Aquaculture
Collaborative Research Support Program

ELEVENTH WORK PLAN ADDENDUM

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Contents of the Eleventh Work Plan Addendum

Cross-Sectoral and International Extension Exchange and Learning

Aquaculture and Human Health Impacts 1 (11AHHR1)/Activity/Ecuador, Mexico

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Objectives
The overall objective is to enhance the effectiveness of extension efforts for improving outcomes related to health and aquaculture in Western Mexico with LAC-wide applicability. The CRSP efforts will build on and expand the range of current training and exchange efforts conducted by the partners in to improve the effectiveness of extension as a vehicle for disseminating BMPs for shrimp culture. Specific objectives include:

1) Provide a structured cross-sector exchange between aquaculture, agriculture, conservation, and health promoters so that methods and lessons learned can be shared, evaluated, and adopted to increase the effectiveness of aquaculture extension.
2) At the same time, the awareness of agriculture, conservation, and health promoters will be raised to increase their knowledge of the relationship of small-scale aquaculture to health and to mutually identify areas for future collaboration.
3) Through the involvement of participants from other CRSP LAC projects, share lessons learned and increase the applicability of the extension exchange and the three studies to areas outside the Pacific Mexico area.
4) Through linking the extension exchange to execution of three studies examining the relationship between aquaculture and health, use this as an opportunity for evaluation and input to the on-going studies as well as a peer review for purposes of quality control.

Significance
Mexico is a nation fortunate in having a strong national capacity for scientific and technological research and development, including aquaculture, supported by national and state policies and institutions that encourage innovative research. It also has a long history of social policies that target agrarian development and community participation in land ownership and production. Mexico seemingly has the full range of bio-physical, environmental and biological resources required to establish a strong base for aquaculture development including abundant freshwater and seawater resources, a long coastal line with extensive bay systems, inputs such as fuel and feed, large internal and external markets, and a relatively educated labor force.

Recent political and social reforms including legalization of private aquaculture, opening of U.S. markets under NAFTA, increasing opportunities for obtaining capital and financing, and increasing federal and state support for entrepreneurism would also seem to serve to make Mexico an even more conducive setting for aquaculture.

Aquaculture is of particular importance to the Western Coast of Mexico. The three coastal states of Sinaloa, Sonora, and Nayarit are the source of 45% of Mexico's fisheries and aquaculture products. Because of the social and economic significance of aquaculture, it plays a key role in coastal management efforts (Villalba-Loera, 2003). Both the negative and positive aspects are the focus of community-based

management efforts led by Conservation International (CI), UAS, CRC/URI, and PACRC/UHH. Particular emphasis is put on working with the cooperatives and *ejidos* (social sector) that engage in shrimp culture on small and medium-scales. Participation of the social sector in shrimp culture provides local rural communities with one of the few alternatives to participation in the declining fisheries of the region, but problematic aspects that threaten its viability and social contributions require urgent action. The current efforts focus on shrimp culture, but growing bivalve culture and freshwater fish culture industry exist and need equal attention.

Sadly, the full potential for small-scale aquaculture in Mexico has never been fully realized and the predominant form of aquaculture, shrimp culture, continues to be problematic. Although a variety of factors have contributed to the current scenario, two institutional tendencies emerge. One is the apparent gap between the species and topics scientists and research institutions dedicated funds and efforts towards, and the realities of the production priorities of the aquaculture sector. Two recent analyses demonstrate that a gap exists between research institutions and the productive sector for aquaculture. Allocation of scientific resources and efforts does not correlate to the importance of species and topics to the productive sector. For example, while mojarra (cichlids, including tilapia), oysters, carp and shrimp account for 93% of aquaculture production in Mexico, only 41% of aquaculture publications dealt with these species. Of these papers, 29% were on shrimp-related topics although shrimp accounts for 10% of total aquaculture production (Aldana-Aranda and Baqueiro-Cardenas, 2002). This may also indicate a bias towards higher-value, market-oriented production as a topic of scientific interest opposed to production aimed at increasing food security or the income of rural communities (Cruz-Suarez et. al., 1996).

A second institutional gap is the relative strength of scientific research as opposed to extension. Scientific research is not translating fully into technical assistance. Aldana-Aranda and Baqueiro-Cardenas (2002) cite 21 major institutions conducting research on 60 aquaculture species. While data does not exist comparing the level of effort expended on aquaculture research versus extension, it is clear that greater incentives and funding levels encourage a disproportionate level of effort dedicated to research with less emphasis on technology transfer. The detrimental effects of this on aquaculture development have become clear during recent efforts to develop Best Management Practices (BMPs) for shrimp culture as part of the Bahia Santa Maria Management Plan and a related effort to conduct a rapid assessment of the feasibility of introducing bivalve culture to new areas with an emphasis on native species (Bahia Santa Maria Management Committee, 2002). Research and development of BMPs has proved to be less of a challenge than finding the means to disseminate them to producers and provide technical assistance to enable producers to adopt improved practices. In the case of culturing native bivalves, a wealth of publications exists and a few pilot efforts have been conducted, but within the three Pacific states of Sonora, Nayarit, and Sinaloa, not a single individual was dedicated to extension for this topic (Haws et. al., 2003).

During the last four years of working with a wide variety of institutions on the theme of best management practices for shrimp culture, it has also become clear that of the major institutions in the Western Pacific area dedicated to research related to aquaculture (CIBNOR, CIAD, UNAM, UAS, and CRIP) or providing support to aquaculture (e.g., ISA), none have dedicated extension agents. Only CESACIN, established in 2001, is characterized by dedicated extension agents and a statewide extension network, with an emphasis on biosecurity and sanitation. While some researchers do dedicate a portion of their time to extension or training, incentives are to do so are less than those offered for research achievements. In the case of shrimp culture, most of the transfer technology occurs through the employment of private consultants or biologists, many of who are foreign nationals. Particularly in the case of the West Coast of Mexico, the predominance of shrimp aquaculture and its reliance on private sources of technical assistance has left the region with a reduced capacity for general aquaculture extension with the result that small-scale culture of non-shrimp species lags far behind its potential.

The status of aquaculture extension is in contrast to an active and vibrant agricultural sector, which does have dedicated extension agents and because of its economic strength and links to U.S. agricultural concerns, is able to pay for high quality technical assistance. The need to meet U.S. sanitary standards and market demands has spurred greater innovation and development in agriculture as opposed

to aquaculture. Only shrimp aquaculture has a significant export market, which has only recently been subject to strict standards as USDA and the FDA increase the stringency of export requirements.

Aquaculture also suffers in comparison to the public health sector. Mexico has also excelled in establishing a comparatively good public health system throughout the country. Public health campaigns are generally well funded. Connecting with the public health sector is important. The CRSP regional expert panel meetings for LAC, Asia, and Africa identified increased understanding of the connectivity of human health and aquaculture as a key need (PD/A CRSP, 2002). The stakeholders of Pacific Mexico also recognize the same gaps in our understanding of causal relationships, as well as the need to include environmental quality as a key consideration in this complex equation.

Perhaps the strongest capacity for outreach and technical assistance is that of the environmental NGOs and national institutions. Over 50 major NGOs operate in the Gulf of California area and community-based outreach efforts are common. The interests of the aquaculture and environmental sectors intersect because of the common interest in maintaining environmental quality, development of alternative livelihoods and community-based management of resources. In the case of the current partnership involved with the Bahia Santa Maria and Marisma Nacionales wetland management efforts, involvement with aquaculture has come about because of the impact of shrimp aquaculture on wetland areas and surrounding communities. The coastal management and environmental efforts focus on developing the means to control development of shrimp culture, to mitigate environmental and social impacts, and to increase benefits to community stakeholders where possible. Successes in managing shrimp culture impacts and benefits can serve as a model for related efforts to diversify aquaculture. Learning from shrimp culture in Mexico has additional value in that most shrimp culture is still conducted by the social sector and *ejidos*, thus providing experience with aquaculture conducted by large, well-organized community-based groups that can be transferred to other forms of aquaculture and to other shrimp farming regions.

The partners involved in the Bahia Santa Maria (BSM) Bay Management Project have worked since 1999 to bring together a core group of public sector and private institutions and individuals with interest in aquaculture extension for the purpose of developing and transferring Best Management Practices for Shrimp Culture in Pacific Mexico (funded by USAID and the David and Lucille Packard Foundation with contributions from local partners: CI, CREDES, UAS, and Management Committee of Santa Maria Bay). Three major needs have emerged from this experience, leaving aside for the moment the question of limited funding for extension. First, individuals playing a role in aquaculture extension can benefit from training to enhance their ability to carry out technology transfer activities. Most workers conducting extension on a regular or occasional basis have receive little if any formal training in training or outreach skills. The need to enhance extension skills becomes more apparent when technically-oriented extension begins to intersect with social, cultural or gender issues outside the normal realm of aquaculturists, as in the case of the development and implementation of BMPs. Secondly, given the lack of a well-developed aquaculture extension network in Pacific Mexico, and the lack of full penetration into rural areas with the most need, linking with extension workers or promoters from other sectors that may have more presence in rural communities could clearly be of benefit to all. Third, aquaculture extension as it is currently practiced tends to focus on selected categories of stakeholders who may not fully represent groups most in need of the benefits of aquaculture nor those most equipped to conduct small-scale aquaculture oriented towards meeting food security or rural health needs. Again, large-scale shrimp producers tend to receive a disproportionate share of technical services compared to the social sector shrimp producers and producers of other species.

To this end, the group of partners involved in the BSM Management activities has targeted increasing extension skills for those involved in the aquaculture activities to increase their effectiveness and to expand their range of skills beyond the typically production oriented aspects so that a more holistic approach to aquaculture development emerges that encompasses issues of health, environmental quality, food security, gender, and rural community development. The BSM group of partners is currently conducting a series of five workshops in 2003–2004 as part of the shrimp BMP effort involving participation of 30 specialists representing regional institutions and the private sector; participants were selected as individuals with the most potential to disseminate BMPs to producers. In this activity, we propose to

build on the current effort to address issues of extension capacity more thoroughly and expand participation to those working in culture of non-shrimp species, experts from other sectors and from other LAC CRSP projects.

This is a unique opportunity to increase the scope of knowledge of a large number of regional extension workers, and researchers and to build interdisciplinary teams. This will be done through an international extension exchange that promotes cross-sector sharing of skills and involvement of international specialists and stakeholders to expand the benefits to the wider CRSP network of extension workers.

Anticipated Benefits

Target groups for this work include: aquaculture extension workers and researchers in Pacific Mexico; key private sector representatives; participants from selected CRSP projects in the LAC region; the Bahia Santa Maria Management Committee; Women's Cooperatives of BSM; Women's oyster culture cooperatives of Nayarit; Women's oyster culture cooperative of Puerto Peñasco; Conservation International; Universidad Autonoma de Sinaloa (UAS, Culiacan, and Mazatlan Campuses); ISA; CIAD; CREDES; Ecocostas; CESACIN; and the Federation of Shrimp Cooperatives. Linkages will also be made to the NOAA International Sea Grant efforts through participation of Maria Haws, Jim Tobey, and Central American partners who are involved in this effort. Haws is partially funded by the University of Hawaii Sea Grant Program as an Aquaculture Extension Agent. Tobey is leading development of case studies and workshops to establish the framework of Sea Grant-like programs in Central America.

Quantifiable benefits will include: demonstrated increases in aquaculture extension skills; increased knowledge of extension and outreach practices used in other fields; increased effectiveness in transferring practices that increase benefits from aquaculture that enhance human health; identification and development of multi-institutional strategies that can be implemented in the future to increase human health benefits.

In addition to the learning exchange, the workshop will also provide a forum for the extension exchange participants to review, provide input and participate in the three case studies (see below). The working group executing the case studies will present the case study designs, preliminary data, and findings and action plans for executing the studies to the collected stakeholders participating in the extension exchange. Not only will this provide the working group with the combined expertise of the participants as a form of peer review, it will allow the participants in the exchange to work through exercises that require exercising new knowledge and skills gleaned from the other sectors. The outcome will be improved and enriched case studies, engagement of a wider audience, and applicability of the case studies to other regions, sectors and a broader group of technical assistance providers.

Activity Plan

Location of Work: Participants will be drawn from three Pacific States of Mexico (Sonora, Sinaloa, and Nayarit), other LAC CRSP projects, and U.S. Institutions with capacities in aquaculture and health issues. They will include the core group of 30 individuals representing the partner institutions involved in the BSM Management Plan and development of Shrimp BMPs. The extension exchange will be held at CREDES in Mazatlan, which possesses a training center and dormitory facilities. The CREDES training center is also centrally located and close to the offices of participating institutions and a number of private farms cooperating with the effort.

Methods: The extension exchange will consist of two major components each of which will have several subcomponents:

1. Extension exchange
   - Basic theory and practice of extension
   - Exposition of specific extension methods and strategies used in aquaculture, conservation, public health, and agriculture by specialists (local and international) in these fields
   - Participatory identification of key issues and lessons for success in each area
   - Identification and development of strategies to enhance extension effectiveness for aquaculture in rural communities with reference to human and environmental health

2. Review of case studies
- Presentation of design and progress
- Review by participants in the workshop
- Participatory revision
- Development of a revised and final action plan for implementing case studies
- Incorporation of participant involvement

Regional Integration

This work will integrate with existing CRSP efforts on several levels. First, the CRSP team conducting research on shrimp-tilapia polyculture conducted at CIAD-Mazatlan will participate in the extension exchange since their expertise in diversification of shrimp aquaculture may benefit the stakeholder groups interested in the same topic and because linkages with the regional extension network may provide a vehicle to disseminate the results of their work. Participation of the CRSP team from UJAT is viewed as highly desirable both because of their capacity in rural aquaculture extension and innovative work with development of native species. We hope to learn from their experiences and to offer them an opportunity to disseminate their results to stakeholders in Pacific Mexico, and participants from Central America, where the UJAT results with tropical gar and native cichlids has been of particular interest. UJATs efforts with clean production technology may benefit from input from the Pacific Mexico BMP development initiative. Additionally, linkages with IAP in Peru will be beneficial for the three efforts in Mexico because of their technological and extension successes. The Pacific Mexico approach of integrating aquaculture and health issues into a broader community-based coastal management effort may offer learning experiences to other CRSP regions.

Schedule

Start date: 1 January 2003
End date: 15 June 2004

	Month							
Task	J	F	M	A	M	J	J	A
Planning for extension exchange	X	X						
Extension exchange event			X					
Participatory review of case studies at extension exchange event			X					
Contribution of findings from the field from participants to case studies*			X	X	X			
Publish workshop findings/ distribute				X	X			
Work shop for final review of case studies**								X

*The participants in the BMP training workshops held as part of the BSM-BMP project are required to perform follow up activities associated with each thematic workshop as part of the learning experience. In the case of the extension exchange, the follow-up activities will be related to contributing to the field studies. The majority of the Mexico workshop participants are representatives of the institutions involved in this CRSP project.

**As part of a continuing series, a workshop on Pond Management for Best Management Practices for Shrimp Culture will be held as part of the BSM-BMP project and will be used an opportunity for the Mexico participants of the CRSP extension exchange to be presented with the final outcomes of the three case studies.

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

Aquaculture and Human Health Impacts 2 (11AHHR2)/Study/Ecuador, Mexico

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Objectives

The overall objective is to characterize the aspects of water quality, water resource use and environmental quality with reference to brackish and freshwater aquaculture as the basis for planning of monitoring activities and aquaculture management to enhance human health benefits. Specific objectives include:

1) Identify and characterize key issues for human health and aquaculture development through analysis and integration of past and on-going research findings on the water resources of Bahia Santa Maria and other coastal water bodies.
2) Integrate findings into the development of Best Management Practices for shrimp mariculture and siting criteria, an on-going effort under the BSM Management Plan. The CRSP effort will provide an additional component of health-related socioeconomic issues to the set of BMPs being developed that is not currently being considered in the original effort.
3) Integrate findings into the development of general codes of practice with reference to human health, siting criteria, and planning for diversification of aquaculture including tilapia monoculture, tilapia-shrimp polyculture, and bivalve culture as a new effort as part of this project. This will provide a component of health-related issues not generally considered in such frameworks and include non-shrimp species. This will serve as a much-needed complement to the more technically oriented code of practice being developed for shrimp only.
4) Develop a cost-effective and community-based plan for water resource monitoring that encompasses the health needs of BSM communities, aquaculture producers (shrimp, tilapia-shrimp, tilapia only, and bivalves) and other user groups that include identification of mitigation actions for key health impacts.
5) As a sub-component of the above, develop a strategic sub-plan that identifies actions required for Santa Maria Bay waters or similar areas to be classified and certified to assure shellfish sanitation needs within the Mexico National and State frameworks, as well as satisfying the requirements of the U.S. ISSC (Inter-State Shellfish Sanitation Committee, defines water quality and handling standards for shellfish culture, harvest, and processing.) to allow for export of bivalves to the U.S. This will include the legal, environmental, and economic aspects of shellfish sanitation. This will be a shared sub-component with 11AHHR3 (see below). This will help establish the basis for cleaner and healthier shellfish production and potentially increased production of organisms low on the food chain with subsequent environmental and food security benefits.
6) Identify next steps required to implement recommendations stemming from this work.

Significance

The health, livelihoods, and well-being of coastal inhabitants depends on the quality and use of water resources. The Santa Maria Bay in Sinaloa, Mexico, offers a good field study and training site when

considering issues of the connectivity of the use and status of water resources, human health, and aquaculture. Located in the heart of a major agro-industrial area and adjacent to communities that are growing rapidly, water quality impacts have been documented, but are not well characterized. These include agricultural run-off, sewage, eutrophication from multiple sources including shrimp ponds, scarcity of potable water, competition for freshwater resources, changes in hydrology affecting the environment, and possibly increasing water-borne diseases such as dengue and contamination from multiple sources (Paz-Osuna, 2002). The 450,000 hectares comprising this major wetland area are economically and ecologically key to the Western Pacific region. It typifies the estuarine systems of Pacific Mexico. The work done by the BSM Management Committee has been taken as a model for wetland management by other coastal communities occupying the extensive wetland systems along the Pacific Coast.

Shrimp farming is major economic activity in the area, with 396 farms active, 80 inactive, and another 12,000 hectares designated for pond construction. The shrimp culture industry has been targeted by the BSM Management Committee and partners (CI, UHH, URI, etc.) as a major concern since shrimp culture may contribute to water resource impacts (eutrophication, competition for wetlands and water resources) while at the same time representing one of the few alternatives to fishing in the area. Rural communities are inextricably linked to the fate of the shrimp culture industry because of the high level of involvement of cooperatives and the community labor force, many of whom are women.

An additional issue is the desire of the stakeholders to begin culturing other species such as bivalves, tilapia, and local species of fish as stand-alone efforts or through integration with shrimp farming. Using abandoned shrimp ponds to culture alternative species is of particular interest, but issues with water resources cast some doubt on the ability to convert ponds to other uses. Water quality issues are also significant in considering bivalve culture because of real and potential dangers to human health, the recent appearance of oyster diseases, and increased interest in classification of waters according to ISSC standards to allow for export to the U.S.

The challenge will be to identify and define the complex range of water resource issues in reference to aquaculture and human health, determine cost-effective methods to monitor, evaluate, and mitigate impacts, and develop measures to prevent human and animal health impacts as aquaculture continues to develop. The constraints imposed by water resources on aquaculture will also be considered. Additionally, the participants will define the steps needed to reach the point at which a system could be established to classify bivalve growing waters to allow for export to the U.S. and to prevent health impacts in the case of local consumption.

Anticipated Benefits

Target groups: Management Committee of Bahia Santa Maria, Women's Fishing Cooperative of BSM (oyster growers);Women's oyster growing cooperatives of Puerto Peñasco and Nayarit; Guevarra Oyster Company; Municipalities of Navolato and Angostura. Participants in extension exchange (see above), including institutions providing technical assistance in coastal management and aquaculture development (UAS, UHH, CI, URI, CIAD, CREDES, CESACIN, and ISA).

The three cases studies will be conducted by an Aquaculture Health Working Group formed from specialists from the participating institutions. A BMP Working Group already exists, and is responsible for development of the BMPs under the on-going project. There is considerable overlap between the membership of the two working groups, which will facilitate exchange of information and collaboration between the working group.

Anticipated benefits will include research findings that will be integrated into Best Management Practices for shrimp culture, shrimp-tilapia polyculture, bivalve culture, and tilapia/freshwater fish monoculture. The BMPs will benefit all groups involved in their development and will be disseminated by the core group of extension agents and researchers being trained in the extension exchange and the regular series of BMP training courses. Siting criteria for aquaculture will benefit the private sector, public sector entities involved in permitting and planning, and communities practicing or entering into aquaculture endeavors, and is most relevant to preventing impacts due to physical changes affecting

water resources. The work conducted during this study will also set the stage for community based monitoring and other actions to be adopted by the BSM Management Committee that will contribute to improvements of water quality with multiple benefits to the environment, human health, and aquaculture. This work will also provide the basis to improve shellfish sanitation for on-going bivalve culture and that being established in BSM and other locations.

This study will provide multiple benefits. The large body of on-going and past research findings will be synthesized and put into an accessible and understandable framework for the benefit of user groups participating in environmental management efforts and aquaculture development. The BMPs for shrimp culture currently under development will be expanded and enriched through inclusion of water resources and health related recommendations. New BMPs with a special emphasis on health issues will be developed for species and culture systems coming into production to prevent replication of the impacts occurring with shrimp mariculture. Identification and characterization of health related issues will be the first such effort in the region and will help guide workers in decision-making and planning of future efforts.

Research Design

Location: The work will be focused on and conducted primarily in Santa Maria Bay, but will also involve the communities that surround the Marismas Nacionales (a wetlands area) in Nayarit through inclusion of women's oyster growing cooperatives and other aquaculture stakeholders. A women's oyster farming cooperative from Sonora will also be included. The primary producer of *Crassostrea corteziensis* (Pacific tropical oyster) will also be involved in this effort and is located in southern Sinaloa. The participants in the extension exchange will be included in the work and will actively participate in the research. Shrimp cooperatives and tilapia farmers will be included in addition to the public sector entities working to develop BMPs including ISA, CI, CIAD, CESASIN, and CREDES.

Santa Maria Bay has been intensively studied from many perspectives, but a gap exists in terms of issues related to health, environment, and aquaculture. The first step will be to compile and review existing materials. Community focus groups and site visits to communities, aquaculture facilities, and other sites such as agricultural areas will be conducted to gather information and perspectives first-hand as well as to involve the community in the process of identifying and characterizing key issues. The BMP Working Group (formed as part of the BMP effort) will also review policy, legal, and permitting documents related to the shellfish sanitation requirements of Mexico and the U.S. and in tandem with data from BSM and Marismas Nacionales, develop a strategic action plan that maps out requirements to classify and certify waters to meet U.S. standards for shellfish sanitation while at the same time satisfying Mexican standards. A key part of this sub-component will be consultations with the responsible institutions to develop immediate and practical steps that can be taken to implement recommendations.

The preliminary findings of the Aquaculture Health Working Group will be presented to stakeholder groups for critique and review, then finalized and published. A key action will be the development of recommendations to be submitted to the BMP Working Group for incorporation into the BMPs under development. The final report of the Aquaculture Health Working Group will be presented to the collected group of stakeholders in the region at a second training workshop (sponsored by the BMP effort as part of a technical training series). The same materials will be published and sent to the CRSP workers who participated in the extension exchange.

Regional Integration

This project will integrate with local and regional efforts to minimize the impacts of aquaculture, initially focusing on shrimp culture, but also expanded to include other forms of freshwater and brackish water culture. Points of intersection include the clean production technology being developed at UJAT and the BMPs being developed in Sinaloa. The larger CRSP goal of expanding culture of native species and species low on the food chain is also addressed by this work through the steps taken enabling the cultivation of bivalves, tilapia and native species and to maximize the returns from this production. Ef-

forts related to enhancing food security are also addressed through optimizing shrimp production by cooperatives, providing an additional seasonal crop through increased culture of tilapia whether as a monoculture or polyculture, and increasing the production of bivalves by women, cooperatives and others in rural communities.

Schedule
Start date: 1 January 2003
End date: 15 June 2004

	Month							
Task	J	F	M	A	M	J	J	A
Compilation, review and synthesis of on-going and past research results	X	X	X					
Site visits and assessments	X	X	X					
Presentation of case study protocols and preliminary findings at the extension exchange			X					
Finalize study, including contribution of workshop participants			X	X	X			
Workshop for integration of findings and participatory assessment*					X			
Submission of findings to BMP Working Group / integration into BMPs					X	X	X	
Develop community-based monitoring protocols				X	X	X	X	
Draft shellfish sanitation plan			X	X	X	X	X	
Final stakeholder review								X
Publication and distribution								X

*The fourth workshop in the on-going shrimp BMP technical series will focus on Pond Management. To take advantage of the presence of the collected stakeholders, many of whom will also be involved in the CRSP effort, and additional day will be added to the workshop schedule to allow for consideration of the CRSP case studies.

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

Aquaculture and Human Health Impacts 3 (11AHHR3)/Study/Ecuador, Mexico

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Objectives

The overall objective is to identify and characterize critical points in aquaculture production that affect the level of participation of women, youth, and disadvantaged stakeholders as a first step to developing strategies to increase health related benefits of aquaculture in Sinaloa. Specific objectives include:

1) Analyze the role of women in the predominant form of aquaculture in Pacific Mexico (shrimp culture) to characterize and quantify their modes of participation, degree of benefits received, and the affect of these factors on food security and human health for women and their families.
2) Analyze the role of women in the context of secondary culture systems (i.e. shrimp-tilapia polyculture; freshwater fish; oysters; native bivalves) in Pacific Mexico to characterize and quantify their modes of participation, degree of benefits received, and the affect of these factors on food security and human health for women and their families.
3) Based on these results, develop strategies using participatory methodologies that target key points liable to enhancement and disseminate to stakeholders.
4) Assess the feasibility of targeting disadvantaged youth and individuals with physical and mental disabilities in rural communities for adoption of aquaculture to develop a strategic plan for inclusion of these groups in on-going and planned aquaculture extension efforts.
5) Identify next steps required to implement recommendations stemming from this work.

Significance

The aquaculture industry of Sinaloa and Sonora is dominated by shrimp culture operations ranging from small- to large-scale and owned through a variety of means including cooperatives, ejidos and private ownership. Joint ventures between private investors and cooperatives operate in various fashions and have varying degrees of participation in the daily operations. The scales of operations and modes of ownership are mixed (DeWalt, 1998; 2001). Nearly all of these are primarily operated and controlled by male participants, although women do participate in cooperative shrimp farming to a much greater degree. While women work in various aquaculture tasks, one of the most common roles women play in shrimp culture is as the principal source of labor in shrimp processing plants. Women also benefit through marketing shrimp and other marine products, and through a planned small-scale industry in BSM converting shrimp processing waste to edible dried shrimp meal.

Women are also involved in oyster culture in Sonora (Puerto Peñasco) and Nayarit as well as in tilapia and other freshwater fish culture throughout the three state region. Participation in these forms of aquaculture is not perceived as being as lucrative as participation in shrimp culture, but income is more regular and benefits appear to accrue more directly to the household. Women can also integrate oyster culture into an array of household activities when they are the owners and operators as opposed to employment in shrimp farming which has set working hours, often at night.

A second group of stakeholders is also of interest when examining strategies for increasing involvement in aquaculture-disadvantaged youth and individuals suffering from physical and mental disabilities.

Mexico has suffered from increasing rates of violent crime, with the rate of violent crime increasing 90% from 1985 to 1996 from 10.2 to 19.6 per 100,000. Mexico is second only to Columbia in the Americas in the rate of homicide, with a present rate of 12.6 per 100,000 being committed per year (PAHO, 2003). A useful comparison is the homicide rate of the U.S. (7.3 per 100,000), the highest rate among developed countries (CDC, 2003). The Pan American Health Organization has highlighted violence a priority issue as this is the leading cause of death, injury, and reduction in human well-being in the Americas other than communicable diseases. Effects of violence have greater effects on women and youth, although young males (20–30 years) suffer the highest rates of homicides related to violence 39.7 per 100,000 (INS, 2003). Violence is not the only cause of death and injury; Mexico has extremely high rates of vehicular and work place accidents. Accidents have greater social and economic ramifications aside from an immediate increase in mortality. Injuries are long-lasting, often crippling individuals and putting them and their families in dire economic straits. The Mexican National Institute of Health found that on a national level, 33% of the male population had been involved in violent attacks in the previous 12 months. Of these, 17% suffered some degree of long-lasting injury (INS, 2003).

The border and Pacific states of Mexico are particularly at risk due to the involvement of these areas in human trafficking and drug smuggling. This coastal region serves as a major route for South American and Mexican drug sources to the U.S. The inland areas of the Pacific Coast are still sites of marijuana and opium cultivation. A sub-culture of glorification of the drug traffic and traffickers ("narcos") has emerged, drastically affecting the social milieu of the coast. Youth are particularly vulnerable to involvement with illegal activities as few alternatives other than immigration may exist. The increasing involvement of youth in the drug trade and violence related to the lack of alternatives has resulted in a high level of addiction, violent crime, and associated social ills. One consequence is the alarming number of youth and young adults who are physically or mentally disabled as a result of addiction or injury from violence-related events who are dependent on their families and communities for support. It is difficult to fully quantify the magnitude and social cost of these problems, but it is estimated that minimally 400 individuals are left permanently disabled each year in Sinaloa from gun-shot wounds alone.

Steps are being taken to provide support to disabled individuals by the national health organizations and two NGOs, PROJIMO and Healthwrights (www.healthwrights.org), which provide assistance to disabled and recovering individuals in rural communities. Aquaculture is currently being explored by these NGOs working in rural Sinaloa communities with youth who are either physically disabled or recovering from addition as a form of alternative livelihood. Some preliminary experiences by the University of Hawaii-Hilo demonstrate that challenged individuals are capable of undertaking many aquaculture tasks and that they can benefit both financially and emotionally from these successes. Involvement of disabled individuals and youth can also offer solutions to common obstacles faced in development of small-scale, rural aquaculture; disabled individuals can effectively guard fish from theft, be present to provide regular feeding, and are not drawn away from culture tasks by competing demands on their time. Repetitive tasks such as hand sexing of tilapia can also be accomplished by teams of individuals with complementary abilities. Teaming of individuals with different abilities allows formation of groups that can accomplish the full range of aquaculture related tasks.

Increasing involvement of marginalized groups in aquaculture in the case of Pacific Mexico depends on obtaining a better understanding of two broad categories of issues. In the case of shrimp culture, analysis of the ways in which women participate and how their participation affects the household economy, food security and their individual health as workers can lead to identification of practices or strategies to derive more benefits related to health and food security. This must be considered from the dual perspective of women working within the private sector or within the social sector. Women appear to take on different roles and responsibilities when working with other aquaculture species and systems. The issue of whether diversification of aquaculture or polyculture of other species with shrimp can increase the health and economic status of stakeholders, whether directly or indirectly (e.g., through environmental affects) is also of interest.

There are many possibilities for diversification of aquaculture in the Pacific Mexico area. Some of these possibilities include culture of native species, including local species of bivalves. Oyster culture is already wide spread along the Pacific Coast, although bottlenecks exist for production and commercialization. A rapid assessment of the potential for native bivalve culture was conducted in 2002 and 2003 (Haws et. al., 2003). Cultivation of bivalves is of interest since it not only offers an alternative source of income for rural communities as a stand-alone activity in open water areas, but can be integrated with shrimp culture in a variety of ways. Potential exists to use native species of bivalve to stock abandoned shrimp ponds (24 % of the total pond area), inter-cropping with shrimp where temperatures limit the shrimp crops to one per year, and in the canals of active shrimp ponds to depurate effluents. Shrimp hatcheries and wild postlarvae collection facilities, many of which have been recently abandoned, could serve as bivalve hatcheries with minor modifications. The women's fishing cooperatives have been pursuing these goals since 2002 as a sub-component of the Bahia Santa Maria Management Plan with assistance from CI, URI, UHH, and UAS and women's cooperatives elsewhere have track records as long as 25 years.

While oyster culture has potential to provide livelihoods to local communities, questions of which species to promote exist. Originally oyster culture in Mexico depended on native species oyster species such as *Crassostrea cortenzensis*. Seed was obtained through collection of wild spat. This is species is still cultured using wild collected spat in Nayarit, but imported *C. gigas* has become the predominant species throughout Baja and the Pacific side of the Sea of Cortez. Seed is largely obtained from one large U.S.-based company. Eyed larvae are purchased and remote setting occurs in local facilities. Only a limited number of Mexico hatcheries engage in larviculture. Renewed interest in *C. cortenzensis* is emerging as it is being realized that *C. cortenzensis* has higher quality when served when served in the preferred local style (raw, half-shell), thus bringing higher farm gate prices. It is also performs better under the local environmental conditions of southern Mexico. One medium-scale oyster farm in Sinaloa (Guevarra Oysters) has revived culture of *C. cortenzensis* and harvests an average of $900 of product daily, which is insufficient to meet local demand. This farm is being used as a model farm for start-up efforts in BSM by women's oyster growing cooperatives and the owners of the farm have provided technical assistance to them.

In addition to *C. cortezensis* there are a number of local bivalve species that are good candidates for culture including pen shells (*Atrina maura* and *Pinna rugosa*, callo de hacha); several species of scallops; cockles (*Anadara* spp.); and many species of clams. The basic biology of these species are known, but most have been cultured only in small, temporary pilot efforts or are cultured at relative small scales. Several of these bivalve species are of high value, for example, adductor meat of callo de hacha has a local price of US$30 per kilo. A variety of freshwater (tilapia, black bass, native cichlids) and marine fish (pufferfish) are also under small-scale commercial or pilot scale culture. Preliminary assessments indicate high local, national and international demand for these products (Haws et. al., 2002; Q. Fong, personal communication; N. Duncan, personal communication). With the recent decline of shrimp culture and recognition of its frailties, increasing the culture of other species presents new opportunities for aquaculture on the Pacific Coast. It is critical to find ways to learn from the experiences of the shrimp culture industry to make new industries more efficient, environmentally friendly, increase direct participation by local stakeholders and increase health related benefits to these stakeholders.

Anticipated Benefits

Target groups: There are three broad groups of stakeholders that will benefit from this work: 1) women working in the culture of shrimp, oyster, tilapia or entering into culture of emerging species; 2) disabled and recovering individuals and their families and communities; and 3) institutions providing support to these groups including the Bahia Santa Maria Management Committee, UAS, URI, UHH, CIAD, PROJIMO, Healthwrights, CREDES, ISA, and Conservation International.

By studying how women participate in and derive benefits from the culture of oyster, shrimp-tilapia polyculture, and tilapia monoculture and contrasting this to their roles in shrimp culture, critical points will emerge that can inform decision-making and planning for aquaculture development. An unique opportunity exists to use these lessons to guide the on-going work with emerging species to include

women and disabled individuals from the beginning of these industries. Additionally, through a thorough assessment of how disabled individuals and their families and communities can engage in aquaculture, and development of practical protocols to guide this, inclusion of these individuals can become a reality in the near-future.

Research Methods
The methodology used in this study follows the guidelines of the Pan American Health Organization for epidemiological studies combined with the participatory processes used as standard procedure for ICZM efforts by the current partners.

The first step will be to compile and review existing materials related to the subject, although very little examination of gender issues or the participation of disabled individuals exists in reference to aquaculture and health. The project specialists will then hold an initial seminar to develop an implementation plan in early December 2003. Community focus groups, individual interviews, and site visits to communities, aquaculture facilities and other sites such as agricultural areas will be conducted to gather information and perspectives first-hand as well as to involve the community in the process of identifying and characterizing key issues.

Preliminary findings will be presented at the Extension Exchange (see 11AHHR3) for review by the gathered stakeholders. This is an opportunity for critique and input by participants from diverse sectors and countries. As noted above, workshop participants in the regular series of BMP trainings are given follow-up exercises to build on skills developed during the formal training with results being reported at the following workshop. In this case, some participants will be involved in the field work used to collect information for this study. Once the preliminary study is drafted, a peer review process involving specialists in the region as well as selected CRSP workers will review the draft and comment. This input coupled with the input from the workshop participants will be incorporated into the final work. The final materials will be published and distributed to the CRSP workers who participated in the extension exchange.

Regional Integration
The challenge in this case study is to develop simple and feasible strategies whereby researchers and extension agents can successfully work with groups not traditionally involved in aquaculture to enhance current health related benefits from aquaculture and to assist in on-going implementation of small scale aquaculture aimed at diversifying shrimp aquaculture and increasing culture of native species. This will be linked to the CRSP work in Tabasco with indigenous species and with CRSP work beginning in Sinaloa to assess polyculture of shrimp and tilapia. Through inclusion of a representative from Central America, where work is on-going with women's aquaculture cooperative for shrimp and bivalves, an additional level of connectivity will be achieved. Inclusion of work done by IAP in indigenous communities with native species will further enrich this collaborative work.

Schedule
Start date: 1 January 2003.
End date: 15 June 2004.

	Month							
Task	J	F	M	A	M	J	J	A
Compilation, review, and synthesis of on-going and past research results	X	X	X					
Site visits and assessments	X	X	X					
Presentation of case study protocols and preliminary findings at the extension exchange			X					
Finalize study, including contribution of workshop participants			X	X	X			
Workshop for integration of findings and participatory assessment					X			
Submission of findings to BMP Working Group for integration into BMPs						X	X	
Drafting of research report						X	X	
Drafting of feasibility assessment for participation of disabled and youth						X	X	
Final stakeholder review								X
Publication and distribution								X

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

Disease, Predation Prevention, and Food Safety (11DPPR1)/Study/Ecuador, Mexico

Collaborating Institutions

Universidad Autonoma de Sinaloa, Culiacan, Mexico
Eladio Gaxiola Camacho — Principal Investigator

Ecocostas, Guayaquil, Ecuador
Emilio Ochoa Moreno — Co-Principal Investigator

University of Hawaii
Maria Haws — Principal Investigator

University of Rhode Island
James Tobey — Co-Principal Investigator

Objectives

The overall objective is to determine how to enhance food security and human health impacts through increasing the consumption of safe and high quality aquaculture products and increasing economic benefits to aquaculture producers. Specific objectives include:

1) Identify key issues related to food safety and handling for the major aquaculture products of the Pacific Mexico Coast.
2) Identify means by which aquaculture products can be made more accessible to local and national consumers and in safer forms.
3) Develop strategies to overcome obstacles related to food safety and handling to local, national, and international marketing to increase benefits to producers and marketers.
4) Identify means by which high value, locally produced aquaculture products can be exported to U.S. or other international markets to increase economic benefits, particularly in the case of products produced by cooperatives.
5) Develop protocols to increase safe handling practices for the major aquaculture products from stocking to consumption.
6) As a sub-component, study shellfish sanitation issues that affect the safety of locally produced bivalves and prevent exportation of high value species and develop an action strategy that identifies steps required to improve both.
7) Identify next steps required to implement recommendations stemming from this work.

Significance

Food security has multiple aspects. The most direct effect that aquaculture can have is simply through increasing food availability to the producer and nearby consumers. It may also increase the availability of high protein sources for the community. However, more indirect although not necessarily less significant contributions to food security can be made. Increasing household income, diversifying income sources, reducing the risk of food scarcity or income loss during particular periods and acting as a food or income "bank" are all aspects of food safety (Carletto, 1998). The safety, quality, product life and marketability of aquaculture products increases the probability that maximum benefits will accrue to producers, consumers, and vendors. Women, the rural poor and indigenous groups are important stakeholders to take into account when attempting to improve benefits associated with small scale aquaculture.

The Pacific coast of Mexico hosts significant wild capture fisheries (shrimp, mollusks, crab, and fish), a growing aquaculture industry and a thriving agro-industrial sector that exports most products to the U.S. and the rest of Mexico. The three Pacific States of Mexico, Sonora, Sinaloa, and Nayarit produce 45% of the fisheries/aquaculture production in Mexico (SEMARNAP, 2002). The highest value aquaculture product is shrimp followed by oysters, tilapia, black bass, and tilapia. Aquaculture takes on a

variety of forms including pond culture, cage culture and use of impoundments (ISA, 2003). Production, processing, and marketing of aquaculture products is closely linked to that of fisheries products through shared stakeholders, facilities, and institutions.

Relatively little attention has been paid to issues of food safety and handling to date. During coastal planning initiatives (shrimp BMPs, crab fisheries management, feasibility studies for culture of native bivalve species) by UAS, CI, URI, UHH, and partners, it has been found that food safety and handling is a significant problem that affects consumers of seafood and aquaculture products, and has significant implications for the growing aquaculture industry. First, shrimp culture, particularly when conducted by cooperatives and small-scale producers, suffers losses due to poor harvest and post-harvest handling practice and lack of hygienic controls at all levels of the production system. To some extent, the local processing plants have taken steps to institute HACCP and to control quality as a requirement for product export. But several critical gaps exist. Product from plants that do not meet export standards or shrimp which fail to pass safety checks is sold into the local market. The economic and health consequences are unknown.

It is important to keep in mind that in many cases, little if any refrigeration is used, ice may not be made from potable water and that workers are not educated in hygienic measures. One of the most popular ways to consume products is raw or lightly marinated (e.g., ceviche), not uncommonly in restaurants or seafood bars without running water, adequate sanitary facilities or where workers have knowledge of handling practices. As cooperatives and small-scale producers are branching into culture of other species and as they seek to optimize their shrimp production, these chronic issue of quality and safety must be addressed.

As aquaculture expands, it is becoming clear that the lessons learned from the problems with shrimp extend to other aquaculture products. Two trends exacerbate basic problems with food handling and safety. Water quality is declining, requiring that additional care be taken to avoid water borne health issues such as salmonella or *E. coli* contamination. Culture of freshwater fish and their increasing use in traditional raw or semi-raw preparations brings new concerns for health. The recent sushi fad and proliferation of hundreds of small sushi bars and street carts has accelerated this trend. For example, gnathosome parasites from freshwater fish, which can attack the internal organs and neurological system, have been responsible for 400 reported cases in the last year in Sinaloa (Sylvia Paz, personal communication). Intervention to prevent wider spread incidences of aquatic product-borne diseases and illnesses of all types is clearly indicated.

As the aquaculture industry grows and diversifies and as certain demographic trends continue, these tendencies become more important. Culture of native shellfish and high value finfish, particularly those with export potential (internal and international) require higher levels of quality control and understanding of sanitation measures, particularly as marine and freshwater bodies are increasingly contaminated with sewage, chemicals, and run-off from interior areas. The population may also be more vulnerable to seafood-related illness than in the past. Cancer rates are high in Pacific Mexico, attributed to contamination from industrial and agro-industrial contamination. The percentage of elderly in the population is also increasing. Alcohol and drug addiction are major social problems. HIV infection rates continue to climb. All individuals who are part of these populations are vulnerable to vibrio, samonella, hepatitis, *E. coli*, etc. which can be transmitted through contaminated products. Aside from the microbiological concerns, there are concerns that pollution of water bodies by PCB, heavy metals, and other chemicals from surrounding agricultural and mining areas are affecting aquatic products, but little data is available.

Other than the direct effects on the health of local consumers, there are far-reaching consequences of the lack of awareness and control over quality and safety of aquatic products. Local consumers are increasingly concerned about the safety of seafood products and there are some indications that educated consumers are beginning to prefer purchasing imported, frozen products now available from the growing number of local and international supermarket chains such as Gigante and Sam's Club believing that these products are of higher quality and are safer to eat. Secondly, the access of local populations to aquatic products produced locally is limited as transportation even a few miles from the coast can

be complicated and slow; this is exacerbated by the fact that poor harvest and post-harvesting methods reduce product life to a few days. Even small producers have potential markets outside the immediate area, if larger, inland cities can be supplied. Additionally, the Pacific coast of Mexico has excellent air cargo connections with the U.S., Asia, and Europe, to which industrial and agricultural products are being exported. If product quality and shelf life can be extended, and if issues of microbiological contamination can be addressed, small producers in cooperatives could access these markets. For example, a preliminary market study in Hong Kong for Mexican bivalves indicates that high prices ranging from $0.30 to $4.50 per piece could be obtained as Hong Kong consumers are increasingly aiming to buy shellfish from areas perceived as pristine after recent epidemics of hepatitis and similar diseases from contaminated SE Asian grow areas (Fong, 2003; personal communication).

Another dimension to the problem of lack of control over sanitary conditions is highlighted by the issues surrounding shellfish safety. The Baja Pennisula and the Pacific coast of Mexico have a vibrant and growing bivalve industry. Bivalve culture is of increasing interest due to its promise to diversify and in some cases replace shrimp farming in coastal wetland areas, or to be integrated into shrimp farming systems to reduce effluent loads. This industry sits on the door step of major U.S. populations where demand for seafood is high, and where large populations of latinos creates demand for local species, mostly to be consumed in raw form. To date, only one shellfish growing area in Mexico has been able to accomplish the rather staggering task of classifying and certifying its waters as acceptable for shellfish culture under the strict standards of the ISSC. Growers in Bahia San Quintin in Baja California were able to gain certification of its waters and thus were able to legally export its oysters and clams to Los Angeles in 2000. Sadly, this standing was lost after one year of certification when a local official did not comply with administrative requirements on time. This case is illustrative in that it demonstrates that certification of Mexican waters is possible and that high value markets exist in the U.S. It also brought to light the high incidence of illegal shellfish export across the U.S. border. It is not uncommon to see raw shellfish being sold from handcarts in southern U.S. cities just as it is done on the streets of Mexico under conditions clearly contraindicated by U.S. health codes. Importation of shellfish grown in uncontrolled waters clearly has health implications for consumer. At the same time, it also highlights the high level of export potential for Mexican shellfish. Ability to certify waters and export safe shellfish would enhance the economic wellbeing of growers, and the health of both Mexican and U.S. shellfish consumers.

A tertiary issue of maximum utilization and utilization of by-products also exists; the current shrimp culture industry produces a significant amount of waste in the form of shrimp heads. Increased aquaculture production may also lead to increased production of potentially useful or detrimental wastes. Shrimp head waste has been causing major environmental and health problems as it is generally dumped on beaches and in wetlands after processing of wild capture and cultured shrimp. Local women's cooperatives are beginning to produce shrimp meal with the shrimp heads, but face food safety, handling, and marketing challenges. The same women also market aquaculture shrimp, which suffers from the same lack of sanitary handling and holding conditions. Utilization of waste must also be taken into account in planning for future aquaculture development. Developing the means to resolve the shrimp waste issues will help solve a significant environmental and health problem, and provide a model for other aquaculture waste issues.

Once again, the connections between human health, environmental health and aquaculture become increasingly more acute as populations grow, environmental quality deteriorates and as aquaculture expands and diversifies. A thorough understanding of casual relationships and development of strategies to improve economic, social, and human health outcomes from aquaculture is key to deriving maximum benefits from aquaculture development while reducing impacts.

Anticipated Benefits

Target Groups: Management Committee of Bahia Santa Maria, Women's Fishing Cooperative of BSM (oyster growers); women's oyster growing cooperatives of Puerto Penasco and Nayarit; small-scale shrimp and tilapia farmers, Municipalities of Navolato and Angostura; participants in extension exchange (see above); institutions supporting aquaculture development (ISA, UAS, CIAD, CREDES, UHH, URI, and Ecocostas).

By identifying critical points in the production systems of shrimp, oysters, and fish that affect quality and safety, steps can be taken to raise awareness, implement remedial measures and design training and outreach efforts. This will be linked to the on-going BMP efforts. Improving pre- and post-harvest handling practices can lower health risks and increase sales and distribution range of aquatic products thus increasing the incentive for stakeholders to engage in small-scale aquaculture. Options to allow small-scale producers to derive more economic benefits will be identified. Access to aquatic products will be expanded if products can reach inland areas in safe condition and consumers are assured of the quality and safety. Populations in Mexico at risk from disease or contamination associated with aquatic products will also benefit. U.S. populations that may be consuming black-market products will also benefit. Efforts to diversify and expand production of products such as shellfish and fish will also benefit by overcoming key obstacles to mobilizing and selling product into higher end markets either locally or internationally.

Research Methods

Location: This work will be focused in the three Pacific coast states of Mexico, Sonora, Sinaloa, and Nayarit.

Methods: The methodology used in this study follows the participatory processes used as standard procedure for ICZM by the current partners.

The first step will be to compile and review existing materials related to the subject, although very little exists with reference to food safety and handling issues for Pacific Mexico. Literature research will include the scientific and gray literature, as well as policy, permitting, and other normative materials from Mexico and the U.S. relevant to the topic. The project specialists will then hold an initial seminar to develop an implementation plan to carry out the remainder of the work in early December 2003. Community focus groups, individual interviews, and site visits to communities, aquaculture facilities, and other sites such as agricultural areas will be conducted to gather information and perspectives first-hand as well as to involve the community in the process of identifying and characterizing key issues. Particular attention will be paid to examination of the agricultural and fishing sectors as a models for HAACP, GMP, and logistics-related issues such as transportation, storage, and export requirements that can be adapted to aquatic products quality and safety. Stakeholder groups of particular interest include the women's oyster growing cooperative, the social sector shrimp producers, tilapia farmers, and local marketers and vendors, many of whom are women.

Preliminary findings will be presented at the Extension Exchange (see 11AHHR1) for review by the gathered stakeholders. This is an opportunity for critique and input by these diverse participants. As noted above, workshop participants in the regular series of BMP trainings are given follow-up exercises to build on skills developed during the formal training with results being reported at the following workshop. In this case, some participants will be involved in the fieldwork used to collect information for this study. Once the preliminary study is drafted, a peer review process involving specialists in the region as well as selected CRSP workers will review the draft and comment. This input coupled with the input from the workshop participants will be incorporated into the final work. The final materials will be published and sent to the CRSP workers who participated in the extension exchange.

Regional Integration

The challenge in this case study is to develop simple and feasible strategies whereby researchers and extension agents can successfully work with groups not traditionally involved in aquaculture to enhance current health related benefits from aquaculture and to assist in on-going implementation of small scale aquaculture aimed at diversifying shrimp aquaculture and increasing culture of native species. The results of this work should be of particular relevance to the UJAT and CIAD CRSP work as their stakeholders face similar issues. Also, this work has general applicability to most small-scale producer, vendors, or marketers of aquatic products.

Schedule
Start date: 1 January 2003.
End date: 30 August 2004.

	Month							
Task	J	F	M	A	M	J	J	A
Compilation, review, and synthesis of on-going and past research results	X	X	X					
Site visits and assessments	X	X	X					
Presentation of case study protocols and preliminary findings at the extension exchange			X					
Finalize study, including contribution of workshop participants			X	X	X			
Workshop for integration of findings and participatory assessment					X			
Submission of findings to BMP Working Groups for integration into BMPs						X	X	
Develop recommendations for quality and safety protocols						X	X	
Draft shellfish sanitation plan			X	X	X	X	X	
Final stakeholder review								X
Publication and distribution								X

Literature Cited

Carletto, C., 1998. Household food security and the role of women: IFAD experience in Guatemala. International Fund for Agriculture Development (IFAD)/United Nations. Rome. 45 pp.

DeWalt, B.R., 1998. The Ejido Reforms and Mexican Coastal Communities: Fomenting a Blue Revolution? In: W.A. Cornelius and D. Myhre (Editors), The Transformation of Rural Mexico, Reforming the Ejido Sector. La Jolla Center for U.S.–Mexican Studies, University of California, San Diego, pp. 357–379.

DeWalt, B.R., 2001. Community forestry and shrimp aquaculture in Mexico: social and environmental issues. Prepared for delivery at the 2001 meeting of the Latin America Studies Association, Washington, D.C. 6–8 September.

Haws, M.C., O. Blanco, and A. Villalba-Loera, 2003. Rapid assessment of potential for culture of native bivalves in Bahia Santa Maria, Sinaloa, Mexico and other coastal areas. Internal document of Conservation International, Sinaloa, Mexico.

Villalba-Loera, A., 2003. Bahia Santa Maria Informational Brochure. Conservation International, Sinaloa, Mexico.

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

Economic/Risk Assessment and Social Analysis 2 (11ERAR2)/Activity/Tanzania, Ghana, and Kenya

Investigators

Kwamena Quagrainie	US Principal Investigator	University of Arkansas at Pine Bluff, Arkansas
Aloyce Kaliba	US Co-Principal Investigator	University of Arkansas at Pine Bluff, Arkansas
Raphael Mapunda	HC Principal Investigator	Fisheries and Aquaculture Development Division, Tanzania
Kajitanus Osewe	HC Co-Principal Investigator	Fisheries and Aquaculture Development Division, Tanzania
Berno Mnembuka	HC Co-Principal Investigator	Sokoine University of Agriculture, Tanzania
Stephen Amisah	HC Principal Investigator	University of Science and Technology, Kumasi, Ghana
Linus Kumah	HC Principal Investigator	Fisheries Department, Ministry of Food and Agriculture, Ghana
Charles C. Ngugi	HC Principal Investigator	Department of Fisheries, Moi University, Kenya

Objectives

1) Teach farmers simple methods for assessing and evaluating costs and benefits.
2) Teach farmers principles of record keeping.

Significance

It has been reported that farmers who have participated in ACRSP aquaculture development research activities continue to improve in production of farmed fish and have become model farmers (Veverica et al., 2002; Mac'Were, 2002). Producing more fish does not necessarily imply profitability of the fish farming business. Record keeping is an important management tool necessary for business planning and development. If small- and medium-scale fish farming enterprises can be sustained, developed and be profitable, steps should be taken to teach farmers basic valuation methods for costs and benefits at the farm level as well as principles of record keeping.

Small- and medium-scale fish farmers do not receive financial assistance from commercial lending institutions or the government because of the absence of the necessary economic data and information on fish farming. A visit to commercial banks and the Agricultural Finance Corporation (a government lending agency) in Kenya recently revealed that no financial assistance has ever been given towards fish farming. In most African countries, the government provides all sorts of support for farming of traditional agricultural commodities. Farm-level information on production, costs, sales, inventory, etc., could assist fish farmers in evaluating the profitability of their fish-farming ventures. The information is needed for the preparation of enterprise budgets and business plans to secure the needed financial assistance and support for investments and development. Consequently, this activity will train farmers on simple methods for assessing and evaluating costs and benefits as well as principles of record keeping.

Anticipated Benefits

The training will be for small groups of farmers and individual farmers conducted in the farmers' locale. Both male and female fish farmers will be trained. Fish farmers will be able to value inputs used for fish farming including household food materials, and also be able to keep various kinds of farm records. Farmers will have some understanding of records such as yield, production, costs, sales, liabilities, inventory, and profit and loss. Many fish farmers finance their farming enterprises with revenues from other agriculture enterprises. From this training, fish farmers would begin assembling data and information that would be useful for securing loans from financial institutions, including government

lending agencies. Financial institutions will be better informed about the economic viability and the relative profitability of the fish farming business compared to other traditional agricultural enterprises. The fish farming business will then be in a position to obtain the needed financial assistance for investment in the industry.

Activity Design

Location: Tanzania, Kenya and Ghana

In Tanzania, the study will cover two sample regions in the two major fish farming areas, i.e., the Eastern and Southern zones. In Ghana, the study will be conducted in the Brong-Ahafo, Central and Ashanti regions where fish farming is very active. In Kenya, coverage will be in the Western and Central regions where fish farmers are concentrated.

Methods: Small group and individualized training in the farmers' locale will commence. Fish farmers to be trained will comprise of both male and female farmers. The training will utilize techniques such as repetitions, illustrations, discussions, games, and skits/role-plays. The education level of farmers is about the elementary level. In Kenya and Ghana, the medium of instruction in the elementary schools is English, therefore it is estimated that about 50-75% of the farmers will easily understand English while the others will require some translation. In Tanzania, *Swahili* is the medium of instruction in the elementary schools therefore *Swahili* will be used as the medium of instruction for the training. Teaching resources to be used will include flipcharts and handouts.

Team Composition: The US PIs and a HC economist, (or rural sociologist) yet to be identified will be the facilitators for the training sessions.

Schedule

2004: Farmer training sessions.

To be determined: Report writing, and submission.

Literature Cited

Mac'Were, E., 2002. Comparison of tilapia and Clarias polyculture yields and economic benefits resulting from a locally available animal feed (pig finisher pellet), agricultural by-product (rice bran), and a pelleted test diet in fertilized ponds. M.S. thesis, Moi University, Eldoret, Kenya.

Veverica, K. L., C. Ngugi, J. Amadiva, and J.R. Bowman, 2002. On-Farm Trials: Evaluation of Alternative Aquaculture Technologies by Local Farmers in Kenya, final report In: K. McElwee, K. Lewis, M. Nidiffer, P. Buitrago, D. Clair, J. Burright, S. Sempier and H. Egna (Editors), Nineteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp 121–133.

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

Economic/Risk Assessment and Social Analysis 3 (11ERAR3)/Study/Tanzania, Ghana, and Kenya

Investigators

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Raphael Mapunda	HC Principal Investigator	Fisheries and Aquaculture Development Division, Tanzania
Kajitanus Osewe	HC Co-Principal Investigator	Fisheries and Aquaculture Development Division, Tanzania
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Objectives

1) Evaluate smallholder, medium-scale, and community-based aquaculture ventures within rural areas.
2) Identify researchable themes and areas of intervention.

Significance

One of the researchable priority areas identified by the African Expert Panel 2002 was insufficient knowledge of the economics of aquaculture, which is necessary for policy planning and private investment in aquaculture in Africa. With continuing efforts by many NGOs to develop aquaculture in Africa, there is the need to assess present household aquaculture production systems in rural areas and identify target households and natural resource systems with developmental potential for which options can be formulated and their potential impact assessed. In Kenya where ACRSP has operated for a number of years, it is appropriate to assess the level of the fish farming industry to enable continued focus on researchable priority areas. In Tanzania and Ghana however, where ACRSP is initiating collaborative research activities, an assessment of the smallholder, medium-scale and community-based ventures will assist the ME to maximize the benefits of development interventions by ACRSP in these countries.

Economic studies have demonstrated that fish farming is a viable enterprise for African producers with high gains, but minimum costs (Molnar, et al., 1991; Engle et al., 1993; Lightfoot et al., 1996). In particular, Engle et al (1993) demonstrates that fish production in Rwanda represented the main cash crop for over 50 percent of farmers and private pond holders. Large-scale intensive enterprises have proven to be beyond the means of farmers and many African governments and studies have indicated that smallholder commercial farmers are profitable economic activities (Wijkstrom and MacPherson, 1990).

Anticipated Benefits

The study will provide information on issues such as risks, costs, prices, marketing, gender, finance and policy as they relate to rural aquaculture enterprises. This will be a useful tool for improved decision-making by ACRSP, the host country, and other sponsors/development partners. In particular, the assessment will help to foster linkages between the research institutions/stations and policy makers. Information obtained from this study will enable ACRSP to support the development of a demand-driven and more effective applied research and extension support systems at the rural level, with a focus on improving the competitive capacity of smallholder, medium-scale, and community-based aquaculture ventures. A report will be prepared that presents detailed findings and implications for ACRSP and

other NGOs to assist in providing technical assistance to smallholder, medium-scale, and community-based aquaculture ventures.

Research Design and Activities

Location of Work: Tanzania, Ghana and Kenya

In Tanzania, the study will cover two sample regions in the two major fish farming areas, i.e., the Eastern and Southern zones. In Ghana, the study will be conducted in the Brong-Ahafo, Central and Ashanti regions where fish farming is very active. In Kenya, coverage will be in the Western and Central regions where fish farmers are concentrated.

Research Plan and Methodology: The study will involve a comprehensive questionnaire for households involved in fish farming or other aquaculture ventures. Both male and female fish farmers will be surveyed. The questionnaire will be developed after discussions and consultations among the PIs in the US, Ghana, Kenya and Tanzania, other scientists, extension officers, farmers and other stakeholders. The survey will aim at collecting detailed operational, technical, financial and household data. Since most fish farmers are not engaged solely in aquaculture production, similar information will be collected for other farming enterprises.

A dynamic multi-period adoption model will be developed and used to assess the factors affecting a decision to engage in fish farming, and adoption of different fish production technologies. With this framework, the first step is the decision of a farmer whether or not to engage in fish farming. In a second step, a farmer chooses production practices and associated costs to maximize the present value of current net returns plus terminal land value, with a subjective belief that the land value will be higher in the second period. At both steps, farmer's socio-economic and demographic characteristics, and the technology characteristics that include economic measures are crucial in the decision-making process.

Team Composition: Enumerators will be mainly teachers in K12-Grade 6 as well as college students. These individuals are very familiar with the rural areas and are experienced with collecting information from farmers. The government and NGOs use them quite frequently for economic surveys, voter registration and elections. The US PIs and a HC economist, (or rural sociologist) yet to be identified will train the enumerators, process the data and perform the economic analyses.

Regional Integration

The scope of this work will provide insights into general policy guidelines for initiating and guiding technical assistance in aquaculture development within the African sub-region.

Schedule

April - May 2004: Design survey instruments.
June - August 2004: Administer survey instrument.
To be determined: Analysis of survey results, report write-up and submission.

Literature Cited

Engle, C.R., M. Brewster, and F. Hitayezu, 1993. An economic analysis of fish production in a subsistence agricultural economy: the case of Rwanda. Journal of Aquaculture in the Tropics, 8:151–165.

Lightfoot, C., M. Perin, and J.K. Ofori, 1996. Analytical Framework for Rethinking Aquaculture Development for Smallholder Farmers. In: M. Perin, J. Ofori, and C. Lightfoot (Editors), Research for the future development of aquaculture in Ghana. ICLARM/IAB/GTZ Workshop Accra, Ghana. pp. 4-10.

Molnar, J.J., A. Rubagumya, and V. Adjavon, 1991. Sustainability of aquaculture as a farm enterprise in Rwanda. Journal of Applied Aquaculture, 1(2):37–62.

Wijkstrom, U.N. and N.J. MacPherson, 1990. A Cost Benefit Analysis of Culture Based Fisheries Development in Small Dams and Dugouts. Field Work Paper 1: The Economics of Culture Based Fisheries. Field Doc. F1:TCP/GHA0051, FAO, Rome, 7pp.

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

Economic/Risk Assessment and Social Analysis(11ERAR4)/Study/Tanzania, Ghana, and Kenya

Investigators

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Objectives

1) Estimate the potential economic impact of small- and medium-scale aquaculture developments on community development.
2) Assess the impact of fish farming on rural poverty alleviation and food security.

Significance

Besides contributing to food security and poverty alleviation, aquaculture has been an employment and income generating activity for many African farmers. Many small-scale farmers have small land holdings in areas of diverse and risk prone agriculture. Such areas depend solely on natural rainfall for most of the agricultural activities. In some areas, ponds may also provide a focal point for agricultural diversification and increased sustainability, by providing a source of water. Molnar, et al.(1991), Engle et al. (1993), and Lightfoot et al. (1996) have demonstrated that fish farming in developing nations could be a profitable business because of high gains, and minimum costs. Although fish provides far less nutritional animal protein than other livestock, rural dwellers in many Africa countries greatly depend on fish as part of their daily diet. It is estimated that fish provides at least 40% of dietary animal protein in sub-Saharan Africa (Edwards, 2000). Aquaculture contributes towards poverty reduction in poor regions in China, Indonesia and Vietnam. In Africa, the impact of aquaculture on rural poverty alleviation and food security has scarcely been assessed.

Anticipated Benefits

This activity will provide measurable outcomes of aquaculture on rural economic growth, poverty alleviation and food security, which is the major thrust of ACRSP research activities worldwide. The impact measures will be useful tools for improved decision-making by the respective host country governments, development sponsors and partners. Results from the impact analysis of rural aquaculture development will also be useful to lending institutions and private investors for making sound investment decisions.

Research Design and Activities

Location of Work: Tanzania, Ghana and Kenya

In Tanzania, the study will cover two sample regions in the two major fish farming areas, i.e., the Eastern and Southern zones. In Ghana, the study will be conducted in the Brong-Ahafo, Central and Ashanti regions where fish farming is very active. In Kenya, coverage will be in the Western and Central regions where fish farmers are concentrated.

Research Plan and Methodology: The study will involve a comprehensive questionnaire for households and communities involved in fish farming or other aquaculture ventures. Both male and female fish farmers will be surveyed. The questionnaire will be developed after discussions and consultations among the PIs in the US, Ghana, Kenya and Tanzania, other scientists, extension officers, farmers and other stakeholders. The survey will aim at collecting detailed operational, technical, financial, and household data. Since most fish farmers are not engaged solely in aquaculture production, similar information will be collected for other farming enterprises.

The survey responses will be consolidated at the community level and used to construct an aggregate input-output square matrix used to assess impact of certain sectors on a nation's economy, but can be modified to assess the impact on regions or communities (Bulmer-Thomas 1982). Input-output analysis has been widely employed in assessing development effectiveness in attaining equity-based outcome of policy. The input-output matrix is the basis for computable general equilibrium modeling as well (see for example Adams and Parmenter, 1995; Wobst, 2001). The base matrix will be used to calculate the economic multipliers, which are the foundation for estimating economic impact. The economic multipliers capture direct economic effects associated with specific activity (in this case aquaculture development), indirect effects associated with new demand of inputs and services, and induced effect associated with changes in household income and employment. What is unique about this study is that, the multipliers will be used to estimate the impact of an activity on economic output, employment creation, and ability of the aquaculture development to stimulate growth in other sectors of the rural economy. The multipliers can also be used to examine resource competitiveness by examining the resources account (e.g., looking at the value of family labor for each production activity).

Team Composition: Enumerators will be mainly teachers in K12-Grade 6 as well as college students. These individuals are very familiar with the rural areas and are experienced with collecting information from farmers. The government and NGOs use them quite frequently for economic surveys, voter registration and elections. The US PIs and a HC economist, (or rural sociologist) yet to be identified will train the enumerators, process the data and perform the economic analyses.

Regional Integration

This study is a logical step toward developing sustainable aquaculture in Africa. Several NGOs and government agencies are involved in developmental activities in Kenya, Ghana and Tanzania. The results from the study will highlight the impact of the activities of NGOs in the region as well as provide insights for potential NGOs that are considering providing technical assistance to aquaculture development in Africa.

Schedule

April - May 2004: Design survey instruments.
June - August 2004: Administer survey instrument.
To be determined: Analysis of survey results, report write-up and submission.

Literature Cited

Adams, P.D. and B.R. Parmenter, 1995. An Applied General Equilibrium Analysis of the Economic Effects of Tourism in a Small, Open Country." Applied Economics, Vol. 27 #10:985–994.

Bulmer-Thomas, V., 1982. Input-Output Analysis in Developing Countries: Sources, Methods and Applications, John Wiley & Sons Ltd.

Edwards, Peter, 2000. Aquaculture, Poverty Impacts And Livelihoods. Natural Resource Perspective, Number 56, June 2000, Overseas Development Institute, London, UK.

Engle, C.R., M. Brewster, and F. Hitayezu, 1993. An economic analysis of fish production in a subsistence agricultural economy: the case of Rwanda. Journal of Aquaculture in the Tropics, 8: 151–165.

Lightfoot, C., M. Perin, and J.K. Ofori, 1996. Analytical Framework for Rethinking Aquaculture Development for Smallholder Farmers. In: M. Perin, J. Ofori, and C. Lightfoot (Editors), Research for the future development of aquaculture in Ghana. ICLARM/IAB/GTZ Workshop Accra, Ghana. pp. 4–10.

Molnar, J.J., A. Rubagumya, and V. Adjavon, 1991. Sustainability of aquaculture as a farm enterprise in Rwanda. Journal of Applied Aquaculture, 1(2):37–62.

Wost, P., 2001. Structural Adjustment and Inter-sectoral Shifts in Tanzania: A Computable General Equilibrium Analysis. Research Report No. 117. Washington, DC: International Policy Research Institute.

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

Indigenous Species Development 3 (11ISDR3)/Experiment/Mexico

Investigators

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Kevin Pope	Co-Principal Investigator	Texas Tech University

Objectives

The goal is to develop culture techniques for common snook in southern Mexico, by determining the timing and morphological pattern of gonadal sex differentiation in common snook fry and juveniles.

Significance

Artisanal fisheries based on the capture of wild populations are the primary current source of fish for the food market in the southern region of Mexico. However, because of its geographic and hydrological features, this region also has been considered one of the most promising areas in Mexico for the development of aquaculture. Although native fishes are deeply embedded in the culture of the region and constitute important food staples for its people, to date most aquaculture programs have relied primarily on non-native species such as tilapias and carps. These exotic species have escaped the confines of aquaculture farms and are now reported to have invaded biologically sensitive areas such as the Pantanos de Centla Biosphere Reserve (Tabasco), the most important wetland system in southeastern Mexico. The impact of these exotics on the ecological viability of the area remains largely unexplored but is likely to be considerable. This proposed work is based on the premise that the development of aquaculture of indigenous species is preferable for the region in the context of both market acceptability and ecological compatibility.

Species of "robalo," or snook, are among the most important indigenous fish species along the Mexican coastline of the Gulf of Mexico. Among the species of snook, the robalo blanco, or common snook (*Centropomus undecimalis*) are caught in relatively greater numbers and enjoy a high market value (Anonymous, 2002). During the last few years, the average annual catch for common snook has been approximately 5,000 tons in Mexico and 900 tons for the state of Tabasco (Anonymous, 2002). However, there is an overall national trend for diminishing catch volumes despite occasional and short-lived local increases, a situation that has led to concerns for the health of the regional snook fisheries and to calls for improved management practices (Anonymous, 2002). The natural range of common snook extends from North Carolina to Brazil (Muller et al., 2001), and therefore the status of natural snook populations is also of international concern. In places such as Florida, USA), common snook were until recently considered a "species of special concern" for which commercial harvest was banned, and strict management regulations are currently in place for its recreational fisheries (Anonymous, 2001).

Reproductive Biology of Common Snook and Current Status of Its Aquaculture

Knowledge of the reproductive biology of common snook is limited. Histological observations of the gonads of fish collected from the field are consistent with the concept that common snook are protandric hermaphrodites. Namely, they appear to first develop as males and thereafter reverse into females. In Florida, all fish younger than one to two years (depending on site of collection) seem to be males, an even sex ratio is observed at five to seven years, and most fish older than 12 to 15 years seem to be females (Taylor et al., 2000). Interestingly, the available data (Taylor et al., 2000) also indicates that within

the same age class, females are larger than males. This size differential is particularly pronounced in younger fish, one to two years old, where the fork length of females is 60 to 70% longer than that of males (Tables 2 and 3 in Taylor et al., 2000). The spawning season for common snook runs from spring through early fall, depending on the geographical location, during which they spawn multiple times (Peters et al., 1998; Taylor et al., 1998). Although it is sometimes assumed that sex reversal in common snook occurs after their first spawning (Muller et al., 2001), there is histological evidence suggesting that males may retain their gender through consecutive spawning seasons (Grier and Taylor, 1998). Additional studies are clearly needed to obtain a better knowledge of the reproductive biology of common snook. Further, most studies of common snook reproduction have focused on Florida populations and research with populations in other geographical locations is necessary to determine the general applicability of the results obtained.

Techniques for aquaculture production of snook are at present not fully developed. Snook broodstock has been difficult to maintain in captivity and thus the few available hatchery-spawning programs have relied on wild-caught fish. Wild-caught broodstock are either immediately processed upon capture to obtain gametes for in vitro fertilization, or they are brought to the hatchery where they are promptly injected with hormones to induce spawning (Anonymous, 2001). Fingerlings for stocking purposes have been successfully produced using this technique.

Rationale for Proposed Research

The finding that female snook are larger than males of the same age class, especially in the younger fish (see preceding discussion), suggests that females have an intrinsically faster growth rate than males. This finding has obvious and important relevance for the development of aquacultural techniques for snook. For example, sex determination in most fishes is readily manipulated by exogenous administration of sex steroids early during gonadal development (Schreck, 1972; Hunter and Donaldson, 1983; Contreras-Sánchez, 2001). Also, in many species including those with strong genetic determinants of sex, sex ratios can be manipulated by changes in water temperature (Strüssmann and Patiño, 1995, 1999; Patiño et al., 1996). Control of sex ratios by environmental techniques such as water temperature has the advantage that they are not associated with real or perceived concerns for the use of steroids ("endocrine disruptors") in aquaculture. Therefore, this proposed project is designed to determine if sex ratios of common snook can be changed in favor of females by manipulation of water temperature or application of exogenous sex steroids (estrogen) and if growth rate is associated with gender. To our knowledge, the effects of temperature on sex determination of naturally hermaphroditic teleost species has not been examined, but in other protandric teleosts the exogenous administration of estrogens generally results in female formation (Guigen et al., 1993; Condeca and Canario, 1999; Lee et al., 2000).

The development of an aquaculture industry for common snook would benefit the Gulf Coast region of Mexico for various important reasons. It would be consistent with regional plans for the development of aquaculture as a source of income and of food fish. It would also be consistent with the commonsense premise that the use of indigenous species for aquaculture has a much lower probability of causing ecological damage compared to exotics such as tilapia or carp (see preceding discussion). Finally, it would provide relief from the intense fishing pressure currently being exerted on wild snook populations.

Anticipated Benefits

Incorporation of native species, such as common snook, is needed for the further development of Mexican aquaculture. This study will focus on the evaluation of techniques that may result in enhanced growth rates of farmed common snook by manipulating sex ratios to favor the formation of faster-growing females. Culture techniques for native species will benefit fish farmers in southern Mexico and Central America by promoting aquacultural diversification while avoiding the potentially harmful ecological effects associated with the widespread use of exotic species. If the proposed protocols provide positive results, farm trials will be set up at Ejido Rio Playa and workshops will be conducted to train farmers, students, and technicians. One graduate student and one undergraduate student will be directly involved in the project, and it is anticipated that many more undergraduate students will also participate during the course of the study. At least one publication in a refereed scientific journal is expected from the results of this proposed study.

In addition, this project would strengthen ties between Texas Tech University (TTU) and Universidad Juárez Autónoma de Tabasco (UJAT) and foster current efforts to establish collaborative research projects between the two institutions. In support of these efforts, R. Patiño and K. Pope traveled to Villahermosa, Tabasco, in 2001 to participate in a symposium on reproductive physiology and early life history of fishes. The symposium was organized under the auspices of UJAT.

Research Design

Location of Work: All experiments will be conducted at UJAT with the assistance of a graduate student from TTU and personnel from UJAT.

Year 1 Experiment: Timing and morphological pattern of gonadal sex differentiation in common snook

Methods: Snook fry will be obtained by collection of ripe wild broodstock (during spawning season in the summer) and in vitro fertilization of eggs. Fish will be fed *Artemia* nauplii initially and trained to accept artificial feed afterwards.

Laboratory and Pond Facility: UJAT; fish will be initially maintained in 20 to 40 liter tanks and transferred to circular 140 liter tanks as the fish grow in size.

Culture Period: One year.

Stocking Rate: Initially 100 fry per tank. After treatment or as needed due to growth, juveniles will be transferred to recirculating systems with 140 liter tanks for grow-out. If fish require more time for grow-out, fish will be transferred to 1 m^3 mosquito mesh hapas.

Test Species: Common snook (*Centropomus undecimalis*).

Nutrient Inputs: None.

Water Management: Water will be maintained at 27.5ºC, 25% water exchange once a week. Water pH, dissolved oxygen, and temperature will be monitored daily.

Sampling Schedule: Samples for histological inspection of the developing gonads will be collected on the day of hatching, at bi-weekly intervals during the first two months post-hatch, and monthly thereafter for a total period of one year. Sample size will be 12 fish per sampling time. Criteria for gonadal differentiation will be as described by Patiño and Takashima (1995).

Statistical Methods and Hypothesis: This is a purely descriptive study whose purpose is to provide the basis for deciding the timing of the experimental manipulations in Experiment 2. Thus, statistical analysis will not be necessary. All fish are anticipated to form an immature testis within the first year of hatching, most likely within the first several weeks or months.

Schedule of Performance: Data collection, May 2003–April 2004; Technical report, 30 April 2004.

Literature Cited

Anonymous, 2001. Snook Sea Stats Publication. Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, Florida, 4 pp.

Anonymous, 2002. La Pesqueria de Robalo del Golfo de México. Anales de la Secretaria de Pesca, México, pp. 773–792.

Condeça, J.B. and A.V. Canario, 1999. The effect of estrogen on the gonads and on in vitro conversion of androstenedione to testosterone, 11-ketotestosterone, and estradiol-17β in *Sparus aurata* (Teleostei, Sparidae). Gen. Comp. Endocrin., 116:59–72.

Contreras-Sánchez, W., 2001. Sex determination in Nile tilapia, *Oreochromis niloticus*: gene expression, masculinization methods, and environmental effects. Ph.D. thesis. Oregon State University, Corvallis, Oregon.

Grier, H.J. and R.G. Taylor, 1998. Testicular maturation and regression in the common snook. J. Fish Biol., 53:521–542.

Guigen, Y., B. Jalabert, E. Thouard, and A. Fostier, 1993. Changes in plasma and gonadal steroid hormones in relation to the reproductive cycle and sex inversion process in the protandrous seabass, *Lates calcarifer*. Gen. Comp. Endocrin., 92:327–338.

Howells, R.G., A.J. Sonski, P.L. Shafland, and B.D. Hilton, 1990. Lower temperature tolerance of snook, *Centropomus undecimalis*. Northeast Gulf Science, 11:155–158.

Hunter, G.A. and E.M. Donaldson, 1983. Hormonal sex control and its application to fish culture. In: W.S. Hoar, D.J. Randall, and E.M. Donaldson (Editors), Fish Physiology, Volume 9B. Academic Press, New York, pp. 223–303.

Lee, Y.-H., F.-Y. Lee, W.-S. Yueh, P. Tacon, J.-L. Du, C.-N. Chang, S.-R. Jeng, H. Tanaka, and C.-F. Chang, 2000. Profiles of gonadal development, sex steroids, aromatase activity, and gonadotropin II in the controlled sex change of protandrous black porgy, *Acantopagrus schlegeli* Bleeker. Gen. Comp. Endocrin., 119:111–120.

Muller, R.G., M.D. Murphy, and F.S. Kennedy Jr., 2001. The 2001 stock assessment update of common snook, *Centropomus undecimalis*. Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, St. Petersburg, Florida, 56 pp.

Patiño, R., K.B. Davis, J.E. Schoore, C. Uguz, C.A. Strüssmann, N.C. Parker, B.A. Simco, and C.A. Goudie, 1996. Sex differentiation of channel catfish gonads: Normal development and effects of temperature. J. Exp. Zool., 276:209–218.

Patiño, R. and F. Takashima, 1995. The gonads. In: F. Takashima and T. Hibiya (Editors), An Atlas of Fish Histology: Normal and Pathological Features, Chapter 9, 2nd Edition, Kodansha, Tokyo; Gustav Fischer Verlag, New York, pp. 129–153.

Peters, K.M., R.E. Matheson Jr., and R.G. Taylor, 1998. Reproduction and early life history of common snook, *Centropomus undecimalis* (Bloch), in Florida. Bull. Mar. Sci., 62:509–529.

Schreck, C.B., 1974. Hormonal treatment and sex manipulation in fishes. In: C.B. Schreck (Editor), Control of sex in fishes. Virginia Polytechnic Institute and State University Extension Division, Blacksburg, Virginia, pp. 84–106.

Strüssmann, C.A. and Patiño, R. 1995. Temperature manipulation of sex differentiation in fish. In: F.W. Goetz and P. Thomas (Editors.), Proceedings of the Fifth International Symposium on the Reproductive Physiology of Fish, FishSymp95, Austin, Texas, pp. 153–157.

Strüssmann, C.A. and R. Patiño, 1999. Sex determination, environmental. In: E. Knobil and J.D. Neill (Editors), Encyclopedia of Reproduction, Volume 4. Academic Press, San Diego, pp. 402–409.

Taylor, R.G., H.J. Grier, and J.A. Whittington, 1998. Spawning rhythms of common snook in Florida. J. Fish Biol., 53:502–520.

Taylor, R.G., J.A. Whittington, H.J. Grier, and R.E. Crabtree, 2000. Age, growth, maturation, and protandric sex reversal in common snook, *Centropomus undecimalis*, from the east and west coasts of Florida. Fish. Bull., 98:612–624.