be most involved in assessment information collection work, a four-day planning meeting devoted entirely to the discussion of assessment methods is also necessary.

Quantified Anticipated Benefits

Although the assessment procedures shared at this conference will be expressed in terms of, and applied directly to, aquacultural research and outreach, they will be easily applicable to other technologies as well. Thus, the outcomes of this planning meeting will allow HC personnel to serve their communities' and countries' development interests. Quantifiable benefits include number of attendees, number of technologies addressed, and number of host-country institutions involved.

Activity Design

Location and dates of work: Seattle, October 4 – 7, 2010

Methods:

Furthering the goals of Investigation #1 (09BMA07OR) above, 14 AquaFish HC investigators (2 from each of the 7 current AquaFish projects) will attend the meeting to participate in discussions about:

(a) technology input-output characterization and estimation, and
(b) Bayesian probability estimation, updating, and inference.

Approaches to be covered in these sessions include Buccola (2008), Carlin and Louis (1996), and Fare and Primont (1995).

Furthering the objectives of Investigation #2 (09TAP05OR), the same HC investigators will discuss:

(a) identifying impact indicators,

(b) data needed to implement minimum-data impact assessment, and
(c) the use of the minimum-data model software.

Approaches to be considered include Alston, Norton, and Pardey (1995); Antle and Valdivia (2006); and Antle et al. (2009).

Investigation deliverables will consist of:

(i) research-discovery documentation and training materials;
(ii) minimum-data software, documentation, and end-user materials.

Schedule

A one-hour plenary session will be held each morning to cover material that is common to research-discovery and research-impact assessment. During the remainder of each day, participants will be divided into two groups, one discussing discovery assessment and the other impact assessment. The groups will be rotated each day so that equal time is spent on discovery assessment and impact assessment methods.

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TOPIC AREA
MARKETING, ECONOMIC RISK ASSESSMENT & TRADE

❖

MARKET ASSESSMENT AND PROFITABILITY ANALYSIS OF AQUACULTURE ENTERPRISES IN UGANDA

Marketing, Economic Risk Assessment & Trade/Study/09MER01AU

Collaborating Institutions & Lead Investigators

Alabama A&M University (USA)	James O. Bukenya
National Fisheries Resources Research Institute (Uganda)	Gertrude Atakunda
	John Walakira
Makerere University (Uganda)	Theodora Hyuha
Gulu University (Uganda)	Nelly Isyagi

Objectives

1. Conduct economic evaluations of selected aquaculture enterprises to enable producers, extension personnel, and other decision makers to more accurately assess the potential of commercial aquaculture enterprises in Uganda.
2. Assess financial mechanisms used in fish production, marketing and processing in terms of marketing-related financial flows and transactions.
3. Identify investment requirements, credit needs, and financial channels for aquacultural development, and how these could be augmented to provide better services to the sector.

Significance

Until recently, most fish farmers in Uganda were poor people in villages who practiced aquaculture for subsistence with ponds of usually less than 500 m² constructed using family labor (Jagger and Pender 2001; Nyombi and Bolwig 2004). These were low or no input production systems, with little or no need for routine management. Those who had some training in the management of ponds usually fertilized their ponds with either chicken droppings or cow dung and any other organic house waste (Ministry of Agriculture Animal Industry and Fisheries 2000**)**. Production was usually in the range of 5 kg to 10 kg/100 m² (i.e. 500 kg to 1,000 kg per hectare) per annum. However, with rising market prices for fish, government intervention, the quest for profitable production, and stagnating supply from capture fisheries, farmers are beginning to build more and larger ponds of 1,000 m² or more, and using higher stocking densities (Department of Fisheries Resources 2005). Current estimates are that 20 percent to 30 percent of the smallholder subsistence ponds have been transformed into small-scale commercial production units (Department of Fisheries Resources 2004). However, before deciding whether to undertake, continue or to expand a commercial aquaculture enterprise, a prospective aquaculturist needs to evaluate profitability.

Also, the importance of the fish export earnings for the Ugandan trade balance is one of the reasons that, in recent years, most government attention has been directed towards export. Recent statistics show that Uganda's fish exports to the premium markets of the European Union, US, Japan and the Middle East currently stand at US$150 million (Shs240 billion). Exports to the regional markets of South Africa, the Great Lakes Region states of Democratic Republic of Congo (DRC), Rwanda, Burundi and Sudan stand at between US$30million and $40 million (Eurofish 2007). With this emphasis on exports, the study of the domestic market for fish and fishery products has not received the attention it deserves. However, domestic marketing affect the performance of the fish-exporting sector given that all fish products, before being exported, have to pass through some stages in the domestic market. Efforts to ameliorate information on domestic fish marketing and on identifying

constraints and opportunities for the improvement of production and marketing arrangements are thus paramount. [1]

Quantified Anticipated Benefits

3. The main target groups are individual farmers and rural communities. The findings will reveal the potential for commercial fish farming at small-scale enterprises and availability of local markets.
4. Participating fish farmers will directly benefit from this work. They will be informed of the results of the study and will receive recommendations on the most profitable practices, levels of income stream that would yield higher returns and samples of developed enterprise budgets and cash flow plans.
1. The sector provides employment to fishermen, fisher mongers and those employed in fish processing. Therefore, enhancing the profitability of the sector has an important direct and indirect impact on poverty reduction efforts in Uganda. The direct benefits arise from direct dependence on the fisheries, especially the lake communities. Indirect benefits arise from secondary employment through services that are provided in support of fisheries.
2. The results of this research will be used by other investigators in this project by providing data for validating economic feasibility of different aquaculture production systems.
3. The project will strengthen the capacity of NARO to disseminate the findings of this project and identify the needs for possible follow-up activities in the field of fisheries products marketing in Uganda.

Research Design & Activity Plan

The project will comprise of two main subcomponents which will cover issues related to profitability analysis of aquaculture enterprises, fish marketing, credit for fish marketing and production, and economic modeling for fisheries marketing development.

Study: **ProfitabilityAnalysis of Aquaculture Enterprises**

The need of the aquaculture industry to prove its economic viability with only limited public support will determine its future. Thus, the condition for a healthy industry is the profitable management of production units, should they be private or public (Hishamunda and Jolly 2001). Regarding the profitability analysis of the aquaculture development in Uganda, two-stage activity approach will be used.

Activity 1: *The first step in determining and assessing aquaculture firm-level production costs, management practices, and marketing arrangements, is to identify the number, size, and location of existing aquaculture producers and processors and the current markets they serve.*

Given their relatively small number, a complete list of current producers and processors will be developed[2]. Producers will be interviewed to collect detailed information on technical and economic factors related to the aquaculture enterprises as well as other farm and non-farm business activities. This information will include, but is not limited to, the types, sizes, and costs of their physical facilities; operating costs of their enterprises by item such as feed, labor, medication, harvesting, and interest charges; production records and market outlets with associated volume and price; aquaculture management practices and problems; characteristics of other farm and business enterprises, and their relationships to the aquaculture enterprise; and information on current decision processes and attitudes towards financial price, and production risk. Processors will be interviewed to collect information on their facilities, costs of processing, and markets. A survey instrument (written

[1] The understandings generated by I4 will undergird a more rigorous framework for supporting the expansion and redirection of aquaculture enterprises. Previous work focused more on the training and implementation of record-keeping. I4 will seek to meet with farmers and use their records to evaluate their enterprises.

[2] A list of current producers and processors, as comprehensive as possible, will be developed in collaboration with NaFIRRI and other NGOs in the country. NaFIRRI's Extension personnel will be major collaborators in developing contacts as they are: (a) knowledgeable of activities in their respective areas, (b) able to facilitate contacts with and the cooperation of producers, and (c) major users of the results of the proposed research.

questionnaire) will be developed for the producer and processor surveys. As part of the development process, the questionnaires will be pre-tested on a small sub-sample of respondents. Once data are collected, in addition to generating basic descriptive statistics, the data will be used in a quadratic programming economic-optimization model (outlined in a following task). For enterprises with technical problems identified during the initial interview, follow-up interviews including appropriate technical personnel from the National Fisheries Resources Research Institute (NaFIRRI) will be scheduled to identify production constraints and develop recommendations on ways to enhance efficiency.

Activity 2*: Assess the financial viability of a range of aquaculture enterprises including the effects of incorporating aquaculture as a diversification strategy for traditional agricultural firms.*

Representative enterprises - and enterprise sizes - will be specified based on information obtained in the interviews, technical specifications of alternative enterprise structures, and available information from other studies. Start-up and operating cost estimates will be generated from data collected in Activity 1 and from previous published studies. Enterprise budgets will be developed for existing aquaculture production systems as well as for potential new, innovative types of systems (as well as feasible aquaculture species in the study area) identified during the course of this study. Completed budgets will allow potential aquaculture producers to compare costs and returns among the alternative systems and to make initial assessments of the range of returns to their own labor, management, and investment.

The primary data developed in Activity 1, in conjunction with the problems identified during the interview process, will be used to develop management guidelines that will improve economic efficiency and profitability for both current and future aquaculture producers. The enterprise budgets will be included in business plans and outlines of accounting systems necessary for adequate management and financial control of successful farm aquaculture enterprises and made available to producers and farmers as part of the knowledge transfer/outreach component of this project. As part of a sensitivity analysis, the enterprise budgets will be used to assess the impacts of potential changes in market price trends and seasonal price variations on the profitability of small to medium-scale aquaculture enterprises. Using a standard farm management/production framework, production timing to take advantage of seasonal price variations will be considered in terms of effects on costs and revenues, and variations in input costs will be analyzed to determine their effects on profitability and management strategies.

The second part of Activity 2 is to investigate the risk-return characteristics of aquaculture. From a farmer's perspective, aquaculture can either be a stand-alone activity, or it can be combined with existing production alternatives as part of a risk-reduction strategy. Uganda agricultural producers, as a group, tend to be risk averse and certain aquaculture enterprises could potentially fit in well both with producers' resource endowments and their risk characteristics. The risk-return tradeoffs associated with a given enterprise can be quantified either in isolation or in conjunction with alternative enterprises. The latter can be accomplished within the standard quadratic programming (QP) (or portfolio analysis) framework (Markowitz 1991). A QP model will be constructed to provide insights into producer decision-making as outlined below.[1]

[1] The enterprise budgets to be developed as part of this task will provide the data to estimate this model. Data from the producer survey will be only one component that goes into estimation of the model. Additional data to estimate the QP model include historical information on aquaculture product prices and feed and other input costs; this information is available from NaFIRRI. A time frame of three years is selected. This is expected to be long enough to reflect expected variability in aquaculture product prices/input costs. Information generated from the analysis will include expected returns and level of risk (calculated as the standard deviation of expected returns) for aquaculture products individually as well as in combination with other enterprises that will be identified. The QP analysis can be used to identify the optimal portfolio (one that minimizes an investor's risks for a given level of net returns) for different degrees of risk aversion. This can be accomplished by varying the parameter, lamda, in the General Algebraic Modeling System (GAMS) computing package (Thompson and Thore 1992). The approach illustrated in Teegerstrom et al. (1997) will also be employed here. In the unlikely event that sufficient data are not available to estimate a QP model, alternative models (such as a dynamic-stochastic simulation) will be explored. Including the results of such models, the knowledge transfer/outreach objective will enable producers to see the expected returns and associated level of risk for aquaculture products, individually or in combination with other enterprises, given different degrees of risk aversion (ranging, for example, from low to high levels of risk aversion). This information will be useful both to entrepreneurs considering entering or expanding aquaculture production as well as to existing agricultural producers interested in adding an aquaculture enterprise to their operation.

Study: **Fish Marketing and Credit Flow for Fish Marketing and Production**

Activity 1: For this subcomponent of the study, an assessment of fish marketing and credit flows will be conducted. We will interview a purposively selected set of producer respondents: 100 farmers at the site, 90 traders/wholesalers/retailers, and 60 fishers. We will survey a sample of 300 consumers. We will determine the actual number of financial institutions, processors, and exporters existing in the three study areas. Since the study will focus on domestic fish marketing, marketing of fisheries products at the farm level will be the main focus; together with issues such as the operations of traders, i.e. wholesalers, retailers, processors and exporters, in the market. Altogether, the study will target seven groups: fish farmers, fishers, wholesalers, processor/exporters, retailers, large consumers and lenders.

Activity 2: To identify and better understand fish marketing and credit issues in the country, secondary data on the development of the fisheries sectors in past and present years will also be collected and reviewed, mainly from NARO, FAO, the Uganda Bureau of Statistics (UBOS) and data from the FISH project. Information related to the sector development plans, programs and other issues will be gathered from different departments in the Ministry of Agriculture Animal Industry and Fisheries in the form of reports, papers, etc. Guidelines for in-depth interviews will be developed. Data and information collected will be coded and incorporated into computerized databases using SPSS (Statistical Package for the Social Sciences) software.

***Student Involvement*:** We will involve two students in the proposed activities. The students will work under the guidance of the PIs and will assist in a number of support functions including, survey administration, collection of literature review, project set-up, conducting listening sessions and overall economic analysis. The students will also be expected to be working on their dissertation at the same time.

Regional and Global Integration

The economic viability of aquaculture enterprises depends on firm-level technical production relationships, the effects of scale, input and output prices, and the market and organizational structure of the industry. Given site specificity, and since the analysis is motivated primarily by the needs of the nascent Uganda aquaculture industry, the study area is limited to Uganda; however, there will be spillover effects. Thus, information from surrounding Countries (including but not limited to Kenya, Tanzania, Burundi, Rwanda, Congo, Sudan and Zambia) will be examined as a part of this analysis. In addition to providing a useful regional perspective for this study, implications can be derived from the results of the proposed study that, in turn, could benefit the aquaculture industry in surrounding countries. For example, the recommendations on the most profitable practices, levels of income stream that would yield higher returns and samples of developed enterprise budgets, cash flow plans and business plan from this project can and will be shared with farmers in the region through the proposed regional conference and workshops. Particularly, the Lake Victoria Fisheries Organization is highly interested in several concepts of the overall project and will provide the venue whereby member countries can benefit from information for this and other proposed activities.

Schedule

This study is planned to be implemented as below:

Objective/Activity Schedule	Year One				Year Two			
	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul
Project set-up/Stakeholder Meeting								
Recruit Students/Develop linkages with NGOs								
Study. 1: Activity 1								
Study 1: Activity 2a								
Study 1: Activity 2b								
Evaluation Study 1 Activities								
Study 2: Activity 1								

Study 2: Activity 2								
Evaluation Study 2 Activities								
Impact Assessment[11]								
Progress Reports								

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[11] A more detailed description of the impact assessment and the Log Framework Implementation Plan is available from the lead investigator upon request.

VALUE CHAIN DEVELOPMENT FOR TILAPIA AND CATFISH PRODUCTS: OPPORTUNITIES FOR WOMEN PARTICIPATION

Marketing Economics, Risk Assessment & Trade/Study/09MER02PU

Collaborating Institutions & Lead Investigators

Purdue University (USA)	Kwamena Quagrainie
	Jennifer Dennis
Moi University (Kenya)	Charles Ngugi
	Julius Manyala
Ministry of Fisheries Development	Judith Amadiva

Objectives

A review of past CRSP research studies in Africa suggests a strong production focus, leaving many fish consumer and marketing questions unanswered. The need to place some emphasis on consumer preference research and value chain development derives from the strategic challenges that the Kenyan aquaculture industry faces. A value chain is defined as the different stages of the fish production process, e.g. input supply, production, marketing, consumption, which are linked through different relationships. The purpose of this study is to understand consumer preferences and trends in the demand for tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) products in Kenya and to develop value chain involving women that could lead to economic growth and to help overcome underemployment and poverty among women. Information about the Kenyan fish consumer can be utilized to prepare effective marketing strategy for fish farmers involving the development of desired product and delivery to desired location at prices customers are willing to pay. This includes analyzing specific value-chain activities and integration of women that would create some competitive advantage. This study is structured around five main objectives:

1. Identify the factors that influence consumer decision-making and purchase behavior regarding tilapia and catfish product options;
2. Examine consumers' preference structure and decision criteria for tilapia and catfish products that are farmed and wild caught;
3. Assess the state of women participation in fish value chain, identifying opportunities and constraints to improving their welfare;
4. Train women in fish value participation to identify points of intervention;
5. Develop a Farmed Fish Marketing Information System (FFMIS) based on consumer information and existing national fish farming inventory.

This study has relevance to the aquaculture industries and commercial fisheries in Kenya and Africa as a whole because it will provide valuable insights into how consumers make decisions to purchase tilapia and catfish and investigate which product attributes contribute to the decision process. A number of questions drive this objective: What are consumers' attitudes and beliefs about tilapia and catfish in Kenya? What factors influence consumers' perceptions of these fish products and purchase behavior? For instance, what role do demographics, value orientations, decision heuristics, perceptions of risk to human health, age factor, price, or taste play in consumers' decision processes? This insight is essential for understanding why consumers make the choices they do and what this means for fish demand, and the opportunities that can be created for the aquaculture industry (Gempesaw et al., 1995; House et al. 2003; Asche et al., 2005). For example, information about the Kenyan consumer purchase behavior of tilapia and catfish products can be utilized to develop the desired products and attract price premiums or value addition opportunities.

The study will also focus on value addition and value capture opportunities in farmed tilapia and catfish. This approach will be used to determine the necessary strategic opportunities and value addition options along the fish marketing chain for women. It is important to consider the

participation of women along the fish marketing chain and the benefits from participation in fish trade because the role of women in food production, processing and marketing has become relevant as a way of fighting poverty and ensuring food security in Africa. In a study of the effect of capitalist penetration on gender relations among the Ga of southern Ghana, Robertson (I990) shows that Ga women gained both wealth and increased autonomy during the late 19th and early 20th centuries when trading opportunities were so lucrative that women withdrew from productive work to devote themselves fully to trade. This study will examine how women can benefit from value chain integration that allows them not only in playing the traditional role of marketing but also in input supply, production and adding value and realizing additional benefits. This could provide a real opportunity to improve their economic situation (e.g., higher income, diversification of income sources, more reliable income) by fulfilling product quality and requirements of consumers.

The study will also develop a Farmed Fish Marketing Information System (FFMIS) based on the existing National Fish Farming Inventory database. FFMIS is intended to store information on species being cultured, locality, expected date of harvest, the producer association in charge, expected weight to be harvested. Such will help the development of value chain so that traders, service providers and even consumers can plan their activities in specific value chains. FFMIS will be centralized and fish farmer groups will be responsible for providing information to this database. Where feasible, there will be opportunities to access the database be sending a coded SMS to the data centre to get access the required information from mobile phones. FFMIS is a system open to further development and potential commercialization by interested mobile service providers so as to make it sustainable.

Significance

Women generally play a major role in the production, processing and marketing of agricultural products in many African countries, but agricultural information and production resources are not reaching and benefiting them in the food value chain. This realization has brought about a growing concern about gender issues in agriculture with governments and developing organizations focusing attention on increasing agricultural productivity by improving the condition of women, especially those in the rural and semi-urban areas. One of the broad strategies of CRSP activities is to implement intervention strategies that assist and improve the lives of women relating to equality and empowerment. A better integration into agricultural value chain could lead to improved economic wellbeing and help overcome inequalities and poverty for women.

Aquaculture producers in Kenya can become more competitive if they are much more consumer responsive in their marketing strategies. Competitive advantage of aquaculture products on the level of consumer needs and benefits could attract price premiums with targeted marketing using value chain/links approach. For this strategy to succeed, much additional research is needed into all aspects of consumer preferences in terms of attitudes and beliefs about tilapia and catfish, their perceptions of these fish products, purchase behavior, demographics, value orientations, decision heuristics, price, and taste. In short, the consumers' decision structure or processes for purchasing fish must be examined. The strategy of being responsive to consumers is a critical factor for helping Kenya fish producers reach business and profit goals.

A study of consumer needs and preferences is necessary because information about the fish market would result in an assessment on which concrete value chain can be developed. With a strong demand for fish products, the development of a value chain can be successful and would enable women take on more value-intensive functions in the chain that are hard to replace, and thus attract a larger share of the chain profits.

The development of FFMIS will provide timely market information on tilapia and catfish to enable aquaculture farmers target supply to actual changing market conditions. This study is innovative because it will provide information on the evolving market, and a better understanding of the consumer. Aquaculture farmers could have access to better market opportunities and higher price

points and lower volume markets with product improvement at various level along the marketing channels.

Consumer perceptions of fish products and purchase behaviors can be affected by several considerations. For instance, certain demographic characteristics have been found to correlate with consumer perceptions and behaviors (Hanson et al., 1994; Lusk et al., 2003; Quagrainie and Engle 2006). Systematic differences among different social segments, including level of education, have been found to be a strong predictor of food choices and consumption of fish (Lockie et al., 2002; Verbeke 2001; Verbeke & Vackier 2005). Other studies have reported flavor, availability, price, and geographic reasons as important determinants of seafood consumption (Hanson et al., 1994; House et al., 2003). These factors could be important in differentiating different market segments.

Quantified Anticipated Benefits

The study results will provide an understanding of consumer preferences and trends in demand for tilapia (Oreochromis niloticus) and African catfish (Clarias gariepinus) products in Kenya. This information about the Kenyan consumer can be utilized to prepare effective marketing strategy for fish farmers that involve development of desired product and delivery to desired location at prices customers are willing to pay. It will also enhance the economic welfare of women and help them overcome underemployment and poverty. A number of impacts will result from the study including:

1. A quantifiable assessment of how consumers value attributes and the role they play in fish purchasing decisions;
2. A quantifiable assessment of factors such as food safety, quality, size, product forms, demographics, taste, etc., and the relative importance of these factors. For instance, results will allow us to calculate monetary value of these factors and the tradeoff between pairs of these factors from the consumers' perspective
3. Results from this study would aid in the development of marketing strategies to integrate farm-raised and wild caught product markets with existing fisheries management plans in Kenya. The Kenya government can realize significant cost reductions related to tilapia and catfish management in the rivers and lakes.
4. Results will identify the areas of intervention of women into the fish value chain, and provide an assessment of constraints and opportunities for improving and securing their position in the chain.
5. Women will be better Integration into the fish trade in Kenya.
6. A Farmed Fish Marketing Information System in Kenya
7. Tiliapia has become a popular fish in the US, and results from the study will help US tilapia producers gain insight into selected value attributes of tilapia.
8. US fish farmers looking at improving market access in emerging foreign markets will have insight into consumer preferences, marketing and distribution of value added products, market research information on potential consumer-ready foods

Research Design & Activity Plan

This project will use personal interviews/survey research design for data collection. The interviews will collect data from across Kenya, targeting 500 consumers. Existing literature on public preferences for fish and seafood attributes, perceptions of aquaculture and commercial fishing industries, and models of consumer purchasing behavior will help to generate sets of measures of beliefs and attitudes about wild caught and aquaculture products. Other questions will assess frequency of purchase, importance of purchase decision criteria, and product preferences. Beliefs, attitudes, decision criteria items, and preferences for specific product attributes will be measured with 7-point Likert-type scale questions. Some flexible choice modeling experiments will also be conducted to assess the value of product attributes and measure the degree of substitutability between attributes in consumer purchasing decision. Standard socio-demographic questions (age, income, education, family status, and tribe) will also be included in the survey instrument, as these have been found to

relate to the type of and reason for food purchases (Green et al. 2003; Lockie et al., 2002) and will be important for understanding any market segmentation results that may occur.

A training workshop for women will be conducted in collaboration with the Women in Fishing Industry Project (WIFIP) based along the shores of Lake Victoria, Kenya. The workshop will focus on helping women fish traders to identify income generating activities along the fish value chain and intervention strategies. For example, during the annual fishing ban on Lake Victoria, when income is at its lowest for the women fish traders, the women can engage in fish farming/aquaculture activities to provide additional household income. Consequently, women need some training in fish pond construction and fish propagation.

Impact Indicators:
1. Number of value attributes identified from fish consumers.
2. The value consumers place on factors such as food safety, quality, size, product forms, demographics, taste, etc., and the relative importance of these factors.
3. Number of fish farmers with direct understanding of developing desired fish products and delivery to locations at prices customers are willing to pay
4. Number of databases developed for Farmed Fish Marketing Information System
5. Number of people utilizing FFMIS
6. Fish and fish product value-chains activities developed

Schedule

Task	Dates
Grant is initiated	Oct – Nov, 2009
Development of survey instrument & scales of measurement	Dec 2009 – Feb 2010
Random selection of target cities & survey strategies	Mar – May, 2010
Pilot test survey instrument & refine survey as needed	June – July, 2010
Develop structure of FFMIS & databases	July – Dec, 2010
Conduct personal interviews / administer questionnaire	July – Oct, 2010
Data entry & analysis	Oct – Dec, 2010
Information Dissemination at Conferences	Jan – Feb, 2011
Train women in fish value participation to identify points of intervention	Mar – May, 2011
Report writing and development of publication materials and deliverables	Jun – Sep, 2011
Test the application of FFMIS	Apr – May, 2011
Develop Public Private Sector Partnership in FFMIS	Apr – Sep, 2011

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IMPROVING SUPPLY CHAIN OPPORTUNITIES FOR TILAPIA IN THE PHILIPPINES

Marketing, Economic Risk Assessment & Trade/Study/09MER03NC

Collaborating Institutions & Lead Investigators

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Central Luzon State University (Philipppines)	Remedios Bolivar William Jamandre

Objectives

The overall goal is to evaluate and develop an efficient tilapia supply chain to foster the development of viable fast food and supermarket purchases of tilapia from small-scale producers.

Phase 1 - Evaluation

1. Develop tilapia supply chain maps for each market level, i.e., producer, wholesale, restaurant, supermarket, fast food stores, etc., to identify specific activities and services, key players, logistical issues, external influences, and flow of product, information and payment among market levels.
2. Analyze tilapia supply chain performance for efficiency, flexibility and overall responsiveness.
3. Identify areas for improvement in supply chain (i.e. behavioral, institutional and process).
4. Provide recommendations to improve the tilapia industry, in general and specific supply chain items.

Phase 2 - Development Undertaking

1. Design specific improvement measures based on the identified areas of improvement from Phase 1.
2. Test the improvement measures in the market place, then assess and refine the improvement measures.
3. Design and implement measures to ensure the sustainability of the improved supply chain of tilapia.

Significance

Linking up small-scale producers and commercial Philippine outlets desiring tilapia and abroad is the crux of this proposal. "…if the government marketing people can link up the tilapia and catfish farmers to companies producing fish fillet for the local and the overseas market,… they can get past the middlemen and sell direct to a premium market. There is a big, big market for tilapia fillet..." (Ronquillo, 2008). Tilapia is well-established in local, traditional markets in the Philippines where smaller fish are produced and consumed. However, for producers to receive higher prices they must meet specifications and volume requirements of more lucrative outlets, such as supermarkets, fast food chains, and export clients. Current market investigations by this CRSP project have found such markets to be rapidly expanding and have varying requirements for fish size, product form and timely availability. These requirements have implications for selecting appropriate processes and supply chain participation. Specifically, there is a trend towards targeting local urban markets with standardized, value-added "easy-to-cook" or "supermarket-type" products (e.g., "tocino" or "longanisa", dried and smoked, fillet). As competition for markets increases, these trends are likely to grow and intensify. These market opportunities would certainly improve income and employment levels of fisherfolks and their communities. Concomitantly, information on prices, costs and value-added along tilapia supply chain levels would provide needed information to research and development, workers, planners, and other stakeholders to initiate policies and support for the tilapia sector. Likewise, efforts will trace the "non-managed" or informal sector where the marginal participants are mostly involved such as women and subsistence farmers. As such, specific focus will

be done to address their participation with respect to food safety and consumer health through market links.

This investigation will serve as a basis for identifying appropriate interventions, strategies, and policy directions to improve the effectiveness and efficiency of the tilapia supply chain. Six principal questions that the proposed effort will address are:

1) Who are the key customers at each market level and what are their product requirements?
2) How do product, information and money flow through the tilapia supply chain?
3) What are activities, services and key players at each step in the tilapia supply chain?
4) What are the critical logistical issues among and within market levels?
5) What are the external influences requiring attention for efficient distribution and sale of tilapia?

Important secondary questions will be:

1) Under what conditions can small farmers profitably participate in selling to these markets?
2) Are there strategic investments that can expand small farmer participation in these markets?

A supply chain is a set of interdependent firms working closely together to manage flow of goods and services along the value-added chain in order to realize superior customer value at lowest possible cost. All products ultimately reach consumers through supply chains, but supply chain performance may vary in terms of efficiency, customer satisfaction, and competitiveness. Therefore, challenge lies in managing these supply chains for efficient production and distribution of products at the right price, quality and time that they are most wanted by final consumers.

Supply chain management (SCM) improvements primarily occur in economic efficiency (transaction cost economics and agency theory), business relationships (network theory and relationship marketing) and/or operational efficiency (operations management and logistics). Transaction costs are "frictions" brought about by using market mechanisms in moving the commodity along its supply chain. Transaction costs are classified as cost of preparing contracts (search and information; costs narrowly defined), cost of concluding contracts (bargaining and decision-making), cost of monitoring and enforcing contractual obligations, and cost of establishing and tending social relations (Aquino et al. 2007).

Fast-food and supermarket requirements

Product size - fast-food and supermarkets usually require larger fish (600-800 g) along with increasingly popular "butterfly" tilapia fillet (400-500 g), dried tilapia (30-35 g) and smoked tilapia (any size).

Seasonality - the relative stability of tilapia prices across market levels rules out seasonal variation suggesting a consistent pattern in consumption of tilapia. The upward trend in aquaculture production has provided the market with a more stable fish supply.

Volume and product form - minimum volumes required for international markets generally far exceed that of local markets, and are often needed throughout the year. Obvious implications are scale and need to stagger production cycles and harvests. Scale issues imply that volume of tilapia product will require considerable acreage commitment and ability to provide consistent volume every month. Large volumes will require either large producers or well-coordinated small/medium-sized producers. If the Philippine government wants to foster small producer involvement, then there will most likely need to be a concerted effort to establish production/marketing associations.

Product form - alternative targeted product forms, i.e., frozen, fillet, live, bulk or individual, will considerably constrain the set of appropriate technologies. Different product forms imply different harvest sizes and quality needs for storage and distribution time from pond to consumer. Also, and very importantly, will be location of processing. Fish processing for supermarkets will foster development of enterprises that will have further regional income and employment benefits. Ideally, the distance from tilapia pond to the processing facility will not be substantial, though specialized vehicles will be needed.

Destinations - length and cost of transport will greatly affect competitive position of Philippine tilapia. Additionally, cultural traditions are often important in terms of the product form, time period, and are often times of high fish consumption.

Implications for production systems
Scale issues – operation size sufficient to consistently supply large, high quality volumes to supermarkets and fast food chains is limited. Production area in close proximity to processing and hatchery operations and supply of skilled farm managers are likely constraints. Coordination and management will far exceed that needed for local/traditional markets largely due to need to stagger harvest to obtain needed consistent high quality flow of product. Small producer involvement is likely to require some form of association.
Farm management - Methods to produce harvest sized tilapia for supermarkets will be required. An optimum in stocking density and feed input; improved feeding strategies; and better water quality management will be required to maximize yield to meet volume and harvest size requirements. Increased length of growing cycle may exacerbate an already high risk farming system. This increased risk is likely to be a further detriment to small farmer participation in this new opportunity.

Public strategies to foster growth of markets
Associations - facilitation of the formation of producer/marketing associations with the assistance of extension service will be crucial in increasing small farmer chances of establishing themselves in supermarkets and fast food chains. Associations could assist with marketing, financial services and processing availability; several alternatives will be investigated and small producer input will be crucial in their likelihood of success.
Subsidized loans - provision of low or no interest loans for operating or investment is a commonly used method of creating incentives for new endeavors. Unfortunately, the history of repayment of subsidized loans to small farmers is not good. Any government programs of this type will need to be prepared for the financial impact of high default rates.
Storage, processing and refrigeration - infrastructure to facilitate maintenance of quality from pond to final consumer will be an investment that the Philippine government will likely need to foster in some fashion.

Quantified Anticipated Benefits

1. Research, training and educational experiences in marketing and production economics for two graduate students at Central Luzon State University (CLSU) and at Auburn University.
2. Detailed information on production-marketing constraints and opportunities to expand tilapia culture into large volume, high quality, large-sized fillet domestic fast food/supermarket and export markets.
3. Collaboration among CLSU, small-scale farmers, and large-scale tilapia buyers will facilitate improved opportunities for local producers.
4. Facilitate the development of domestic and export tilapia markets that can expand tilapia farming, increase sales, improve farm incomes, and increase small farmer participation.
5. Collect qualitative and quantitative baseline data on lost opportunities for increased product volume and quality through assessment of supply chain.
6. Supply chain evaluations to develop recommendations for improvement in production practices and market chain systems that will enhance benefit flows to farmers supplying targeted supply chains.

Research Design & Activity Plan

Location
This proposed study will cover the provinces of Pangasinan in Region 1; Nueva Ecija, Bulacan and Pampanga in Region 3; and Batangas and Laguna in Region 4. These sites are the major production areas of Philippine tilapia. The major demand centers include cities of Dagupan and Baguio in Region 1; Tarlac, Angeles and Cabanatuan in Region 3; and National Capitol Region in Region 4.

Methods

1. Literature will be reviewed to gain understanding of the challenges of expanding local tilapia production into fast food, supermarket and export markets through supply chains. This literature review will serve as an excellent starting point for the MS theses that will result from this project.
2. Secondary data analysis will be used to examine detailed product form specifications that are imposed by fast food and supermarkets in several countries (Hatch and Kinnucan 1993). Data from supermarket and fast food chain suppliers will be collected and analyzed to ascertain seasonality, product form, size and other important characteristics for Philippine tilapia production systems.
3. Existing research results and extension experience will be used to tailor production systems to fast food/supermarket needs. Small/intermediate producers' ability to participate in niche market opportunities will be given special priority (Popma et al. 1995; Hatch and Hanson 1991). CLSU researchers, extension professionals, and Hatch will assist in specifying production systems for each of the targeted niche markets. Typically, fast food and supermarkets require more intensive, skill and financially demanding production systems (Hatch et al. 1998; Engle and Hatch 1998). To meet needs of intensifying production processes, multi-stage systems are often required (Agbayani et al. 1993; Hatch et al. 1996). Increased risk levels can be expected as production systems intensify (Hatch et al. 1987) and distribution requirements become more stringent. For some niche markets, refinements will be minor, but in other cases, substantial changes will be required (Nerrie et al. 1990). If changes are substantial, success in selected niche markets is greatly diminished. Researchers and extension experts' interaction will be crucial to identifying realistic fast food and supermarket opportunities.
4. Jamandre and Hatch will advise MS students on project-related work and their degrees.
5. Data collections methods are: secondary data; tracer survey schedule, structured questionnaire; and key informants interview. Secondary data will be synthesized to describe the overall picture of tilapia production and distribution. In-depth interviews of key informants, and survey of tilapia farmers, traders, wholesalers, niche buyers, and customers will supplement secondary data. Information on supply chain flow of products, information, payments, activities and services conducted by supply chain members, key players, and external influences will be traced, collected, examined and analyzed. This will include analysis of institutional arrangements and relevant regulatory procedures.
6. Supply chain mapping for each stage of the supply chain will be conducted. At least one shipment from product source to ultimate destination, even from outside the province, will be traced. This will validate supply chain maps based on interviews; document practices at each chain stage; quantify costs and margins associated with such practices; and track changes in product volume/quality along the chain. A monitoring checklist will be employed to ensure all needed information/data will be gathered.
7. A set of indicators will be employed to evaluate effectiveness and efficiency of existing tilapia supply chains. Effectiveness of the chain to meet the requirements of key customers, such as quality standards and delivery volume, schedule and flexibility, and other social concerns (i.e., environment, equity and fairness issues) will be analyzed based on gathered information. Efficiency will be examined by activity and cost schedule construction along selected supply chains using the formula:

$$C_a = \sum_{j=1}^{n} C_{ij}$$

where C_a = price paid by key customer (i.e. final customer) per unit of product and C_{ij} = cost *i* of activity *j* (*j* runs from 1 to n to reflect all activities along the chain from point of production to the point of delivery to key customers). Inefficiencies of selected current supply chains will be determined by comparing actual and potential costs using the formula: Ca/Cp = E, where Ca = actual cost, Cp = potential cost, and E = inefficiency level. Other efficiency measures for analysis include cost (i.e., tilapia production, distribution and transaction), profit, as measured

by return on investment; and inventory management, i.e., warehouse, capital requirements, damage and loss of product.

8. Once the supply chain has been evaluated and impact of various practices along the chain are established, areas for improving the supply chain will be identified. A participatory approach will be used so that identification of improvement will be arrived at by consensus. It must be recognized that any change in the existing chain will affect certain interest of members and may bring about issues, which the chain members can resolve privately. An example of this might concern how the benefits from improvements will be shared among members. Supply chain champions will be identified by considering the structure of power along the chain and relative interest of members in chain improvement; and they are expected to ensure that identified improvements will be carried out.
9. Supply chain improvement will involve testing of interventions identified in the evaluation phase (Jamandre et al. 2009). Depending on chain and problems being addressed, several trial runs maybe needed before the chain can be optimized. Activities and processes will be orchestrated through supply chain champions. Six principles of successful SCM will guide recommendations: a) focus on customers / consumers; b) creation/sharing of chain value with all members; c) making sure product fits customer specifications; d) effective logistics/distribution; e) information/communication strategies that include chain members; and f) effective relationships giving leverage and shared ownership. Phase 1 indicators will be examined in Phase 2 to determine supply chain improvements.
10. Areas for supply chain improvement will be identified based on generated data, supply chain map, and performance. The results will be validated by asking key industry players what areas in the supply chain need to be improved and how these will be accomplished.

Schedule

Jan 2010–March 2010: Literature review, secondary analysis to determine data collection needs and interviews to be accomplished before Hatch in-country travel.

April 2010–June 2010: Hatch will travel to the Philippines to initiate interviews and surveys to assess the implications of fast food chain and supermarket requirements on tilapia production systems.

July 2010–September 2010: Develop tilapia specific supply chain maps that identify specific activities and services, key players, and logistic issues.

October 2010–December 2010: Perform performance analysis in particular supply chain based on efficiency, flexibility and overall responsiveness. Identify areas for improvement in tilapia supply chains.

Jan 2011–March 2011: Complete a draft analysis that will incorporate recommendations to the GOP on actions they can take to assist tilapia producers in developing supermarket and fast food supply chains.

April 2011–June 2011: Hatch travel to Philippines to complete data collection and ensure progress on data analysis and present recommendations to appropriate stakeholders and GOP officials.

July-September 2011: Final report and Philippine students' Master's theses completed.

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VALUE CHAIN ANALYSIS OF SNAKEHEAD FISH IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM

Marketing, Economic Risk Assessment & Trade/Study/09MER04UC

Collaborating Institutions & Lead Investigators

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Cantho University (Vietnam)	Le Xuan Sinh

Objectives

The objective of the study is to conduct a value chain analysis of snakehead fish in the Lower Mekong Basin of Cambodia and Vietnam in order to propose major solutions for a further development of snakehead industry with the regards given to the main stakeholders in the study areas.

Significance

Pond and cage culture is common in inland freshwater areas of Vietnam and Cambodia. The most important species of fish in terms of volume and value of freshwater fish production in the two countries are Pangasius catfish (Pangasius spp.) and snakehead fish (Channa spp.). Vietnam and Cambodia have developed the farming activities of snakehead fish in cages for years, including Loc Bong or giant snakehead (Channa micropeltes) and Loc Thuong or common snakehead (Channa striatus). These are two countries where Loc Bong (Channa micropeltes) occurs, only. In Vietnam, cage culture of giant snakehead in An Giang and Dong Thap provinces was started in 1960s while the farming of common snakehead was started in 1990s and becomes popular in the flood-prone areas of the Mekong Delta of Vietnam now. In Cambodia, cage culture of giant snakehead was started in 1990s. During 1991 to1993 there were a few household who were interested to culture giant snakehead, but in 2001 to 2005 the numbers of households raising giant snakehead increased very fast throughout the country such as in the Great Lake Tonle Sap River, the Mekong and Bassac River. Fish products from cage culture, are sold to domestic and international market in both fresh and processed forms (Hap et al. 2006). Schinittou et al (2004) reported that the cage for culturing snakehead in the two countries was big, about 125 m^3 in average, ranging from 40 to 625 m^3, the appropriate yield was 160 kg/m^3 per crop but might reach more than 600 kg/m^3 per crop. However, the farming of these fish species inland water bodies heavily depends on wild indigenous fishes both for seed and feed while the wild fish stock in freshwater bodies of the delta has been rapidly depleted due to many reasons (Sinh et al., 2005). Snakehead culture has been banned in Cambodia from 2005 because of the concern on depletion of wild fish stock.

The Investigation 1 of Aquafish-CRSP (Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets) has one component to survey the farming of snakehead in the Lower Mekong Basin (LMB) of Vietnam and Cambodia in 2008 and 2009. Despite of the ban of farming snakehead, a few farmers still stocked this species due to the lack of alternative jobs and the aim to utilize freshwater trash fish available during the annual flooding season. Furthermore, the Cambodian government is currently promoting the culture of giant snakehead using pellet feed in stead of using trash fish feed. Snakehead fish for human consumption in Cambodia is mainly from wild fish capture. Wild snakehead fish are traded via the border of Cambodia and Thailand while cultured snakehead fish are imported from downstream areas of Vietnam. An overview of trans-boundary of fisheries between the tow countries was provided by Loc et al. (2007).

In the Mekong Delta of Vietnam, snakehead fish for food of the community is mainly from cultured source now. Common snakehead (Channa micropeltes) is culture in all of provinces and cities in the delta, but mostly in the places affected by annual floods in terms of hapa and pond culture or culture in tanks. Giant snakehead (Channa micropeltes) is traditionally and commonly cultured in cages in

An Giang and Dong Thap provinces. The initial results from Investigation 1 showed that the seed of snakehead were mainly from on-farm reproduction. After the harvest, most of the fish production was sold to the middlemen for reselling in the towns or cities of the delta and Ho Chi Minh City, and a small proportion was transported to Cambodia. However, these marketing channels have not been studied. The major difficulties faced by snakehead farmers are: (1) lack of capital; (2) pollution of cultured area and difficult to treat the fish diseases; (3) unstable price of table fish; (4) increasing price of trash fish for snakehead fish culture. These difficulties have resulted in a decreasing profit and a lower rate of successful farmers. If the cost of self-captured trash fish is taken into account, the rate of successful farmers of giant snakehead in 2008 was 63.6% for crop 1 and 87.5% for crop 2. The figures for common snakehead were 46.4% and 66.5%, respectively.

The initial results from Investigation 1 also showed that the cultured area or volume and the yield of fish varied strongly by type of farming systems. In order to harvest 1 kg of snakehead fish, about 4.0-5.0 kg of trash fish are used. All of the snakehead farmers used fresh water trash fish in flooding season (September to December), but about 60-70% of total amount of trash fish for snakehead culture were from marine capture, yearly. Some farmers also used the meat of golden apple snails as an additional feed for their culturing snakehead fish. This survey also revealed that using trash fish for snakehead culture took away the low value sources of animal protein for a large proportion of local community, and put a higher pressure on natural aquatic resources not only in freshwater but also in marine water bodies (not in one country as well). In addition, water pollution in the concentrated cultured areas of snakehead due to the use of trash fish and high stocking density should be considered. The snakehead fish industry in the Lower Mekong Basin (LMB) of Vietnam and Cambodia has spontaneously developed without any statistics, particularly the lack of information on the stakeholders and management of snakehead industry in Vietnam. Therefore, there is a need to conduct a study covering all of the aspects of snakehead fish industry in the LMB. The results of this study will be useful for management and any further development of snakehead fish industry, as well as contribute to the food security, job creation and marketing of fish products in the LMB.

The value chain approach was firstly mentioned by Michael Porter (1985) in his book "Competitive Advantages: Creating and Sustaining Superior Performance" in which the concept of value added was used to develop the value of business for the activities form the organization's value chain and business arena of the 21st century. In 1990, he considered the value chain framework as "an interdependent system or network of activities, connected by linkages".

The "value chain" is defined by Kapinsky as "the full range of activities which are required to bring a product or service from conception, through the intermediary phases of production, delivery to final consumers, and final disposal after use" (Kaplinsky, 2000). A major benefit of value-chain analysis is through the identification of the nature and extent of barriers to entry along the chain. As a result, such an approach is amenable to explain many of the distributional outcomes that occur in the course of globalization as well as the evolution of such relationships over time (Kaplinsky and Morris, 2001).

The value chain framework has been used as a powerful analysis tool for the strategic planning of an organization in the past two decades. It has been applied to the understanding of commodity chains and export strategies in a number of developing countries and for a various number of commodities. Value chain analysis helps the managers to identify the key activities within the firm which form the value chain for that organization, and have the potential for sustainable competitive advantages for a company. Such analysis focuses on the interaction of actors along each step of the production system (from raw producer to consumer) as well as the linkages within each set of actors (Agrifood Consulting International, 2007).

Run Yu et al (2007) cited that "Supply (value) chain analysis is a relatively new approach for analyzing global fishery production at the micro-industry level. The present review of the existing literature reveals more research questions and the general lack of information rather than any conclusive results. More studies are needed to fully understand the seafood supply (value) chain and

its relation to poverty reduction and sustainable fishery and aquaculture both at the global level and at the individual country level. The priority research area, we believe, is the measurement of the return to the various participants of the seafood supply chain".

In the Mekong Delta of Vietnam, there have been a number of studies on the marketing of fish products (Sinh et al, 1998; Sinh, 2002; Loc, 2006; Son, 2007; Sinh et al, 2007; etc). However, the first report on value chain study of fish products was carried out by Sinh (2006) on the black tiger shrimp industry in Tra Vinh province. This helped to show that the shrimp industry of the province might have a better development if the linkage between chain actors and marketing channels were improved in association with a better investment given to the infrastructure of well-planned concentrated farming areas and processors. It is difficult to find the reports on the marketing of fish products in Cambodia, except some parts of the reports in which the description of fish distribution was provided (Agrifood Consulting International, 2007).

The value chain analysis then conducted more details in the LMB of Vietnam and Cambodia by Loc et al (2009) for Pangasius catfish (Pangasius spp.) and Ca Linh (Henicorhynchus/ Labiobarbus spp.) - a common wild fish in freshwater bodies of the two countries. This study addressed four key questions related to the form and function of value-chains, their contribution to the livelihoods of farmers and fishers, the effectiveness of government policy and the potential for value chain governance to steer towards sustainable production in the LMB. The main finding of the research was that the actors in high value export chains had a higher potential income, but they faced considerably higher economic vulnerability. Alternatively, fishers were severely constrained in their ability to negotiate higher prices for their fish, but this group appeared to be less vulnerable to economic and environmental change due to the social relations of trade. As a result, value chain governance was considered more likely to be effective in high value export chains than domestic or regional value chains.

Quantified Anticipated Benefits

The results of this study will provide information on alternative diets for snakehead, especially those diets that incorporate locally available plant materials, in order to build a long-term sustainable industry. Through an economic analysis of costs of the diets (based on costs of fishmeal and plant proteins vs. trash fish) and the risks of the unavailability of trash fish in the future, the information provided from this study will allow decisions to be made about the development of feed mills for local production of diets for the snakehead industry.

1. At least 20,000 farmers in Cambodia restarting snakehead culture; 20,000 snakehead farmers in Vietnam; 1,000,000 fishers; and about 10,000 fish traders (mostly women) in the two countries will have better information from this study on the marketing of their harvested/captured fish.
2. About 300 scientists, researchers, government fisheries officers/managers and policy makers, extension workers, NGO staff, and private sector working on the issues of snakehead aquaculture in Cambodia and Vietnam as well as in other Mekong riparian countries will be better informed, and have better recommended policies and strategies for sustainable snakehead aquaculture. These will be conducted through Project Inception Workshop, various stakeholder consultation workshops, and final project workshops during the period of 2 years.
3. Four undergraduate students and one master student will be supported and trained through their B.Sc./M.Sc. thesis research in each country (the Royal University of Agriculture, Phnom Penh; and the College of Aquaculture & Fisheries, Cantho University).
4. At least 10,000,000 Cambodians and Vietnamese will get indirect beneficiaries from better information on the snakehead fish products for their weekly consumption.
5. The lessons learnt from the two countries will be transferred and also broadcast to other Mekong riparian countries.
6. Benefits of this investigation to the US include development and improvement of economic methods for assessing the production and marketing of freshwater aquaculture species.

Research Design & Activity Plan

Location of work: The study sites covers 4 provinces of Vietnam (An Giang, Dong Thap, Can Tho and Hau Giang) and 4 provinces of Cambodia (Kandal, Kampong Chnang, Kampong Thom, and Siem Reap). Ho Chi Minh and Phnom Penh cities will be also selected for the surveys because of their role in the fish trading and consumption, in particular snakehead fish. The tras-boundary trading of snakehead between Vietnam-Cambodia-Thailand and that of trash fish between Cambodia-Vietnam should be described, also.

Methods: The total sample size is expected about 930 samples, that is, 465 samples per country. A set of questionnaires will be designed and pretested for interviewing the following groups of stakeholders of snakehead fish industry:

- 40 fish seed suppliers (5 hatcheries or seed providers/provinces).
- 100 fishers of wild snakehead (25 fishers/prov. in Cambodia).
- 200 fish farmers (40 farmers/system, 4 systems in Vietnam & 10 farmers/prov. in Cambodia).
- 150 traders (15 traders/prov. & city) (middlemen & retail sellers).
- 60 local processors (5 processors/prov. In VN & 10 processors/prov. in Cambodia).
- 300 end consumers (30 persons/prov. & city).
- 50 restaurants (5 restaurants/prov. & city).
- 30 market managers (3 persons/prov. & city).

The value chain analysis of snakehead fish in LMB consists of the follows: (1) A function analysis: in this analysis the number, type and function of actors will be determined. The approach focuses questions on the inputs and outputs of production as well as the mechanisms by which value chain actors maintain control production. Focus not only those directly involved in the value chain, but also those within a broader network, providing economic, policy and social support to actors. The data is then presented in 'chain maps' illustrating the main export and domestic channels, proportional outputs and description of the key functions. (2) A map of the material and financial flows from input suppliers to market: This approach calculates the main expenses and net profit margins of production for the actors and consolidated the expenses and margins from the rest of the chain. The analysis emphasizes the percentage value added to the fish at each transaction in the value chain, calculated as the selling price minuses buying price, not taking into account fixed or variable costs of each actor. For grow-out farmers, total cost include the cost of buying fingerlings and the added costs involved in the growing cycle. All the costs and added value will be computed per kg of fresh fish equivalent.

Schedule

The duration of implementation of this proposed investigation will be 24 months, starting from 10/1/09 till 09/29/11. Data collection will be mainly done in 2010 while the months of 2011 will be given to the data analysis, writing the report and workshop, as well as the report finalization and dissemination of the results on the value chain analysis of snakehead fish (*Channa striata* and *Channa micropeltes*).

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TOPIC AREA
WATERSHED & INTEGRATED COASTAL ZONE MANAGEMENT

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EFFECTS OF WATERSHED-WATER QUALITY-AQUACULTURE INTERACTIONS ON QUANTITY AND QUALITY OF WATER FROM SMALL CATCHMENTS IN SOUTH AFRICA AND UGANDA

Watershed & Integrated Coastal Zone Management/Experiment/09WIZ01AU

Collaborating Institutions & Lead Investigators

Auburn University (USA)	Claude E. Boyd
Makerere University (Uganda)	Levi Kasisira
Stellenbosch University (South Africa)	Khalid Salie

Objectives

1. Evaluate watersheds and measure water quality in ponds to determine possible effects of pollution from watersheds and cage culture operations on multiple water use (H_o: *cage culture and pollution from catchments do not degrade water quality in ponds*)
2. Establish runoff potential of watersheds and prepare water budgets for ponds to assess the volume of water available for consumptive use and effects of ponds on downstream flow. (H_o: *Ponds do not reduce downstream flow*)
3. Estimate the amount of transitional and wetland habitat resulting from small ponds and make a general description of the flora and fauna of these habitats *(H_o: Ponds do not result in loss of habitat for wildlife)*
4. Assist Ugandan investigators use South African data to verify models.

Significance

In many places experiencing water supply shortages, there is not a good supply of groundwater or development of groundwater resources is not feasible (Gleick 2004). Large dams traditionally used to capture surface runoff for multiple water use are huge infrastructure developments that require much capital, disrupt local communities, and have many negative environmental impacts. Although there has been considerable effort to develop small-scale water harvesting techniques for capturing water for domestic and agricultural use (National Academy of Sciences 1974; Fraiser and Myers 1983; Yoo and Boyd 1994), little attention has been given to intermediate-sized (1 to 10 ha) impoundments singularly or in series on upland catchments to capture overland flow for multiple water use by rural communities (Boyd et al. 2009). Water is captured before it enters major streams, and there is less effect on downstream flow than caused by large dams (Boyd et al. 2009). Catfish ponds over 7.5% of the area of a catchment in Alabama did not cause reduction in flow (Silapajarn and Boyd 2005. Water harvesting in complexes of small ponds could be applicable to increasing water supply for multiple use in rural communities in African nations.

There already are many ponds for capturing runoff from catchments in the Western Cape region of South Africa. Moreover, Stellenbosch University is evaluating the potential of such ponds for cage aquaculture. A careful evaluation of interactions among land use, cage culture, water quality, and downstream discharge for the ponds would be useful in developing better water management practices for farms in South Africa and other nations.

The SPAW model and the Tollner preliminary screening model that uses the NRCS Curve Number approach for runoff estimation will be employed on Uganda. The key need for verifying the models is to check the selection of runoff coefficients (curve numbers) using data sets that will be available from the work in South Africa for a range of conditions including pasture, row crop, and forest conditions. An analysis of soil conditions and runoff data obtained in South Africa will be used to select runoff coefficients following South African practices. A GIS evaluation will be used to make a regional analysis of watershed conditions in South Africa and a comparable analysis in Uganda (see Study 2/5). The GIS analysis will serve as a bridge between the findings in South Africa and the little-explored areas of Uganda where water supply needs are critical.

This experiment applies to the production systems design and best management alternatives objective of the RFP. In particular it will integrate aquacultural activities with other agricultural and rural activities, improve water supply and water use, and lessen the possibility of negative environmental impacts of capturing water for beneficial use.

Quantified Anticipated Benefits

The main target groups are individual farmers and rural communities. The findings will reveal the potential of small pond water harvesting for rural water supply. Data also will be obtained on possible impacts of land use and cage culture on quality of water for multiple use. Environmentalists and water management agencies will be interested in a water capturing system that has less impact on downstream flow, protects and enhances wetlands, and potentially increases biodiversity. Results of this research will be particularly useful to the Ugandan component of this project by providing data for validating models related to water storage in small ponds.

Increasing aquaculture production in African nations would benefit biodiversity by lessening fishing pressure in natural waters. Ponds create habitat by providing a high shoreline length: water surface area ratio that results in a large edge effect to attract many species. Upper ends of ponds usually function like wetland areas and favor a diversity of species. Watershed management practices to protect water quality will assure vegetative cover on watersheds and create habitat for a variety of species. Complexes of small ponds will have less effect than larger dams on downstream flow patterns.

Research Design & Activity Plan

This investigation must be done in South Africa because there are no suitable sites with existing ponds in Uganda or other IEHA countries for use in collecting data on hydrology and water quality in ponds for multiple use in which cage culture is being conducted. Availability of ponds and the current research on cage culture by Stellenbosch University provides a unique opportunity to build upon an existing effort in South Africa to obtain information critical for enhancing aquaculture efforts in Uganda and other IEHA nations.

Ponds already being used in a cage aquaculture experiment by Stellenbosch University will be available for this study. These ponds are in the Western Cape region of South Africa within a 50-km radius of Stellenbosch. Four ponds containing cage culture and four ponds without cage culture will serve as controls.

Although trout are cultured in ponds in South Africa, and these species cannot be cultured in Uganda, the study in South Africa involves water quantity and feeding waste issues that are general across species in cage culture. Water in ponds in South Africa is put to multiple uses, and hydrologic and water quality concerns about water use are the same in both countries. The waste in cage culture comes from uneaten feed and feces that enter the water from the cages. The nature of the waste and their influence on water quality are the same for trout cages as for tilapia cages.

tilapia cages.

Stellenbosch University is collaborating on the cage culture effort with the Water Research Commission (WRC), the agency responsible for water management, research, and development in South Africa, and the Department of Water Affairs and Forestry (DWAF), the regulatory agency for water in the country. The host country PI has discussed the work plan for the proposed AquaFish CRSP effort in South Africa with WRC and DWAF, and both agencies are supportive of the planned work and desire to be kept informed of progress and to be involved by supplying advice as needed. DWAF advice will be particularly useful on issues related to regulations that might affect application of findings. WRC can help with acquisition of meteorological records, runoff data, and other water-related information needed in the study. Several local Catchment Management Authorities and the Western Cape Department of Agriculture also are engaged in the cage aquaculture project, and they are interested in the watershed effort.

The US PI for the South Africa effort (C.E. Boyd) will maintain contact with the US PI for the Uganda effort (E. W. Tollner) to assure that data collection in South Africa will supply the needs in Uganda. They will meet in the USA in 2009 to assure that there is agreement on Ugandan data needs and how data should be collected in South Africa. Tollner and two Ugandan collaborators will visit South Africa in early 2010 to observe the data collection. Boyd will visit Uganda to assist in application of the findings. The findings from South Africa will be critical for use in the Uganda study to verify the models.

Water Budget

Average pond depths will be determined by sounding (Shelton and Boyd 1983), and pond areas will be obtained by conventional surveying techniques. Watersheds will be delineated on topographic maps and areas estimated by planimetry. Land uses and the extent of each use on watersheds will be obtained by direct observation, mapping, and discussions with land owners. Information will be obtained from land owners for uses of fertilizers, manures, herbicides, insecticides, and other agricultural chemicals. The presence of refuse disposal areas, septic tanks, and other sources of domestic wastes will be recorded.

Water quality will be measured monthly in ponds by methods outlined by Eaton et al. (2005). Analyses will include specific conductance, turbidity, pH, dissolved oxygen, total alkalinity, total hardness, chlorophyll *a*, total nitrogen, total phosphorus, total suspended solids, fecal coliform organisms, biochemical oxygen demand, and water temperature. In addition, if the survey of land use reveals sources of heavy metals, pesticides, or other chemicals on the watershed of a particular pond, water from that pond will be analyzed for the particular substance(s) that could be in the water as a result of their use on the watershed. Water budgets for the ponds will be determined by methods outlined by Boyd (1982) and Boyd et al. (2000) using the basic equation:

$$\text{Inflows} = \text{Outflows} \pm \text{Change in storage volume.}$$

The basic equation will be expanded as follows:

$$P + RO + I = (S + E + C + D + OF) \pm \Delta S$$

where: P = precipitation; RO = runoff; I = intentional additions; S = seepage; E = evaporation; C = consumptive withdrawal; D = intentional discharge; OF = overflow; ΔS = change in storage over period of measurement.

A standard, US Forest Service-type rain gauge will be installed at each farm and read daily by the farm manager. Overland flow will be measured by the NRCS Curve Number method (Yoo and Boyd 1994). Monthly and annual discharge from catchments (total runoff) will be estimated by the soil moisture accounting method described by Yoo and Boyd (1994). Evapotranspiration also will be determined by the Thornthwaite method (Thornthwaite and Mather 1957). Air temperature needed in the Thornthwaite method will be recorded with a data logger installed at each farm. Evapotranspiration will be estimated by subtracting discharge from precipitation. Pond evaporation will be estimated using an equation developed by Boyd (1985) for determining evaporation rates from surfaces of aquaculture ponds.

Water levels in ponds will be monitored in 8 to 10 ponds. Stilling sells will be made by forcing a length of 10-cm diameter PVC drain pipe vertically into the pond bottom, and the top will extend above the water surface. Each pipe will have a 1-cm diameter hole below the water level to equalize the water level in the pipe with the pond surface. A hook gauge will be used to measure changes to water level over time. Seepage estimates will be obtained by subtracting pond evaporation from water level change during periods when no water entersponds from rainfall, runoff, or intentional additions and no water overflows or is intentionally drained from ponds.

Basis for Estimating Reduction in Catchment Discharge

Water falling on a catchment either becomes overland flow, evaporates, is transpired by plants, or infiltrates to become soil moisture or groundwater (Leopold 1997). Soil water is lost by evapotranspiration and groundwater enters streams as base flow. Because the amount of soil moisture and groundwater levels normally are about the same from the beginning of one 12-month period to the next, the discharge of a catchment is equal to annual precipitation – evapotranspiration (Yoo and Boyd 1994).

Ponds receive direct precipitation and overland flow, and when full, overflow. Water seeps and evaporates from ponds, but seepage infiltrates into the ground. Overflow and seepage from the lowermost pond enters streams. Thus, reduction in discharge from catchments caused by ponds equals the amount that evaporation from pond surfaces exceeds evapotranspiration that would have occurred had ponds not been present.

Estimation of Reduction in Discharge

The reduction in discharge volume will be estimated as follows:

$$\Delta = [(\ +\ )] - ((\ -\ ))$$

where: ΔV = discharge volume (m^3); ET = evapotranspiration from land surface (m); E = evaporation from pond surface (m); A_p = pond surface area (m^2); Ac = land surface area of catchment (m^2).

The percentage reduction in discharge of the catchments as a result of ponds will be estimated with the equation:

$$\frac{(\ -\ )}{(\ +\ )} \times 100.$$

Biodiversity Considerations:

The pond water balance studies will provide estimates of downstream discharge from ponds in South Africa. Tollner and his Ugandan collaborators will include provisions in their models for estimating effects of ponds on downstream flow. Estimates of transitional habitat between land and water will be mapped and their areas estimated for existing ponds in South Africa. The shoreline length:water surface area ratio will be estimated, and the amount of wetland area in the upper ends of ponds determined. A general description of the flora and fauna of the transitional

and wetland areas will be made. The models developed by Tollner and collaborators also will include a procedure for predicting the amount of transitional and wetland area that will be created by construction of ponds at a particular site. Finally, watershed management practices that will be formulated for use on watersheds for water harvesting will specifically address the creation of land use patterns that will be beneficial for encouraging greater biodiversity.

Schedule:

	YR 1	Project YR 2				Project YR 3			
		1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
C.E. Boyd and E.W. Tollner meet in US to coordinate studies in SA and Uganda	x								
Evaluate watersheds in SA and do GIS evaluation of similar sites in Uganda		x	X						
C.E. Boyd visits SA site to assist in setting up hydrologic study		X							
Collect hydrologic data in SA and obtain weather records for SA and Uganda		x	x	x	x	x	x		
C.E. Boyd visits SA and Uganda to assist in efforts, E.W. Tollner visits SA to see site					x				
Collect water quality data in SA				x	x	x	x		
C.E. Boyd visits SA related to data analysis							x		
Data analysis, reports, and manuscripts						x	x	x	
Final reporting									x

Schedule

Start date: July 1, 2007
End date: September 30, 2009

Activity/Month	July 07-May 08	June-July 08	August-December 08	January-September 09
Project Preparation	x			
Pond/Water Sampling		x	x	
Stream Biotic Sampling		x		
Analysis/BMPs/Reports			x	x

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SURFACE CATCHMENT DEVELOPMENT AND SUSTAINABILITY EVALUATION FOR MULTIPURPOSE WATER SUPPLY FOR MEETING AQUACULTURE AND OTHER WATER NEEDS

Watershed & Integrated Coastal Zone Management/Study/09WIZ02AU

Collaborating Institutions & Lead Investigators

Auburn University (USA)	Claude Boyd Joseph J. Molnar
University of Georgia (USA)	E.W. Tollner Herbert Ssegane
Alabama A&M University (USA)	James Bukenya
Makerere University (Uganda)	Levi Kasisira Peter Mulumba Monica Karuhanga Beraho
Gulu University (Uganda)	Nelly Isyagi

Objectives

- Develop GIS suitability maps based on soils, topography and climate.
- Evaluate currently successful operations in terms of wetland impacts.
- Demonstrate a pond model for use in locating and constructing ponds to protect wetlands and enhance biodiversity.
- Extrapolate model findings to other sites having similar physical suitability based on runoff capture, water quality, as well as economic and social potential.

Significance

The aim of this activity is to develop an integrated suite of software approaches for modeling surface catchment sustainability and develop the necessary capacity for equipping local university and extension personnel to use the suite for assessing water availability for multiple uses including an increasing interest in aquaculture. Such decision tools can assist in the proper location of impoundments to protect wetlands and promote biodiversity. According to a 1998 FAO report (Aguilar-Manjarrez and Nath 1998); about 60 % and 65 % of the surface area of continental Africa was suitable for small-scale subsistence and commercial fish farming, respectively. Burundi, Republic of Congo, Rwanda, and Uganda were identified as some of the top ten countries most suited for small-scale subsistence and commercial fish farming. Aguilar-Manjarrez and Nath (1998) identified water as the most important factor for inland fish farming.

The main sources of water for fish ponds in Africa are rainfall runoff and perennial rivers and streams (Kapetsky 1994). Swamps and wetlands are other convenient sources of water for small-scale subsistence fish farmers. For the rainfall runoff water source most of the fish ponds have been established in regions or districts with annual rainfall of about 1100 mm. For example Kapetsky (1994) established that in southwestern Kenya, fish farming was more prevalent in districts with annual rainfall of 1400 mm. for Zambia, the fish farms were found in districts with annual rainfalls between 700 mm and greater than 1400 mm. the erratic nature of the rainfall coupled with the spatial variability of the rainfall amount necessitates water storage for sustainable water supply throughout the fish production cycle.

Other challenges associated with the water requirement include diversion of water for other uses by upstream communities, accrued water disputes due to downstream water requirements, water quality issues arising from iron and sediment enriched water from swamps and wetlands.

Upstream activities such as discharge of industrial effluent have resulted in stagnated fish growth and fish kills in downstream ponds. Rice farmers in constant contact with similar sources of water (for example men and women farmers in Kibimba, Doho and Olweny irrigation schemes - Uganda) have fallen prey to the Bilharzia. Bilharzia is one of the waterborne diseases that flourishes in streams or swamps with low water velocities. Incidences of river blindness have been reported in some parts of western Uganda. Therefore, adequate planning, design, construction, and maintenance of the water structures are relevant for ensuring sustainable water supply system. Also, there is little information relating water quality monitoring and best practices for watershed reservoir construction, biodiversity protection, and management for multiple uses.

The thrust of this project is to develop strategies to better employ water capture in regions of potentially erratic rainfall based on modeling for surface catchment site evaluation in the presence of potential streams, wetlands or surface water runoff. There are at least three runoff models for water quantity that look at sustainability of a surface catchment with given situation and given water needs. This work will be coordinated with other activities focusing on water quality.

SPAW North American model: One model, SPAW (Soil-Plant-Air-Water) is a compartment model that was developed for the USDA-ARS by Saxton et al. (2006). SPAW simulates the daily hydrologic water budgets of agricultural landscapes by two connected routines, one for farm fields and a second for impoundments such as wetland ponds, lagoons or reservoirs. Climate, soil and vegetation data files for field and pond projects are selected from those prepared and stored with a system of interactive screens. Various combinations of the data files readily represent multiple landscape and ponding variations. Field hydrology is represented by: 1.) daily climatic descriptions of rainfall, temperature and evaporation; 2.) a soil profile of interacting layers each with unique water holding characteristics; 3.) Annual crop growth with management options for rotations, irrigation and fertilization.

Schematics are shown in Figures 1a and 1b.

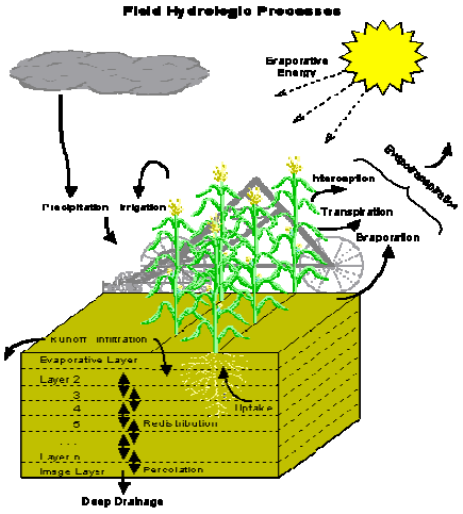

Figure 1a. Field water balance (from Saxton et al. 2006).

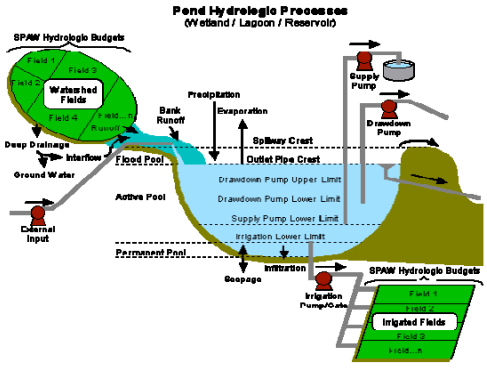

Figure 1b, Pond water balance

The simulation estimates a daily vertical, one-dimensional water budget depth of all major hydrologic processes such as runoff, infiltration, evapotranspiration, soil water profiles and percolation. Water volumes are estimated by budget depths times the associated field area. Pond hydrology simulations provide water budgets by multiple input and depletion processes for impoundments which have agricultural fields or operations as their water source. Data input and selection of previously defined data files are by graphical screens with both tabular and graphical

results. Typical applications include analyses of wetland inundation duration and frequency, wastewater storage designs, and reliability of water supply reservoirs.

Given adequate soils, surface coverage and climatological data, SPAW provides reasonably good results. The challenge will be to assess usefulness of this model with the lack of definitive soils data and somewhat limited climatological data. We believe local expertise can provide reasonable estimates of needed parameters that will enable conservative and useful predictions of sustainability. A sensitivity analyses will provide direction for future data collection efforts.

ACRU South African model: A model known as ACRU has been in development in South Africa over the past 20 years (Schulze 1995). The SPAW and ACRU models are physically based conceptual models with daily time steps. They are multi-purpose and integrative. They may be lumped points or can be distributive. They provide risk analysis of catchment sustainability and can also extend to other agricultural and, by extension, aquacultural analysis via water supply considerations. The quantitative water quality consideration would be based on Tollner et al. (2007) and in discussion with other project PIs having extensive fish pond water quality experience. We anticipate using data from South Africa (Stellenbosch) in our validation as well. All demonstration dams would be in conformance with safe dam policies in Georgia, which has limits on dam height and stored volume. The project offers oversight and guidance to communities and individuals wishing to construct water catchment ponds. Another attractive feature of SPAW is that it is also designed to evaluate ponds in a wetland setting. Inundation can be predicted and tracked. We will work with our PIs in Uganda to ensure that ponds are not located in areas where endangered plant and animal species are identified.

Spreadsheet screening tool: A spreadsheet model has been recently developed and published for water supply development in Central America (Tollner et al. 2004). The spreadsheet model requires some 21 inputs to describe climate, soils, cover, slopes, watershed lengths, and pond characteristics. Many of the watershed inputs may be ascertained from remote sensing imagery and from climatological data. Past experience in Africa has shown us that reasonably good quality hydrological data and remote sensing data may be found through the use of host countries students and PIs coupled with the UGA remote sensing center. The resulting water supply could be used to satisfy specified uses ranging from fish production to water supply, as well as biodiversity protection. This model is simplistic and does not have any GIS capability. The model partitions annual rainfall and evaporation into average monthly amounts and is based on monthly estimates of rainfall and runoff. The spreadsheet suite developed by Tollner et al. (2004) also contains a water balance model for the levee pond used in aquacultural production. These tools were widely presented across Central America, were featured in several publications, and remain available for download on the Internet.

The spreadsheet model is envisioned to serve as a preliminary screening tool to be used for assessing catchment sustainability. Cooperative studies by host country personnel could document water quality and quantity, as well as use suitability for targeted sites.

Quantified Anticipated Benefits

- Pond siting would begin with development of a suitable GIS atlas for pond development based on climate, soils and topography, as we have already identified a student with excellent GIS background and experience who has excellent familiarity with GIS African data. Potential benefits will be quantified by studying some reasonably successful existing operations as controls, and using them as a basis for encouraging other sites with similar or more desirable physical situations. Economic and social aspects would be similarly evaluated in cooperation with other project investigators and dialogue with men and women in the study areas. Based on previous experience in southern Africa, we anticipate that pond construction technique has been lacking. We also plan to complete model designs that address issues associated with pond construction technique and best management practices (BMPs) for level control, spill way design, drainage, livestock avoidance and mosquito control proposed work would bring together previously

developed remote sensing techniques and water supply modeling techniques. The software suite and instructional modules will encourage building of local capacity through enhancing analysis skills of host country personnel for water supply development. Demonstration workshops are planned for each country, leaving behind a software suite of tools customized for the individual location.

Research Design & Activity Plan

Ponds are a keystone for small to medium size water supply development in areas where groundwater is limited. Our strategy is to motivate development of one or two demonstration ponds, model them. Given that it is impossible to physically demonstrate ponds in all the myriad of conditions that one may realistically encounter in siting decisions, we are going with a modeling approach that has been well tested in US conditions and in other countries.

Excellent calibration data is said to exist in South Africa. We intend to do some calibrations in cooperation with C.E. Boyd in activity 1. We also anticipate doing some GIS studies of sites in SA and using them as a bridge to potential sites in Uganda. Pond siting decisions would start with economic and social feasibility, with the question being introduced early in market development workshops and clientele interactions by social scientists. An assessment of water quality would be included. The physical research would begin with a remote sensing assessment of host countries, building on considerable experience in sub-Saharan Africa. The assessment would include soils, topography and climate. Working with host country men and women, sites would be identified for the preliminary screening analysis based on the spreadsheet tool. Sites holding promise would be further analyzed using the SPAW model, gleaning from the ACRU model.

A qualitative assessment of potential water quality issues would be completed based on watershed assessment techniques, with attention to fish production. Sites deemed desirable for aquacultural production would also include levee pond water balances for assessing the aquacultural water demand. Strong coordination will be maintained with parallel activities devoted to water quality. Avenues will be explored for developing funding for construction of model ponds. Model ponds will be constructed to be in compliance with safe-dam guidelines.

Regional Integration

The US PI for the Uganda effort (E.W.Tollner) will maintain close contact with the US PI for the South Africa effort (C.E. Boyd) to assure that the data collection effort in South Africa will supply the needs in Uganda. They will meet at either Auburn University or University of Georgia in the first weeks of the project in 2009 to assure that there is complete agreement on the Ugandan data needs and how the data should be collected in South Africa. Tollner and two Ugandan collaborators will visit South Africa in early 2010 to observe the data collection. Boyd also will visit Uganda to assist in application of the findings. The findings from South Africa will be critical for use in the Uganda study to verify the models. The project is targeting the development of a watershed and basin assessment center at Makerere University by building a physical science and social science interdisciplinary center to complement such centers at the University of Natal and Stellenbosch University and other African countries. This institution will provide foundational information for guiding human activities to mitigate impacts on wetlands and biodiversity. This project is inherently integrative as it initiates and increases cooperation among diverse interests with the common threads of maintaining the health of a common benefit, the community water supply, protecting wetlands, and promoting biodiversity.

One of the models under study is developed in South Africa, and it will be highlighted to give the software suite a strong local identification. The concept is replicable in other parts of Africa as well as other developing countries. Close working collaboration will be maintained with the Sustainable Management of Watershed – CRSP (SUMAWA) and other CRSP projects. The concept is replicable in other parts of Africa as well as other tropical regions. The AquaFish CRSP student at UGA is a Ugandan who looks forward to applying the results learned in Uganda.

Schedule

	YR1	Project Year 2				Project Year 3			
		1-3	4-6	7-9	9-12	1-3	4-6	7-9	9-12
Travel to coordinate with HC, visit successful ops		x	x						
Preliminar Remote Sensing analysis	x	x	x	x					
Identify good existing operations to begin water quantity modeling and quality assessment			x	x	x	x			
Initial site selection with GIS and preliminary screening				x	x	x	x		
HCPIs – visit potential sites with good GIS based likelihood to be socially and economically viable					x	x	x	x	
Advanced model synthesis					x	x	x		
Construct model ponds pending outside funding availability		x		x		x		x	
Community Workshops					x				x
Final reporting							x	x	x

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TOPIC AREA
MITIGATING NEGATIVE ENVIRONMENTAL IMPACTS

❖

INVASION OF THE RED SWAMP CRAYFISH (*PROCAMBARUS CLARKII*) IN CHINA: GENETIC ANALYSIS OF THE INVASION AND THE IMPACTS EVALUATION

Mitigating Negative Environmental Impacts/Study/09MNE01UM

Collaborating Institutions & Lead Investigators

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Shanghai Ocean University (China)	Liu Liping

Objectives

1. To determine changes in population genetic structure of the red swamp crayfish after successful invasion and fast dispersal in China
2. To investigate impacts of invasion of the red swamp crayfish in China

Significance

Because of the increased transfer of non-indigenous species (NIS) to new ecosystems and a growing awareness of their potential impacts on recipient ecosystems, there has been a growing interest in evaluating biological invasions over the past 20 years. Recently, much attention has been paid to several aquatic species (LeBlanc et al. 2007; Valentine et al. 2007). The red swamp crayfish (*Procambarus clarkii*), which is native to the south-central USA and northeastern Mexico, is one of the more infamous invasive species in the world (Huner 1988; Zhu and Yue 2008).

Successful invasion requires that a NIS passes through a series of filtering stages that include transport, release, establishment, and, in many cases, dispersal. A successful invader is characterized by a number of biological and ecological features that favor their dispersal and establishment into new habitats. The red swamp crayfish lacks some of the common and efficient dispersal characteristics, such as easily transported resting eggs or highly mobile larval stages. Compared to plants or invertebrate species such as insects or mollusks, the natural dispersal ability of this species is relatively weak (Geiger et al. 2005). Usually, anthropogenic activities such as an introduction or transplant for aquaculture are considered to be key factors in translocation of the red swamp crayfish, but there has been little information available. However, high reproductive output, short development time, and flexible feeding habits provide this species a very strong adaptability to various ecosystems once it is introduced.

The features mentioned above have made the red swamp crayfish a successful invasive species globally. Introduction of this crayfish into the Mediterranean region and Europe is a very well documented example of the quick expansion of an alien species (Adao and Marques 1993; Correia and Costa 1994; Geiger et al. 2005). In 1973, it was introduced to two aquaculture installations located in Sevilla (Lower Guadalquivir River Basin) and Badajoz in southwestern Spain (Habsburgo-Lorena 1983). Following introduction, the red swamp crayfish became a widespread species throughout the Mediterranean region in only three decades (Adao and Marques 1993; Correia and Costa 1994; Arrignon et al. 1999; Stucki 1999). This history in Europe makes the red swamp crayfish an excellent model to study central questions on how population genetics change during invasion of an NIS, particularly an invasion introduced by human activities. Additionally, information on population structure alterations will help in prediction of changes during invasion

by other alien invasive species and establish possible methodologies for prevention and control of invasions.

As in the Mediterranean region and Europe, the invasion status of the red swamp crayfish is also serious in China. This crayfish was introduced to Nanjing, China from Japan in the 1930s. Presently, this species has been found in almost all forms of waters including lakes, rivers and even paddy fields in most provinces of China: from Liaoning Prov. (northern China) to Guangdong Prov. (southern China) and from Taiwan Prov. (eastern China) to Sichuan Prov. (western China) (Li et al. 2005; Liu et al. 2008).

Unfortunately, there has been little attention paid to invasion of this crayfish into natural waters of China. Instead, because of its high commercial value, there has been much attention paid to understanding of reproduction and artificial breeding of this species (Gong et al. 2008). Aquaculture for red swamp crayfish has developed rapidly, and it is becoming an important aquatic product in China (Bi et al. 2008). However, there are serious impacts occurring due to the rapid expansion of this species in natural waters (Tang 2001; Li et al. 2005). The invasion of red swamp crayfish is a major threat to native crayfish and as well as macrophytes, due to its predatory and foraging activity (Geiger et al. 2005). The red swamp crayfish appears to be an important pest of wet-seeded rice (*Oryza sativa*) fields (Anastacio et al. 2005). As a vector of many diseases, this crayfish may have a severe impact on the conservation and reintroduction of native crayfish (Die'guez-Uribeondo et al. 1995). In addition, red swamp crayfish accumulate heavy metals and other pollutants in body tissues and transmit them to higher trophic levels (Geiger et al. 2005). Understanding the impacts of this invasive species can help develop better culture techniques and control methods for this commercially important species.

Presently, controlling the dispersal of the red swamp crayfish and performing environmentally safe culture of this species are two major issues for many countries of the world. This study, focusing mainly on the sources of animals that are now widely dispersed, will help determine the relative importance of single introduction events compared to repeated expansions by additional human interventions. Current work on tilapia in Belize (Esselman, in progress) demonstrates that the spread of tilapia in that country occurred mainly through repeated introduction to new watersheds due to human aquaculture operations.

Quantified Anticipated Benefits

Evaluation of the spread of red swamp crayfish will serve as a model of the population genetics approach to invasion dynamics. We will identify source area(s) and invasion center(s), as well as dispersal patterns as a means to determine the role of aquaculture in the spread of crayfish. Such work matters to both developing and developed countries and will help expand invasion models being applied in the U.S. Deliverables from this study include a fact sheet on invasive species, focusing on dispersal mechanisms and the role of aquaculture in this dispersal, as well as publications in the primary literature.

Research Design & Activity Plan

1. Large geographic analysis: to study changes in genetic structure of the red swamp crayfish in China, to identify invasion centers and dispersal patterns, and to explore whether populations were derived from single or multiple introduction events.

Study areas:
Evaluation over a large geographic area will include sampling sites that cover most of the distribution range in China, including Hubei, Hunan, Anhui, Liaoning, Jiangsu, Jiangxi, Zhejiang, Guangdong, Guangxi, Sichuan, Shandong, Shanxi, Xinjiang, and Taiwan provinces. One to three sites from each province will be evaluated. Totally, 20-40 sampling sites will be evenly selected from both the periphery (5-10) and center of the species' distribution in China.

Materials and methods:
30 - 50 individuals (muscle cut) will be sampled from each site. Samples will be stored in 100% ethanol for DNA extraction. mtDNA and nuclear SSR (simple sequence repeats) markers will be used for population genetic analysis. Genetic diversity within sites will be calculated using the computer program ARLEQUIN, including the number of alleles (A), the observed heterozygosity (H_O) and the expected heterozygosity (H_E) for nuclear markers (SSRs), as well as haplotype diversity (h) and nucleotide diversity (π) for mtDNA analysis. The Markov chain method will be used to detect significant deviation from Hardy–Weinberg equilibrium using the computer program GENEPOP. The degree of population subdivision will be evaluated by pairwise multi-locus estimates of F_{ST}. Patterns of isolation by distance (IBD) will be detected by examining the correlation between Rousset's (1997) $F_{ST}/(1\text{-}F_{ST})$ and geographical distance. A Mantel test will be conducted using GENEPOP. A UPGMA tree based on Nei's distance (Nei 1978) will be used to demonstrate population genetic similarity and clustering. Phylogenetic relationships among mtDNA haplotypes will be estimated through the neighbor joining (NJ) and maximum-likelihood (ML) reconstruction methods. Support for NJ and ML will be evaluated by 1,000 bootstrap replicates. An analysis of molecular variance (AMOVA) will be conducted to determine the hierarchical genetic structure.

2. Fine geographic scale analysis: released or escaped individuals from aquaculture facilities work as a possible way for the invasion and dispersal of the red swamp crayfish into natural water bodies

Compare population structures sampled from hatcheries and waters nearby to evaluate the invasion risks.

Study areas: The fine scale geographic analysis will focus on the hypothesis that released or escaped individuals from aquaculture facilities play one of the key roles for invasion into natural water bodies. Evaluations over a small geographic range will be done in three to five aquaculture hatcheries and water bodies nearby in Hubei Province, which is the culture center for red swamp crayfish in China. Generally, considering the aquaculture hatcheries as centers, sampling will also be done from near to distant waters. For each sampling group, one hatchery and at least 3-5 natural waters from near to distant will be sampled for further analysis.

Materials and methods: All the indices in f.1.2. will be evaluated. In order to examine the feasibility for discrimination by detecting kinship between individuals without parental genetic information, genetic relationships among individuals within and between the hatchery populations and populations nearby will be estimated. Nei's standard genetic distances DA between all pairs of individuals will be estimated to show the phylogenetic relationship among individuals. Based on the distance matrix, the software MEGA version 3.1 will be employed to construct NJ dendrogram.

Survey of impacts of the red swamp crayfish invasion in China

Scope of survey: northward to Liaoning, southward to Guangdong, eastward to Taiwan, and westward to Sichuan.

The main method for this analysis will be a survey of experts using a questionnaire to evaluate the effects of red swamp crayfish on native crayfish, macrophytes, and diseases, accumulations of heavy metals, areas of destroyed rice fields and destruction of water conservation projects. In addition, the internet will be a good channel to get some information about the distribution of the red swamp crayfish. Care will be exercised in both surveys to insure that information comes from reliable sources. The information we obtain will be used to develop a summary of potential impacts of the red swamp crayfish in China.

Schedule

1 October 2009 – 29 September 2011. Report submission: no later than 29 September 2011.

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RATION REDUCTION, INTEGRATED MULTITROPHIC AQUACULTURE (MILKFISH-SEAWEED-SEA CUCUMBER) AND VALUE-ADDED PRODUCTS TO IMPROVE INCOMES AND REDUCE THE ECOLOGICAL FOOTPRINT OF MILKFISH CULTURE IN THE PHILIPPINES

Mitigating Negative Environmental Impacts/Experiment/09MNE02NC

Collaborating Institutions & Lead Investigators

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Maria Rovilla J. Luhan

Objectives

The general objective of this work is to reduce feed inputs and promote integrated culture for a more cost effective milkfish farming and reduce its environmental impacts while also providing additional income from seaweed and sea cucumber culture. The specific objectives are the following:

1. To compare a 1-2% reduction in feed ration to the standard feeding levels on milkfish production characteristics (growth, feed conversion) in pens in coastal marine water.
2. To establish a more environmentally-friendly milkfish production system in cages or pens using the concept of integrated culture.
3. To test the capacity of the seaweed and sea cucumber to absorb excess dissolved nutrients and for nutrient recycling and bioturbation of sediments, respectively, in a milkfish farm.
4. To disseminate information on feeding rates and demonstrate the economic feasibility of integrated culture systems through season-long training for community-based livelihood projects.
5. To conduct skills development training workshops on milkfish processing and value-adding (e.g. deboning) for women in major milkfish growing areas as a potential supplemental livelihood opportunity.

Significance

Milkfish culture is the largest finfish aquaculture industry in the Philippines with a harvest area of 280,000 ha and total production of 300,000 metric tons annually (BAS 2006). As part of the Philippine government's food security and poverty alleviation programs, expansion of milkfish culture is a high priority (Rosario 2006) both to wean fishers off capture fisheries and to increase income of farmers and fishers alike, whose poverty levels are disproportionately high (Rivera et al. 2006). Milkfish production is increasing at 5% annually with much of the production moving away from traditional culture in brackishwater ponds to fish cages in coastal marine waters, with a 14% increase in marine cage culture seen in 2005 alone (BAS 2006). Cage culture of milkfish in coastal marine environments is done at higher densities and with significantly greater inputs of artificial feeds. Using this practice, however, has led to wastage of artificial feeds and excessive nutrient loading in receiving waters (Sumagaysay et al. 2004), exacerbating pollution problems and contributing to periodic fish kills in areas of intensive milkfish culture.

Currently, milkfish are fed daily at levels ranging from 10% to 4% of body weight (BW) depending on fish size (Coniza 2009). Based on our recent findings in phase I of the AquaFish CRSP, initial feeding rates of 7.5% BW of small fish produce similar growth rates to those seen in response to 10% BW feeding (De Jesus-Ayson and Borski 2009). Anecdotal evidence indicates that some of the feed in production scale cages is also wasted. We will evaluate whether a 1-2% reduction over the entire production cycle of milkfish might be as effective as standard feeding procedures in production scale cages.

In modern coastal integrated mariculture, shellfish and seaweed are cultured in proximity to net pen fish culture (Troell et al. 1997). The red algae *Kappaphycus alvarezii* (Hayashi et al. 2008) and *Gracilaria heteroclada*, seaweed species widely distributed in the Philippines (Luhan et al. 2006) efficiently take up dissolved inorganic nitrogen in effluents from fish holding facilities. Seaweed production and quality are often enhanced in areas surrounding fish net pens than elsewhere (Troell et al. 1997). *K. alvarezii* is the most economically important seaweed in the Philippines. Monoculture of this seaweed in coastal waters of the country had generated high revenues to the small fishers. The farming of *K. alvarezii* in close proximity to fish cages has not been tried, though polyculture with grouper in cages was found to be economically feasible (Hurtado-Ponce 1992). On the other hand, the sea cucumber (*Holothuria scabra*) is an economically important species that is currently overexploited in the Philippines and worldwide. It feeds on detritus and algae and as such is an excellent species for polyculture with other farmed fauna (Purcell et al. 2006). This project will test the viability and economic feasibility of an integrated culture of milkfish, seaweeds and sea cucumber that is more environment-friendly and will bring added income to coastal communities.

Milkfish is traditionally traded in chilled or frozen form. However, there is a growing trend towards processing and production of value-added products. Marketing of milkfish outside the Philippines is constrained by the fact that it has numerous bones and spines embedded in its flesh. Women have been deboning milkfish for a long time. As part of a year-long training project, women will be trained on this and additional processing and value-adding techniques (e.g. deboning, smoking, marinating deboned milkfish in various flavors). Capacity building in this area will provide potential supplemental income to women.

Quantified Anticipated Benefits

1. Demonstrate that decreased feed ration can reduce milkfish production costs with no loss in yield.
2. Provide direct evidence of the effectiveness of integrated culture in mitigating environmental impacts of intensive milkfish culture while providing farmers additional income from seaweeds and sea cucumber production.
3. The investigations will take advantage of the strong research and extension capabilities of SEAFDEC to promote environmentally friendly culture of milkfish in the Philippines and Southeast Asia. This will include development of an extension manual on integrated culture.
4. Workshop training on milkfish culture and integrated culture will benefit 30 milkfish farmers and impact at least 4 communities in an area where milkfish are farmed in the Philippines.
5. The skills development workshop on processing and value-adding in milkfish will benefit at least 20 women in each of the sites targeted for season-long training on integrated milkfish culture. It will provide them with opportunities for supplemental income.
6. The research should produce a more favorably produced product for the U.S., the largest importer of milkfish from the Philippines, while also providing more sustainable technologies for coastal aquaculture that could benefit the U.S. and other countries whose coastal aquaculture is on the rise.
7. At least two graduate students (University of the Philippines in the Visayas) will be supported as research assistants for the project; 5 BS Fisheries students and 2 high school students can be trained under the project annually as part of SEAFDEC AQD's on-the-job training for undergraduates and summer science internship for high school students programs, respectively.

Research Design & Activity Plan

Location: These experiments will be undertaken on Iloilo and Guimaras islands of the Vasayas region of the Philippines. Experiments will initially be conducted in tanks at SEAFDEC AQD (Iloilo) to test the efficiency of *K. alvarezii* to absorb excess nutrients and the efficiency of sea cucumber for nutrient recycling and bioturbation of sediments. Following these initial studies,

field production trials will be conducted in fish cages in marine waters at SEAFDEC AQD's Igang Marine Station (Guimaras).

Methods

1. Effect of reduced ration size on cage culture of milkfish

This experiment will consist of a

- control group fed daily under standard milkfish feeding schedules used by farmers, which is a feeding rate of 10% of fish biomass per day when the body weight ranges from 10-50 g; 8% of fish biomass when the body weight is between 51-100 g, 6% of fish biomass when the body weight reaches 100-200 g and 4% of biomass when body weight ranges from 201-300g; and

a. treatment group fed at 1-2% lower ration levels at each size range (8% for 10-50 g, 7% for 51-100g 5% for 100-200 g and 3% for 201-300 g fish).

Milkfish fry produced from the SEAFDEC fish hatchery will be grown in nursery ponds at the SEAFDEC Dumangas Brackishwater Station until they reach appropriate size (10 g body weight). Fingerlings will be stocked in triplicate in 5x5x3m cages at a density of 25 fish/m^3. Fish will be fed SEAFDEC formulated feeds (Sumagaysay, 1998). Body weight measurements of at least 50 fish will be taken every 2 weeks to monitor growth and adjust the feed ration. Feeding frequency will be 4x daily, 2x in the morning and 2x in the afternoon. Specific growth rates (SGR) and food conversion ratio (FCR) will be assessed throughout the study. Water quality parameters will be monitored in relation to feed input and fish biomass as described below. Differences in growth rate, body weight, and FCR will be analyzed by a combination of Student's-t-test and one-way ANOVA.

Null Hypothesis: Ration reduction does not alter production parameters of milkfish compared with standard ration levels.

2. Evaluate the efficiency of seaweed to absorb excess nutrients and sea cucumber for nutrient recycling in a milkfish culture system

Initial studies will be done in tanks. Two units of 1m x 1m hapa net cages will be set up in a 5-ton concrete tank and stocked with 25 fish each. The tank will be provided with flow-through seawater. Seaweeds (*K. alvarezii*) will be grown on long lines inside the tank, along the sides of the hapa net cage at 500g, 1000g and 1500g/m/line. Propagules will be tied using long loops at 20cm intervals. The experiment will run for 3 months. Milkfish will be raised as described under experiment 1 using standard feeding rations. Sampling will be done every 2 weeks to monitor the growth of the fish as well as the seaweeds. After 6 weeks, seaweeds will be harvested and total biomass will be recorded. Water quality (nitrate, nitrite and ammonia, pH, dissolved oxygen, total suspended solids (TSS), phosphate, chlorophyll a) in the tank, in the outflow and inflow will be monitored daily using a multiparameter meter, and will be compared between tanks with and without seaweeds.

In a parallel experiment, the same set up will be prepared but the tanks will be lined with sand and stocked with sea cucumber at 1, 3 or 5 individuals per m^2. Stocking density of milkfish, feeding management and sampling schedule will be as described above. Sediment quality will be monitored at the start, midway and at the end of the 3-month experimental period. Sediment samples will be collected and DO, nutrients (ammonia, nitrate, nitrite, phosphate), total protein concentration, sulfides and redox/pH/temperature will be measured. The best stocking density for seaweeds and sea cucumber will be used in subsequent verification trials in a marine cage and brackishwater culture system.

For the cage trial, we will have two groups: 1) a control where milkfish are grown alone using standard production practices, and 2) an integrated culture system with milkfish, seaweed and sea

cucumber. Milkfish fry will be stocked in 5x5x3m cages in triplicate at a density of 25 fish/m^3. Fish will be fed with standard rations and at a frequency described above. Body weight measurements of at least 20 fish will be taken every 2 weeks to monitor growth and adjust the feed ration. SGR and FCR will be calculated. For the integrated culture system, seaweeds *K. alvarezii* will be grown along the sides of the cage at a density determined from the tank experiment. A 45-day growth period will be observed for each cycle. Daily growth rate and yield will be determined every 45 days of culture. Seaweed will be harvested and new propagules will be selected for the next growth period. This system will be repeated until the milkfish are ready for harvest. For each harvest, seaweed sample will be taken for N-P tissue analysis and carrageenan extraction and characterization. Carrageenans (*i.e.* agar) are commercially important byproducts of seaweed used as additives to change viscosity of foods (gelatins, pastes, gum, desserts, etc.). Water quality monitoring will be done during each sampling. Ammonia, nitrate, nitrite, phosphate, chlorophyll a, DO and total suspended solids (TSS) will be measured. The data will be correlated with number of cages, biomass of stocks and feed inputs, as well as seaweeds biomass.

Pens will be set underneath the cages of the integrated culture system and stocked with juvenile sea cucumber (*H. scabra*) at a density determined in the preliminary experiment. Sea cucumber in the pens will be sampled every 45 days to monitor growth and survival. At the end of the production run, total biomass produced will be determined. Sediments will be collected using a core sampler and DO, sulfides and redox/pH/temperature of the sediment-water interface and sediment surface layer will be measured. Sediment quality indicators (bioturbation structures, sediment color, presence/density of fauna, presence of sulfide smell, presence of sulfide-oxidizing bacteria *Beggiatoa*, presence of gas bubbles and other indicators will be monitored. Samples will also be collected for nutrients (ammonia, nitrate, nitrite, phosphate), total protein concentration, microbial community determination and macrofaunal (polychaetes, gastropods, bivalves) identification. Ms. Marie Frances Nievales and Ms. Gwen Anuevo of SEAFDEC, with expertise in sea cucumber and sediment/water quality will work closely with our group in validating the advantages of integrated milkfish culture systems. Differences in water quality, sediment quality and growth rate of milkfish in integrated versus monoculture systems will be compared and analyzed by the Student's-t-test and one-way analysis of variance.

Null Hypothesis: Milkfish growth rate and water quality and sediment quality do not differ between milkfish integrated and monoculture systems.

3. Demonstration of the economic feasibility of integrated culture systems and value-added processing of milkfish through season-long training for community-based livelihood projects
After the completion of field trials, arrangements will be made to demonstrate the economic feasibility of integrated culture systems in a community-based livelihood project through season-long training. Since 2007, SEAFDEC AQD has assisted community-based milkfish farming by 4 baranggays (*i.e.* villages) in Guimaras Island affected by the August 2006 oil spill. The integrated culture system will be introduced to these communities through a workshop and season-long training programs implemented by SEAFDEC AQD using their milkfish cages as a demonstration facility. SEAFDEC staff on this project and several seaweed farmers, for which a majority are women, will aid milkfish producers in maintaining the community-based integrated culture systems.

Additionally, 20 women within the milkfish community will learn the process of deboning, smoking, and marinating deboned milkfish in various flavors as well as procedures for seafood safety as part of the season-long training program. Brochures, books and recipes will be provided to participants along with demonstration processing. We anticipate through the continued outreach support of SEAFDEC staff that these women could then serve as trainers for others. This will sustain the involvement of women in this aquaculture endeavor. Capacity building in milkfish processing and value-added product development could provide additionally income to

women and improve household welfare. We anticipate that this type of training will eventually evolve into processing opportunities for international markets.

Schedule

January - June 2010: Feed ration in fish cages and tank integrative culture systems experiments
June 2010 - January 2011: Begin integrative culture systems trial in fish cages
February - September 2011: Complete integrative culture system trial, demonstration of integrated culture on private farms
April - September 2011: Extension manual writing; Workshops on integrated culture systems and value added processing of milkfish
July - Sept 2011: Final report writing

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INTEGRATING ENVIRONMENTAL IMPACTS, PRODUCTIVITY, AND PROFITABILITY OF SHRIMP AQUACULTURE AT THE FARM-SCALE AS MEANS TO SUPPORT GOOD AQUACULTURE PRACTICES AND ECO-CERTIFICATION

Mitigating Negative Environmental Impacts/Study/09MNE03UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA)	James S. Diana
Huazhong Agricultural University (China)	Wang Weimin
Shanghai Ocean University (China)	Liu Liping

Objectives

1. To develop a mass balance model to formulate methods to reduce the environmental impacts of shrimp aquaculture
2. To simulate shrimp production using different management regimes to determine optimal productivity
3. To maximize profit through economic analysis as means to evaluate potential of eco-certification

Significance

Shrimp aquaculture is of great importance worldwide, with extraordinary expansion since 1970. Global production of shrimp farming increased from less than 9000 metric tons in 1970 to about 1 million metric tons in 2000 (FAO 2001a). Asia plays a leading role in shrimp farming, accounting for almost 80% of world shrimp culture production (Fuchs et al. 1999). China has been one of the world's largest shrimp producers since 1988. Although suffering from disease outbreaks and environmental problems, shrimp farming is still under rapid growth in China.

Shrimp aquaculture has been criticized for negative impacts on the environment, aquatic ecosystem, and human health due to use of fishmeal, land salinization and habitat modification (Diana 2009). Aquatic animal health, food safety, and hygiene issues are increasing due to chemical abuse. According to official statistics, about 43 billion tons of waste water from shrimp aquaculture discharge into the ambient aquatic environment without pretreatment each year in China (Xie and Yu 2007). Excessive nutrient loading leads to eutrophication and hypoxia in adjacent coastal areas. Consequently, the trade-off between seafood production and environmental costs has raised a great concern over how to make aquaculture systems more sustainable and responsible.

Planning for sustainable aquaculture development implies either qualitative or quantitative examinations of different development options in terms of their financial, economic, social, and environmental costs and benefits, and the distribution of these costs and benefits through time and space, and between different groups in society (FAO 2001b). Despite the rapid growth of aquaculture and the growing awareness of environmental issues, few studies have been made which address these issues objectively. Many studies have polarized either emphasizing economic benefits or mitigating environmental impacts.

Optimizing one system based on full or pilot scale experimentation is extremely time consuming and expensive. Alternatively, models are often used to simulate culture systems and also to predict system productivities. In simulation models, flows of energy or materials between compartments are estimated from internal biological flux, such as feeding or sedimentation, modified by external forcing functions, such as temperature, light or salinity. Changes in the variables are then calculated using sets of differential equations. The terms that are included in the equations relating to a particular variable are based on their assumed importance. Subsequent testing of the predictions of the model against experimental data then allows refinement of equations and adjustment of coefficients of the model that determine the flux. To develop an efficient aquaculture production

system, most nutrients applied should be absorbed by fish rather than accumulated in the system, discharged as waste or released to the atmosphere (Diana 2009). Mass balance modeling could be used to assess environmental effects at the farm level, as it has been widely applied to shrimp aquaculture to understand system efficiency and to evaluate environmental impacts and eutrophication potential (Schneider et al. 2005). Mass balance modeling will evaluate how much of the nutrients provided are assimilated directly by fish or released into the environment. Dynamic simulations, using software such as MATLAB and Simulink (MathWorks, Inc., Natick, MA, USA), can improve and optimize a farming system with respect to effluent water quality, production and robustness. POND software is the most widely known simulation tool with a focus on the pond environment (Prein 2007). It can be used to rapidly analyze aquaculture systems under different management regimes and to assist in the optimal management strategies, including nutrient inputs and flows.

Eco-certification is now viewed as a market-based tool for minimizing negative impacts and increasing consumer benefits and confidence in the process of aquaculture production and marketing. Farm gate price has a major impact on farmer behavior. If this price can be linked in any consistent way to better management of aquaculture operations, change will follow rapidly. In an attempt to provide the industry an incentive to promote sustainability, World Wildlife Fund (WWF) has initiated shrimp aquaculture dialogues around the world to establish eco-certification guidelines. These guidelines are intended to establish a credible certification system, giving producers the opportunity to receive a price premium for maintaining a number of good practice standards. In most cases, the efficiency of any practice is not well known, and its relative costs and benefits are even less clear. However, the efficiency and cost-benefit of these practices are paramount to the success of certification. To incorporate the monetary value of implementing good practices and potential for participating in eco-certification programs, economic techniques must be applied in order to address profit maximization of shrimp aquaculture.

Economic analysis provides a systematic evaluation of aquaculture activities, which in turn can lead to the identification of options for planners and decision-makers with regard to best management regimes. It may also provide a framework for a rigorous assessment of the costs and benefits of interactions between activities and production decisions. It seeks to aggregate social, environmental, and financial values relating to a particular enterprise or sector into a single index of total economic value, allowing for a standardized comparison of development alternatives. Cost benefit analysis (CBA) is usually the most appropriate methodology (Knowler 2007). CBA aims to identify and evaluate all the direct and indirect costs and benefits (financial, economic, social, and environmental) associated with a particular action (FAO 2001b). In practice, it is extremely difficult to identify and value (in cash terms) all the costs and benefits, although economists use a range of tools to facilitate this process, and adjust values to allow for market imperfections. This analysis involves identifying the full range of costs and benefits of an action, providing monetary values for them, and using market or "shadow" prices to determine the net impact (Knowler 2007). These costs and benefits can then be aggregated in the form of a benefit/cost ratio providing a simple decision criterion for decision makers. Its objective is to maximize net economic benefits from human welfare perspectives. There are four component stages to cost benefit analysis: 1) delineation of the boundary of the analysis; 2) identification of costs and benefits (e.g.. provision of infrastructure (cost); increased fish supply (benefit)); 3) financial evaluation of the costs and benefits based on market prices for commodities and then conversion of financial to economic values; 4) comparison of economic costs and benefits over time under various alternative scenarios to assess the net economic benefit returned (FAO 2001b).

Quantified Anticipated Benefits

The ultimate goal of this farm-scale integrated assessment is to optimize shrimp aquaculture system in terms of environmental sustainability, economic viability, and social acceptability. The research is expected to advise regulation information and environmental impact mitigation measures for policy makers, and to guide shrimp farmers to implement good aquaculture practices and better manage

their farms in an environmentally friendly manner. Once again, it will assist the U.S. in its evaluation of the environmental footprint of shrimp imports. Results of these analyses will be published in peer-reviewed journals to extend information to government officials. In addition, summary data will be accumulated to provide briefings for government officials and private farmers.

Research Design & Activity Plan

Locations: Guangdong and Fujian Province, China

Site selection: Three industrial-scale intensive shrimp farms with at least 10 ponds each will be selected. The farms should be accessible and cooperative, with appropriate locations to obtain water samples for water quality, inflow and effluent discharge analysis, as well as an ability to take on-farm shrimp and feed samples for later composition analysis. Study farms should also be situated away from shrimp processing plants to avoid confounding problems. All site selection will be under the assistance of Huazhong Agricultural University, China.

Field sampling: Farm data including layout (farm area, pond length, pond width, water depth), yearly water turnover, stocking density and time, mortality rate, growth data, seed cost, harvest size, sale price, cultivation period, and feed conversion ratio will be recorded. Water quality analysis will be conducted by methods described by Boyd and Green (2002). A minimum of two liters of water will be taken from the inflow and effluent during regular water exchange. Water samples will be tested for temperature and dissolved oxygen in the field and then kept on ice until water quality analysis in a laboratory. PH, ammonia nitrogen, nitrate nitrogen, total phosphorus, total nitrogen, suspended solids, biochemical oxygen demand, chlorophyll, and salinity will be tested. Samples of material including shrimp tissue and shrimp feed will also be taken on each farm for mass balance analysis. All these samples will be tested at the Huazhong Agricultural University following standard procedures. Onsite interviews will be conducted at each site to investigate routine management, chemical use, the costs, and associated challenges of implementing more stringent water quality control on farms of various sizes, the openness of farmers to participating in eco-certification programs, and the perceived and actual profit threshold required for adoption of improved treatment techniques.

Evaluation methods:

- Mass balance and dynamic simulation modeling: Mass balance model will be used to analyze the system efficiency. Dynamic simulations of production by using MATLAB (MathWorks, Inc., Natick, MA, USA) and POND will be used to improve and optimize a farming system with respect to effluent water quality, production, and robustness.

- Cost benefit analysis: cost and benefit will be evaluated to maximize profit of shrimp farms and considered as a factor of social sustainability, possibly compared to factors of ecosystem service dollar amounts.

- Statistical analysis: Data will be analyzed using ANOVA, t-test, correlation and regression.

Schedule

1 October 2009 to 29 September 2011.Report submission: no later than 29 September 2011.

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DEVELOPING MANAGEMENT RECOMMENDATIONS FOR FRESHWATER SMALL-SIZED/LOW VALUE FISH IN THE LOWER MEKONG REGION OF CAMBODIA AND VIETNAM

Mitigating Negative Environmental Impacts/Study/09MNE04UC

Collaborating Institutions & Lead Investigators

University of Connecticut–Avery Point (USA) — Robert Pomeroy
Inland Fisheries Research & Development Institute (Cambodia) — So Nam

Objectives

The objective of this study is to develop management recommendations for freshwater small-sized/low value fish in the Lower Mekong region of Cambodia and Vietnam in order to reestablish stocks to support food security and poverty alleviation.

Significance

Over the last decade, the price of small-sized/low value fish has risen considerably and it is predicted to increase over the next few years due to increased demand for fishmeal and fish oil to meet market demands for aquaculture of carnivorous fish (and well as a source of affordable human food). At the local level, prices of small-sized/low value fish vary depending on species, seasons and abundance of other fish and fishery products. Prices also fluctuate with the demand for fishmeal in the livestock and aquaculture industry and the availability of raw materials for fishmeal production. Given that aquaculture is predicted to grow while capture fisheries remain stable, it will become increasingly more difficult to meet the demand for small-sized/low value fish for human consumptions.

There is an increasing conflict between the use of small-sized/low value fish for animals/fish and for human consumption. Supplies of small-sized/low value fish are finite, and as indicated by a recent increase in price, i.e. demand is outstripping supply. It has been argued that it would be more efficient and ethical to divert more of the limited supply to human food, using value-added products, etc. Proponents of this suggest small-sized/low value fish as food for poor domestic consumers is more appropriate than supplying fishmeal plants for an export income oriented aquaculture industry, producing high value commodities. On the other hand, food security can also be increased by improving the income generation abilities of poor people, and it can be argued that the large number of people employed in both fishing and aquaculture has this beneficial effect, via income generation, rather than direct food supply.

In general, the disposition of small-sized/low value fish is market driven and dependent upon local economic mechanisms. Without external interventions (such as incentives and subsidies) it will be the economics of the different uses of small-sized/low value fish in different localities that will divert the fish one way or the other. For example, in Viet Nam, as the national demand for fish sauce is predicted to double over the next 10 years, there appears to be direct competition for mixed small-sized/low value fish between *Pangasius* feeds and those needed to make low-cost fish sauce. Traditional small-scale pig, duck and chicken rearing uses small-sized/low value fish but large-scale pig, duck and chicken farming uses agro-industrial formulated feed containing fishmeal.

Small-sized/low value fish are important to the communities and aquaculture, as well as the ecosystems in Cambodia and Vietnam. There is a need to support the development of a policy and management framework to address aquaculture and capture fisheries interactions.

Quantified Anticipated Benefits

1. 200 scientists, researchers, resource managers, government officials, non-government organizations, and inter-governmental organizations concerned with and working on the issue of low value/trash fish in Cambodia and Vietnam, and in the Asia-Pacific region in general, will be better informed and have recommendations for improved management of freshwater small-sized/low value fish in the Lower Mekong region through project various orientation meetings, two inception workshops, and four consultation meetings, which will be conducted in both Cambodia and Vietnam.

b. Benefits of the investigation to the US include lessons learned on the management of freshwater fish and methods to mitigate negative environmental impacts will be shared with US fisheries managers.

Research Design & Activity Plan

Location of work: The study will be implemented in both Cambodia and Vietnam.

Methods: This study is primarily a desk policy analysis. Significant data and information on the problem, issue, status of stocks, utilization, supply and demand trends and impacts will have been collected from other investigations of this project. This will provide a solid foundation for developing management plans and interventions. This investigation will involve: (1) a re-analysis of all this data and information and (2) the development of fisheries management recommendations to conserve the biodiversity of freshwater small-sized/low value fish species in the Lower Mekong region. A series of stakeholder consultations with all relevant government and non-government organizations, research and academic institutions, and the private sector in both Cambodia and Vietnam will be conducted to obtain additional information and to validate findings and recommendations. A focus in the recommendations will be on management for food security and poverty alleviation in the region. Regional cooperation to address these issues will be required from not only Cambodia and Vietnam, but Thailand and Laos. Coordination will be established with the Southeast Asian Fisheries Development Center and the UN Food and Agriculture Organization regional office in Bangkok.

Schedule

This study is planned to be implemented as below:

Activity	Beginning	Ending
Data analysis	01/2011	05/2011
Stakeholder consultations	05/2011	07/2011
Policy management report preparation	05/2011	07/2011
Stakeholder consultations	07/2011	08/2011
Final policy management report preparation	08/2011	09/2011

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THE IMPACT OF FISH STOCKING ON WILD FISH POPULATIONS, FISH PRODUCTION AND AQUATIC ENVIRONMENT IN IRRIGATION RESERVOIRS IN SOUTH VIETNAM

Mitigating Negative Environmental Impacts/Study/09MNE05UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA)	James S. Diana
Nong Lam University (Vietnam)	Nguyen Phu Hoa
	Le Thanh Hung
Shanghai Ocean University (China)	Yang Yi

Objectives

1. To determine changes in wild fish population in reservoirs with and without stocked exotic fish species.
2. To determine food web interactions in reservoirs.
3. To investigate impacts of fish stocking on environmental carrying capacity.

Significance

Exotic species are defined as species or subspecies introduced outside their natural past or present distribution. These introductions include any materials, such as gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (Bartley and Fleischer 2005). Among various reasons for introduction of exotic aquatic animals, aquaculture development is a major motive (Welcomme 1998). The introduction of exotic species into a new region may cause not only environmental and socio-economic effects, but also be associated with "genetic pollution" (Cripps and Kumar 2003). Invading exotic species in the United States cause major environmental damages and losses adding up to almost $120 billion per year (Pimentel et al. 2005). The introduction of exotic species into a new region will risk corrupting native fish communities through predation, competition for habitats and food, disease, hybridization and other adverse environmental impacts (Welcomme 2001, Cripps and Kumar 2003), and can also produce imbalances in the fish community, disrupting food chains, and threatening the survival of non-target species (Welcomme 2001).

The southeast of Vietnam is characterized by uphill geography. To support agriculture in this area, more than 50 small reservoirs (from 10 to 50 ha) and about 10 medium reservoirs (200-400 ha) were built for irrigation. In Binh Phuoc and Dong Nai provinces, many surrounding communities make use of the large water area (<50 ha) by stocking cultured fish species into reservoirs. This has been hypothesized as a damage to natural fish populations, but there are no formal analyses about that and no evidence on reasons for these changes. Of course, the reservoirs themselves are not natural systems and may have altered fish communities, with some riverine and some lacustrine species. Moreover, there has been no evaluation of the impact of water quality from reservoirs used for fish culture on the use of that water for irrigation.

Tilapia, bighead carp, silver barb, common carp and grass carp are common species stocked into big reservoirs like Tri An reservoir (Luong et al. 2004) in south east Viet Nam (Si 2007). These species may compete for food and habitat but also serve as prey of native existing species (Luong et al. 2004). Previous CRSP project results have shown that the interaction among aquatic flora and fauna in Tri An reservoir is very complicated, due to the varying fishery harvest, the continual input of new species, and the large size of the reservoir. However, using the methodologies from Tri An studies, especially Ecopath modeling, it should be feasible to estimate carrying capacity, stocking rate and species composition of smaller reservoirs. These studies will estimate the degree and extent of damages on fisheries and biodiversity of indigenous fish species due to the introduction of cultured fish species in small reservoirs.

Quantified Anticipated Benefits

The major impact of this study will to estimate the number of indigenous species which have been affected by introduction of exotic species into each reservoir. Specific information on the impacts of cultured fish species on fisheries and biodiversity of indigenous fish species will allow governmental agencies and local communities to establish policies, plans and mechanisms for management of stocking of cultured fish species.

Specifically, this study will estimate the impact of stocking cultured fish species on fish production and economic value of the fishery in small irrigation reservoirs. The food web will be studied in reservoirs with and without cultured fish species to determine diet overlap between some cultured and wild species. We will estimate environmental carrying capacity for fish stocking in each reservoir. Moreover, physical-chemical and biological parameters will be monitored to provide useful information on the impact of aquaculture activities on environment, especially in waters used for irrigation purposes. We will also produce fact sheets for each reservoir, indicating the dominant species present and their origins.

Research Design & Activity Plan

Large geographic scale analysis:

- Study areas: 4 reservoirs without stocked fish and 4 with aquaculture practices
- Materials and methods: estimate fish catch and fish species composition in each reservoir in 2 years from relevant reservoir management agencies or fishermen every month using questionnaires and direct interviews.
- Workshop: As reservoirs are widely distributed in south east Viet Nam, and cultured fish species have been introduced into many reservoirs either intentionally or unintentionally, two 1-day workshops in Dong Nai and Binh Phuoc provinces involving farmers, reservoir management entities and government officials will provide useful information on appropriate management strategies for cultured fish species in reservoirs and general recommendations on policies for the introduction of cultured fish species.

Fine geographic scale analysis:

- Study areas: 1 reservoir with aquaculture practices in Dong Nai Province and 1 reservoir without fish stocking in Binh Phuoc Province will be evaluated for diet overlap between cultured and wild fish species, as well as water quality parameters

- Materials and methods:
  - 5 cultured fish species and 5 wild fish species (10 samples/species) will be collected and dissected every month from each reservoir for determination of their food habits.

  - Morphology for volumetric estimation will be carried out by determining the area and depth contours of the reservoir using SURFER 6.0 software (Keckler 1997) from three-dimensional data recorded by an Echo Sounder.

  - Water samples will be collected at 0900-1000 h monthly at nine stations in each reservoir to determine physical-chemical parameters (temperature, pH, DO, alkalinity, total nitrogen, total phosphorus), phytoplankton biomass (chlorophyll a and primary productivity), zooplankton biomass and production. Glass microscope slides (27.5 x 77.3 mm) will be used as artificial substrates to collect periphyton. Benthos and prawns will be sampled monthly at nine stations at each reservoir, with 3 replications in each station using an Ekman dredge with an area of 225 cm^2. Species abundance and biomass of benthos and prawns will be quantified. The biomass was determined by ash-free dry weight. Biomass of small wild fish will be recorded at harvest only. At stocking, small wild fish will be sampled by gill netting and electrofishing in designed blocks to estimate abundance. During the entire culture period, biomass of small wild fish will be calculated as the mean

of the biomasses at stocking and at harvest, thus not taking t into account that growth (and consumption) rates vary throughout the culture period (Ruddle and Christensen 1993).

All of the above parameters will provide information about food chain and food web in reservoirs. They are also input parameters required by Ecopath 5.0. Ecopath modeling will be used to evaluate carrying capacity, stocking rate and fish species composition.

Schedule

1 October 2009 – 29 September 2011. Report submission: not later than 29 September 2011.

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EVALUATING THE RELATIONSHIP BETWEEN SEMI-INTENSIVE AQUACULTURE AND NATURAL BIODIVERSITY

Mitigating Negative Environmental Impacts / Activity / 09MNE06UM

Collaborating Institutions & Lead Investigators

University of Michigan (USA) — James Diana
Shanghai Ocean University (China) — Liu Liping

Objectives

1. Gather participants for a symposium to evaluate the relationship between semi-intensive aquaculture and natural biodiversity
2. Prepare manuscripts for inclusion in a book, summarizing the results of the symposium;
3. Based on the symposium, revise manuscripts to incorporate current information and any necessary changes;
4. Finalize production of the book from review of edited manuscripts.

Significance

It is abundantly clear that aquaculture production is increasing as a response to increasing human populations and the need for food (FAO 2007). These responses produced positive results related to food availability for the human population (Delgado et al. 2003), as well as negative results related to environmental impacts of aquaculture systems (Naylor et al. 2000). While most evaluations of the impacts have occurred in the developed world, 92.3% of all culture harvest occurs in developing countries. Aquaculture is the fastest growing food production system globally, with an 8.8% increase in production of animal crops per year since 1985 (FAO 2007). Diana (2009) reviewed the status of aquaculture and fisheries and their interaction with global biodiversity. That review used data from Boyd et al. (2005) to list eight categories of negative impacts, with five having importance to biodiversity conservation. These included:

1. Escapement of aquatic crops and their potential hazard as invasive species or on the genetics of wild species;
2. The relationships among effluents, eutrophication of water bodies, and changes in the fauna of receiving waters;
3. Conversion of sensitive land areas such as mangroves and wetlands;
4. Other resource use, such as fishmeal and its concomitant overexploitation of fish stocks;
5. Disease or parasite transfer from captive to wild fish stocks.

A similar listing of potential negative impacts has been described in the various aquaculture dialogues, such as the Shrimp Dialogue, coordinated by the World Wildlife Fund (Bernard 2008). It is also important to realize that aquaculture may have significant positive impacts on biodiversity. Diana (2009) also recognized four of these:

1. Production of fish can reduce pressure on wild fish stocks, which may already be overexploited;
2. Stocking organisms from aquaculture systems may help to enhance depleted stocks with limited reproductive success;
3. Effluents and waste from aquaculture can increase local production, abundance, and diversity of species;
4. Destructive land-use patterns, such as slash-and-burn agriculture, may be replaced by more sustainable patterns, such as aquaculture in ponds, which also may generate income, reduce poverty, and improve human health.

In reviewing the literature on aquaculture and its environmental impacts, current information both on environmental impacts and on aquaculture systems are important in order to do an adequate evaluation. Using published literature, which has a several-year time lag between initiation and publication, results in aquaculturists using old environmental information in their analysis of potential effects, or in conservationists using old aquaculture information. This could only be overcome by bringing all participants together to a similar venue for an analysis of current aquaculture systems and biodiversity conservation. Such a venue is the focus of this proposal.

In addition to timing, it is also important to realize the variety of aquaculture systems, both in locations, as well as in intensity of use (New 2003; Diana 2009). The AquaFish CRSP has predominantly worked in developing countries with semi-intensive aquaculture systems. These systems tend to be more environmentally benign in many of the characteristics related to effluents, disease, and other impacts of intensive aquaculture. However, they generally use more land and also use invasive or exotic species. A secondary characteristic of this symposium will be to evaluate biodiversity effects of semi-intensive aquaculture systems, therefore limiting the potential impacts to those of a moderate-scale aquaculture intensity.

We propose a three-day symposium, organized by the CRSP, and involving participants from both sides of the debate on aquaculture and biodiversity. The environmental impacts summarized in Diana (2009) will be used as a structure for determining the various potential chapters of the resulting book, and attempts will be made to solicit leaders in thought on the relationship between biodiversity and aquaculture to focus on each of these topic areas. CRSP participants will be included where possible, as well as other experts. This would lead to approximately 15-20 participants in the symposium, depending on their background and the willingness to work across topic areas. The symposium would best function by being scheduled independent from any other meetings, so the authors can concentrate not only on their presentation, but also on their interaction with other colleagues and understanding of the current state of the science.

Quantified Anticipated Benefits

Aquaculture expansion is contingent upon its environmental impacts and its effect on wild populations, as well as its suitability as a food source for human use. Therefore, some consensus, or at least evaluation, of the relationship between aquaculture and biodiversity conservation is important. This symposium should inform at least 15-20 scientists who attend the symposium on the current status and future directions of research needed to understand the biodiversity-aquaculture nexus. Ultimately, producing a book that can be widely distributed will further expand this information out to a much broader audience of aquaculturists, ecologists, and government policy analysts. Our quantified benefits include a renewed knowledge for the 15-20 participants in the symposium, as well as the publication of a book that will ultimately influence many others on the same topic.

Activity Plan

This symposium will likely be held in Hawai'i, probably Hilo, during the fall of 2010. Participants in the symposium will be identified early and invited to participate well in advance. We hope to gain a broad spectrum of participants to represent all aspects of the biodiversity-aquaculture nexus. Travel costs of participants will be borne by the grant, as well as logistic costs for running the meeting.

Participants in the symposium will be required to prepare a manuscript on their topic prior to the meeting. These manuscripts will be circulated to all participants at the symposium.

The symposium will focus on evaluating current trends and critiquing the various manuscripts submitted. Equal time will be given to both presentation and discussion on each of the topic areas.

Manuscript authors will be asked to revise their manuscript upon completion of the meeting and discussion. These revised manuscripts will then be submitted for peer review and potential inclusion in the symposium proceedings.

Manuscripts that are successfully developed through the peer-review process will ultimately be included in the published document.

Schedule

Symposium: Fall 2010; Report submission: no later than 29 September 2011. Book publication will be delayed beyond the final reporting deadline.

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PART III. PROGRAM-WIDE PROJECTS

SYNTHESIS PROJECT: EVALUATING AQUAFISH ACCOMPLISHMENTS IN A SYSTEMS FRAMEWORK

Collaborating Institution & Lead Investigator

Oregon State University Steve Buccola

Objectives

1. Develop a framework for characterizing AquaFish project accomplishments, taking into account project objectives and resources.
2. Apply the framework to assess AquaFish contributions by Topic Area.

Significance

The AquaFish CRSP seeks to improve food security by fostering sustainable aquaculture development and aquatic resource management in developing countries. Through its Lead Partner Institutions (LPIs), the CRSP provides sub-awards to developing country institutions for investigations to be completed by 30 September 2009.

Each LPI focuses on one of four CRSP Themes, while attending to the remaining three: (a) improving health and nutrition, (b) generating income for small-scale fish farmers, (c) improving environmental management, and (d) enhancing trade opportunities. Awarded LPIs and the investigations they finance must adhere to USAID's core program components: a systems approach; social and environmental sustainability; local and national capacity building; outreach and adoption; and gender integration. Investigations are to build as much as possible on previous USAID-funded work and institutions. The overarching requirement is that a funded investigation or sub-award provide, at its conclusion, a comprehensive development approach to a small-scale aquaculture or fisheries problem. The approach must include some attention to outreach and dissemination, even if outreach is not its main emphasis.

USAID requires as well that AquaFish demonstrate its successes in achieving the country-level investigations' stated objectives. Success must be demonstrable both qualitatively and quantitatively. In their quarterly and annual reports, country-level investigators and LPIs provide two types of quantitative information about their activities and outputs: (a) EGAT indicators, expressed at a somewhat generic level and requested by EGAT/USAID; and (b) DTAP (Development Theme Advisory Panel) indicators, which AquaFish has developed for specific use by AquaFish investigations. Besides these indicators, Lead Partner Institutions and their country-level counterparts provide qualitative information about project goals; institutional, technological, and social environments; and project outcomes and difficulties.

The purpose of this Synthesis Project is to employ the above information, in conjunction with additional data, to express the contributions of the AquaFish CRSP LPIs, and their funded investigations, during the 1 April 2007 – 30 September 2009 period. The analysis will provide USAID and others interested in developing-nation aquaculture with a coordinated view of how the wide-ranging AquaFish studies work together to improve productive efficiency, raise incomes, enhance human health and safety, expand markets, and mitigate fish farming's environmental impacts.

Quantified Anticipated Benefits

The project will provide two outputs:

1. descriptive analyses, by Topic Area, of AquaFish accomplishments; and
2. quantitative analyses, by Topic Area, of the impacts of AquaFish inputs on outputs.

The descriptive analysis will be designed to bring out those aspects of the AquaFish CRSP projects that most effectively satisfy the CRSP objectives, and at the same time identify sources of problems that prevent full attainment of anticipated CRSP benefits. The quantitative analysis will consist of an examination, at the Topic Area level, of how the sizes and qualities of project inputs affect project outputs and value. The descriptive and quantitative analyses will be combined to form a picture of what has been accomplished under each Topic Area.

Research Design & Activity Plan

Each investigation or sub-award in the AquaFish CRSP concentrates on a particular Research and Outreach Topic. Topics are organized under one of two Topic Areas as follows (titles are abbreviated):

Integrated Production Systems
Production System Design
Feed Technology
Species Development
Seedstock Development

People and Ecosystem Relationships
Human Health
Food Safety and Value-Added
Technology and Policy Adoption
Marketing, Trade, and Risk Assessment
Watershed and Coastal Management
Mitigating Environmental Impacts

The systems orientation of the AquaFish CRSP suggest that its country-level investigations be evaluated in groups similar to these. The above groupings involve a wide variety of subject matters and disciplinary foci, even after account is taken of the systems approach that all investigators are required to follow. Because subject matter and discipline greatly influence how an investigation is to be understood and valued, the frameworks and procedures employed in the present Synthesis Project ought to vary according to Topic or Topic Area.

However, topics grouped under People and Ecosystem Relationships probably are too heterogeneous to be included in a single evaluative study. It is important, then, to show how the CRSP's Topics might be better be grouped for evaluative purposes. The CRSP RFP's illustrative descriptions of the Topics to be funded suggest, in terms of conceptual or scientific paradigm, that we group the Topics into the following five categories.

Category I
Production System Design
Feed Technology
Species Development
Seedstock Development

This Category comprises all four Topics in the Integrated Production Systems Topic Area. Its focus is aquaculture and fisheries production. Its main analytic paradigm is physical, and especially biological, science. As such, the CRSP's goal of alleviating poverty and improving food security is best assessed in this Category by asking how and by how much the technical input-output possibilities in the relevant fisheries production sector have been enhanced. That is, how and by how much might fisheries productivity have been improved as a result of the investigation, taking systems interrelationships into account?

Category II:
Human Health
Food Safety and Value-Added

This Category's focus is fish processing and food value. It's main analytic paradigm is, again, the physical and biological sciences. Therefore, the CRSP's goals are best assessed by inquiring into the extent by which, on account of the investigation in question, fish-food quality and quantity have been enhanced per unit of processing cost. In other words by how much has processing productivity grown, taking food quality, human health, and systems interrelationships into account?

Category III: Technology and Policy Adoption
Evaluative paradigms in this Category differ greatly from those in I and II. We here must ask by how much the investigation has: (i) enhanced communication channels among the important aquaculture-fisheries stakeholders and actors, and (ii) educated or otherwise persuaded them to adopt best-practice methods and policies. That is, while Categories I and II (and IV and V below) are evaluated in terms of how much they expand the technical possibilities, Category III is evaluated in terms of how the investigation has moved producers, processors, marketers, and others toward those expanded possibilities.

Category IV: Marketing, Trade, and Risk Assessment
Investigations in this Category should be assessed in terms of the social sciences. We will ask how and in what ways the investigator has identified new markets, grown existing ones, improved handling and transportation logistics, and reduced price distortions in the smallholder fish processing/handling/marketing sector. Studies and activities in this Category would especially be expected to take the entire smallholder aquatic system into account, since markets and risk necessarily involve every element of a market or distribution system.

Category V: Watershed and Coastal Management
This Category is best assessed in terms of the biological sciences and management, for example in terms of ecology and ecosystem management. We will ask how the investigator has helped ameliorate environmental damage, market or other-environmental costs of that amelioration, and likely long-run impacts of these changes on the level and stability of poor families' incomes. Systems considerations, that is the inter-relatedness of physical, biological, and social relationships, should again be accorded an especially heavy weight in this Category.

Data and other information for this study will be taken from the LPIs' quarterly and annual responses to EGAT and DTAP questionnaires, in addition to conversations with and a survey of the LPI principal investigators. The survey will be designed to gather project input and output data unavailable in the DTAP responses. The quantitative analysis employing these data likely will take the form of distance function estimation, a method of characterizing input-output relationships (Fare and Primont).

Schedule

The study will proceed as follows:

- *January – September 2009*: Examine LPI award and sub-award documents, including research/outreach/activity Implementation plans and progress reports.
- *July – December 2009*: Communicate with LPI and investigator personnel to obtain further qualitative information about AquaFish CRSP investigations and their outputs.
- *October 2009 – March 2010*: Conduct survey of LPIs to obtain project input and predicted output data not available in qualitative reports or DTAP reports.
- *January – September 2010*: Based on the above information, conduct preliminary qualitative analysis of AquaFish CRSP Topic Area accomplishments.
- *April – December 2010*: Conduct preliminary quantitative analysis of AquaFish input-output relationships by Topic Area.
- *September 2010 – August 2011*: Respond to LPI and other comments on qualitative and quantitative studies, perform any re-estimation, and write final reports.

General Readings

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COMMUNICATIONS PROJECT: TELLING THE ACRSP & AQUAFISH STORY

Collaborating Institution & Lead Investigator

Oregon State University

Peg Herring
Jeff Hino
Tiffany Woods

Objectives

To tell a compelling story about ACRSP and AquaFish CRSP to a variety of audiences.

1. To provide stories that illustrate the success and sustainable benefits of specific projects in various parts of the world. Stories will be developed for a variety of venues, including feature articles, press releases, proof points, and web-based multimedia.
2. To provide training for participants (scientists, extension workers, USAID personnel) in ways to explain the importance of their work to international media and decision-makers.

Significance

The importance of communicating impacts of CRSP research to diverse audiences has not been lost on USAID. To date, however, the task has fallen mostly to scientists and administrators to tell the stories, and for the most part, the stories have not been vivid or engaging. What have been lacking are experienced journalists and writers to interpret and refine stories of CRSP outputs and impacts. The objective is to allow the fresh perspective of veteran writers/journalists to reframe previously ho-hum accomplishments of the ACRSP and AquaFish CRSP into stories that appeal to people, warm hearts, and engage minds.

This activity will explore and convey one to three success stories each from CRSP projects that were involved in ACRSP and continued into the AquaFish CRSP. Additional success stories will be drawn from successful ACRSP projects that ended in 2007. Science writers will collect information from secondary sources, such as CRSP reports, but also from primary sources, such as interviews and visits to key CRSP sites. The objective is to broaden the audience for these USAID CRSPs by releasing a minimum of six articles to the media (media releases). Both print and video stories will be created for the AquaFish CRSP website, which in turn can be taken up by USAID and the CRSP Council for further distribution.

These products have technical application as stand-alone communication tools that explain the CRSP programs and accomplishments tailored for, and targeted at major Aquaculture & Fisheries CRSP stakeholders, such as Congress, USAID missions, and the general public.

Why Extension and Experiment Station Communications?

If your goal were simply to provide a good quality fish pond, you might hire a contractor to build it. Similarly, if your goal were simply to provide a good story, you might hire a journalist to write it.

But in both cases, the goal of USAID is greater than delivery of a single product. The AquaFish CRSP delivers a toolbox of appropriate technology and the outreach education to apply it and improve upon it. Similarly, extension and research communications delivers a collection of stories and the training to help participants successfully use those stories and develop their own effective messages.

Technology dissemination begins with clear communication. The educational outreach and communications developed by this EESC team reflects their experience translating complex issues of science and policy for the public to understand and use. We are teachers as well as

communicators, and we are leaders in the international community of agricultural and natural resource communications. Profiles of the three communicators are attached below.

Deliverables

We will deliver at least 10 stories during the two-year life of the grant. The stories will reflect the impact of the projects we visit and will be useful in a variety of venues.

ACRSP-AquaFish Success Stories. For each country visited, we will produce one to three success stories that feature long-term projects in Mexico, Philippines, Kenya. These projects have had continuity in personnel and in research foci.

- We will produce an additional one to three success stories for Vietnam (a satellite CRSP site in ACRSP and a new partner site in AquaFish)
  Metric: 4-12 stories

- We will produce an additional one to three success stories for each of the following old ACRSP sites: Honduras, Peru, Thailand
  Metric: 3-9 stories

Success stories include:
- press release (300-600-word stories reporting new findings related to current events)
  feature (500-1200-word stories that involve human interest, community impact, or regional context)
- a set of proof points (concise claims that summarize key impacts from each site)
- web-based multimedia (3-minute videos or slideshows that illustrate the process and progress of each project)

We will produce at least one piece that synthesizes themes across all projects that we visit, a story that will be useful for USAID personnel to explain the global importance of their collective work.

Training. In addition, we will provide training in developing effective messages for AquaFish CRSP participants. This training could include:
- introduction to concepts of clear communication for assembled participants at international meetings in San Diego and Brazil.
- training for site-based personnel to help them prepare for interviews with regional and international media.
- help with translation of technology into clear communication that is useful and meaningful to intended audiences.
- presentation to USAID administrators in Washington, DC

Activity Plan

Over the next two years, we will travel to three continents to report the accomplishments of the ACRSP and AquaFish CRSP program. We will divide the project among three communicators. Although only one communicator will visit each site, all three will be involved in creating stories from each project. That way, each project will reflect our collective expertise in written and visual communications and training.

The sites to be visited are:
Philippines, Viet Nam, and possibly Thailand: Peg Herring will visit during 2010
Kenya: Jeff Hino will visit during 2010
Mexico, Honduras, and possibly Peru: Tiffany Woods will visit during 2010

Schedule

Research will begin immediately on specific projects to be visited. All three communicators will attend the San Diego meeting, February 28 –March 4, 2010, to discuss particular needs with partners. Site visits will follow over the following 8 months. Site-specific stories will be delivered within three months of each visit. Synthesis stories will be developed following completion of all site-specific stories.

The project end date is September 29, 2011. Annual reports will be submitted on September 30, 2010 and September 29, 2011. Trip reports will be submitted by travelers within 2 weeks of travel.

APPENDIX A: CORE RESEARCH PROJECT PARTICIPANTS

Auburn University

Participants	Status	Country
		USA
Joseph Molnar	US Lead PI	Auburn University
Claude E. Boyd	US Investigator	Auburn University
Karen Veverica	US Investigator	Auburn University
James O. Bukenya	US Co-PI	Alabama A&M University
E. William Tollner	US Co-PI	University of Georgia
Herbert Ssegane	US Investigator	University of Georgia
		Uganda
Levi Kasisira	HC Lead PI	Makerere University
Theodora Hyuha	HC Investigator	Makerere University
Monica Karuhanga Beraho	HC Investigator	Makerere University
Peter Mulumba	HC Investigator	Makerere University
Nelly Isyagi	HC Co-PI	Gulu University
Alfonse Opio	HC Investigator	Gulu University
Gertrude Atakunda	HC Co-PI	National Fisheries Resources Research Institute
E. John Walakira	HC Investigator	National Fisheries Resources Research Institute
		South Africa
Khalid Salie	HC Co-PI	Stellenbosch University

North Carolina State University

Participants	Status	Country
		USA
Russell Borski	US Lead PI	North Carolina State University
Peter R. Ferket	US Investigator	North Carolina State University
Upton Hatch	US Investigator	North Carolina State University
Charles R. Stark	US Investigator	North Carolina State University
Kevin Fitzsimmons	US Co-PI	University of Arizona
Christopher Brown	Collaborator	US Department of Commerce-NOAA
		Philippines
Remedios B. Bolivar	HC Lead PI	Central Luzon State University
Wilfred Jamandre	HC Investigator	Central Luzon State University
Emmanuel M. Vera Cruz	HC Investigator	Central Luzon State University

North Carolina State University (cont)

Participants	Status	Country
		Philippines (cont)
Evelyn Grace T. de Jesus-Ayson	HC Co-PI	SEAFDEC-AQD
Maria Rovilla J. Luhan	HC Investigator	SEAFDEC-AQD
Gwen Anuevo	Research Assistant	SEAFDEC-AQD
Marie Frances Nievales	Research Assistant	SEAFDEC-AQD
		Indonesia
Hassan Hasanuddin	HC Co-PI	Ujung Batee Aquaculture Center, Banda Aceh
Coco Kokarkin	HC Investigator	Ujung Batee Aquaculture Center, Banda Aceh

Purdue University

Participants	Status	Country
		USA
Kwamena Quagrainie	US Lead PI	Purdue University
Jennifer Dennis	US Investigator	Purdue University
Rebecca Lochmann	US Co-PI	University of Arkansas at Pine Bluff
Emmanuel Frimpong	US Co-PI	Virginia Polytechnic Institute & State University
		Kenya
Charles Ngugi	HC Lead PI	Moi University
Julius Manyala	HC Investigator	Moi University
Judith Amadiva	HC Co-PI	Ministry of Fisheries Development
Sammy Macharia	HC Investigator	Ministry of Fisheries Development
Jennifer Atieno	Collaborator	Women in Fishing Industry Project
		Ghana
Stephen Amisah	HC Co-PI	Kwame Nkrumah University of Science & Technology
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APPENDIX B: ACRONYMS

Program-Related

ACRSP	Pond Dynamics/Aquaculture CRSP
AFCRSP	Aquaculture & Fisheries CRSP
AquaFish	Aquaculture & Fisheries CRSP
CRSP	Collaborative Research Support Program
HC	Host Country
ME	Management Entity
MOU	Memorandum of Understanding
NGO	Nongovernmental organization
PD/ACRSP	Pond Dynamics/Aquaculture CRSP
PI	Principal Investigator
RFA	Request for Assistance
RFP	Request for Proposals

General

FAQ	Frequently Asked Questions
KSh	Kenya Shillings
NB	Nota Bene, note well
PDF	Portable Document Format

Institutions, Organizations, Government Entities & Programs

ACIAR	Australian Centre for International Agricultural Research
AIT	Asian Institute of Technology, Thailand
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
ATA	American Tilapia Association
AwF	Aquaculture without Frontiers, USA
BAU	Bangladesh Aquacultural University
BFAR	Bureau of Fisheries & Aquatic Resources, Philippines
BIOTECMAR	Cultivos & Biotecnologíca Marina C.A., Venezuela
CESASIN	Comite Estatal de Sanidad Acuicola de Sinaloa (Sinaloa State Committee for Aquaculture Sanitation), Mexico
CETRA	Centro de Transferencia Tecnológica para la Acuacultura (Center for Aquaculture Technology Transfer), Mexico
CGIAR	Consultative Group on International Agricultural Research
CI	Conservation International, Mexico
CIAD	Centro de Investigación de Alimentos y Desarrollo (Research Center for Food & Development), Mexico
CIDEA-UCA	Centro de Investigación de Ecosistemas Acuáticos de la Universidad Centroamericana (Center for Research on Aquatic Ecosystems-Central American University), Nicaragua
CIFAD	Consortium for International Fisheries & Aquaculture Development
CIMMYT	International Wheat & Maize Improvement Center, Mexico
CLAR	Central Laboratory for Aquaculture Research, Egypt
CLSU	Central Luzon State University, Philippines
CRC/URI	Coastal Resources Center/University of Rhode Island
CTU	Can Tho University, Vietnam
DASP	Department of Animal Sciences & Production, SUA
DA-BFAR	Department of Agriculture–Bureau of Fisheries & Aquatic Resources, Philippines
EGAT	Bureau for Economic Growth, Agriculture, & Trade (USAID)
EPA	US Environmental Protection Agency

EU	European Union
FAC	Freshwater Aquaculture Center, Central Luzon State University, Philippines
FAO	Food & Agriculture Organization, United Nations
FD	Department of Fisheries, Kenya
FDA	US Food & Drug Administration
FDAP	Fisheries Development Action Plan, Cambodia
FiA	Fisheries Administration, Cambodia
FISH	The FISH Project (Fisheries Improved for Sustainable Harvest), Philippines
FIU	Florida International University
GESAMP	Joint Group of Experts in the Scientific Aspects of Marine Environmental Protection, FAO
GIFT	Genetically Improved Farmed Tilapia Foundation International Inc., Philippines
GOP	Government of Philippines
GTIS	Guyana Trade & Investment Support Project
IAAS	Institute of Agriculture & Animal Science, Nepal
IARC	International Agricultural Research Center(s), CGIAR
ICLARM	International Center for Living Aquatic Resources Management (= The WorldFish Center), Malaysia
IDRC	International Development Research Centre, Canada
IEHA	Presidential Initiative to End Hunger in Africa, USA
IFREDI	Inland Fisheries Research & Development Institute, Cambodia
ISSC	Interstate Shellfish Sanitation Conference
ISA	Sinaloa Institute for Aquaculture, Mexico
ISTA	International Symposium on Tilapia in Aquaculture
KBDS	Kenya Business Development Services, USAID
KNUST	Kwame Nkrumah University of Science & Technology, Ghana
LAC	Latin America & Caribbean Regions
LSU	Louisiana State University
MARENA	Nicaraguan Ministry of the Environment
MRC	Mekong River Commission
MSU	Michigan State University
NAAG	National Aquaculture Association of Guyana
NACA	Network of Aquaculture Centers in Asia, Thailand
NARS	National Agricultural Research System (of Host Countries)
NCSU	North Carolina State University
NIC	National Investment Center
NOAA	National Oceanographic & Atmospheric Administration, USA
NPRS	National Poverty Reduction Strategy, Cambodia
NSF	National Science Foundation, USA
NSSP	National Shellfish Sanitation Program
OSU	Oregon State University
PACRC	Pacific Aquaculture & Coastal Resources Center/University of Hawai'i at Hilo
RIDS-Nepal	Rural Integrated Development Society-Nepal
SEAFDEC/ AQD	Southeast Asian Fisheries Development Center/Aquaculture Department, Philippines
SEDPIII	Third Five-Year Socioeconomic Development Plan, Cambodia
SEMARNAT	Secretariat of Natural Resources, Mexico
SOU	Shanghai Ocean University, China
SUA	Sokoine University of Agriculture, Tanzania
SUCCESS	Sustainable Coastal Communities & Ecosystems (EGAT/USAID)
TIES	Training, Internships, Education & Scholarships Program (USAID-Mexico)
TNC	The Nature Conservancy, USA
TTU	Texas Tech University, Lubbock

UA	University of Arizona
UAPB	University of Arkansas, Pine Bluff
UAS	Universidad Autónoma de Sinaloa (Autonomous University of Sinaloa), Mexico
UAT	Universidad Autónoma de Tamaulipas (Autonomous University of Tamaulipas), Mexico
UCA	Universidad Centroamericana (Central American University), Nicaragua
UG	University of Georgia
UHH	University of Hawai'i at Hilo
UJAT	Universidad Juárez Autónoma de Tabasco (Autonomous University of Juarez, Tabasco), Mexico
UJAT-CPSR	Cooperativa Pesquera San Ramón (San Ramón Fisheries Cooperative), Mexico
UBAC	Ujung Batee Aquaculture Center, Banda Aceh, Indonesia
UM	The University of Michigan
URI	University of Rhode Island
US	United States
USA	United States of America
USG	United States Government
USAID	United States Agency for International Development
USEPA	US Environmental Protection Agency, USA
VT	Virginia Polytechnic Institute & State University
WAS	World Aquaculture Society
WWF	World Wildlife Fund, USA

Topic Areas

BMA	Production System Design & Best Management Alternatives
FSV	Food Safety & Value-Added Product Development
HHI	Human Health Impacts of Aquaculture
ISD	Indigenous Species Development
MER	Marketing, Economic Risk Assessment & Trade
MNE	Mitigating Negative Environmental Impacts
QSD	Quality Seedstock Development
SFT	Sustainable Feed Technology
TAP	Technology Adoption & Policy Development
WIZ	Watershed & Integrated Coastal Zone Management

Project & Investigation Terms

AOP	Advanced Oxidation Process
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BSE	Bovine Spongiform Encephalopathy
BW	Brackish Water
cDNA	complementary DNA (Deoxyribonucleic acid)
CFU	Colony Forming Units
CG	Compensatory Growth
DO	Dissolved Oxygen
EC	*E. coli*
EPT	*Ephemeroptera*, *Pleocoptera* & *Trichoptera*
FCR	Food (Feed) Conversion Ratio
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GLM	Generalized Linear Model
GMO	Genetically Modified Organism
GnRHa	Gonadotropin Releasing Hormone Analogue
HACCP	Hazard Analysis & Critical Point Control

HIV/AIDS	Human Immuno Virus/Acquired Immune Deficiency Syndrome
HPLC	High Performance Liquid Chromatography
HSD	Hepatosomatic Index
IGF-I	Insulin-like Growth Factor-I
IPM	Integrated Pest Management
LC/MS	Liquid Chromatography/Mass Spectrometry
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
LST	Lauryl Sulfate Tryptose
MC	Microcystins
mRNA	messenger RNA (Ribonucleic Acid)
MT	17α-Methyltestosterone
NL	Notochordal
PDI	Pellet Durability Index
PRCA	Participatory Rural Communication Appraisal
RIA	Radioimmunoassay
RRA	Rapid Rural Appraisal
SGR	Specific Growth Rate
SPE	Solid Phase Extraction
SL	Standard Length
SR	Sex Reversed
SS	Salmonella-Shigella
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UV	Ultraviolet
XLD	Xylose Lysine Desoxycholate