Aquaculture Collaborative Research Support Program
Second Addendum to the Twelfth Work Plan

Prepared June 2007

The ACRSP *Twelfth Work Plan*, published in Fall 2005, described a standardized set of experiments to be undertaken by the Aquaculture Collaborative Research Support Program through July 2006, the end of the current grant period. Subsequently, USAID has provided the necessary funds to continue ongoing research and outreach activities for two additional years. The *Addendum to the Twelfth Work Plan* was published in August 2006, and contained the details of new work plans and official changes to work plans described in the Twelfth Work Plan for the first additional year. This *Second Addendum to the Twelfth Work Plan* contains a revision to the *Addendum to the Twelfth Work Plan* and new work plans for the second additional year. Program activities are funded in part by Grant No. LAG-G-00-96-90015-00 from the United States Agency for International Development (USAID) and by participating US and host country institutions. The authors' opinions expressed herein do not necessarily reflect the views of USAID.

Aquaculture CRSP
Oregon State University
418 Snell Hall
Corvallis, OR 97330-1643
USA
http://pdacrsp@oregonstate.edu

Aquaculture CRSP
Second Addendum to the Twelfth Work Plan

NEW WORK PLANS

AQUACULTURE AND HUMAN HEALTH IMPACTS
3 Workshops on Better Practices for Sustainable Aquaculture (12EIA7)
9 Building the Capacity of Moi University to Have a Working GIS Lab and First Generation GIS Model of the Nzoia River Basin (12EIA8)

SUSTAINABLE DEVELOPMENT AND FOOD SECURITY
14 Aquaculture Outreach in the Amazon Basin (12SDF7)
17 The Eagle of the North and the Condor of the South Aquaculture Exchange Project – Mexico (12SDF8)
20 Sixth International Aquaculture Training Course in the Amazon Region (12SDF9)

INDIGENOUS SPECIES DEVELOPMENT
23 Egg Hatching Quality of Amazonian Fishes (12ISD5)
26 Influence of Dietary Fatty Acid Composition on Reproductive Performance of *Colossoma macropomum* (12ISD6)

WATER QUALITY AND AVAILABILITY
30 Pelagic (Fish) and Benthic Ecology of Selected Sub-watersheds of the Nzoia River Basin (12WQA7)
34 Hydrologic Modeling in the Nzoia River Basin (12WQA8)

APPLIED TECHNOLOGY AND EXTENSION METHODOLOGIES
40 Workshops for the Cultivation of New Species in Brazil and Peru (12ATE16)
42 ACRSP Support for Development of Aquaculture Economics (12ATE17)
46 Special Sessions, Travel and Poster Awards at 2007 World Aquaculture Conferences, Site Descriptions Update (12ATE18)

SEEDSTOCK DEVELOPMENT AND AVAILABILITY
52 Improvement of Tilapia Fingerling Production and Availability in Central America (12SDA6)

FISH NUTRITION AND FEED TECHNOLOGY
56 Reproduction of Pacu (*Piaractus mesopotamicus*) and Surubim (*Pseudoplatystoma tigrinum*) and New Paradigm in Nutrition of Tropical Fishes (12FNF4)

REVISION TO THE *ADDENDUM TO THE TWELFTH WORK PLAN*

APPLIED TECHNOLOGY AND EXTENSION METHODOLOGIES
68 Aquaculture CRSP Support for IIFET 2006 Portsmouth (12ATE15)

Workshops on Better Practices for Sustainable Aquaculture

Environment Impacts Analysis (12EIA7) / Activity / South Africa, Brazil, Thailand

Collaborating Institutions

Auburn University, USA
Claude E. Boyd and Chhorn Lim
Agricultural Sciences, Stellenbosch University, South Africa
Khalid Salie
Embrapa Environment, Jaguariúna, Brazil
Julio F. Queiroz
Kasetsart University, Thailand
Idsariya Wudtisin

Objectives

1. Present workshop on management considerations for preventing sediment and water quality deterioration in small, South African reservoirs with cage culture.

2. Convene workshop on guidelines for development of aquaculture best management practices (BMPs) in Brazil.

3. Provide workshops on bottom soil characteristics of freshwater aquaculture ponds in Thailand with recommendation for pond bottom soil BMPs.

Significance

Soils at some sites may have properties that limit their use for pond aquaculture, and source water for aquaculture facilities may be of impaired quality (Hajek and Boyd 1994). Treatment methods can be applied to correct limitations in soil and water quality and improve conditions for aquaculture (Boyd 1999).

During grow-out of aquaculture species, fertilizers and feeds are used to enhance production. These sources of nutrients are valuable resources and should be used efficiently. Nutrients applied to ponds in fertilizers and feeds and not removed in the biomass of the culture species at harvest enter the culture system leading to dense phytoplankton blooms, high ammonia concentrations, low dissolved oxygen concentration, and other water quality problems (Boyd and Tucker 1998). Organic matter settling to the bottoms of ponds or beneath cages for fish culture can spoil sediment quality and cause adverse effects on culture animals (Avnimelech and Zohar 1986; Schmittou 1993). Practices such as using stocking densities in accordance with system carrying capacity, applying high quality feed and good feed management to minimize wastes, supplementing dissolved oxygen supply with mechanical aeration, drying of pond bottoms between crops, selecting sites with good water circulation for cage culture, and rotating cage locations in lakes and reservoirs at intervals are examples of good management practices that may be applied to avoid environmental deterioration within culture systems.

Effluents and other discharges from aquaculture facilities can cause pollution in receiving water bodies. The most common problems are eutrophication resulting from additions of nitrogen and phosphorus, turbidity from suspended solids, and sedimentation of coarse suspended particles (Schwartz and Boyd 1994). Application of good production practices improves sediment condition and water quality in culture systems to lessen loads of potential pollutants in discharges from aquaculture farms. Nevertheless, water should be reused to the extent possible to lessen discharges. Effluents also can be passed through settling basins to remove coarse solids that would otherwise settle in receiving water bodies (Boyd and Queiroz 2001).

Management procedures considered to be the most practical means of solving a resource management or pollution problem are called best management practices (BMPs). Application of BMPs provides an excellent way of improving aquaculture management and minimizing negative environmental impacts (Clay 2004). Use of BMPs is one way a producer can demonstrate environmental responsibility. Application of better practices also can be a way of achieving compliance with governmental regulations and certification standards (Boyd 2003b).

The major significance for the proposed activities is to present information obtained by the ACRSP-supported investigators to fish farmers and other stakeholders. The US and Host Country PI and Collaborators have directed their efforts to developing methods for improving water and soil quality in aquaculture ponds in Thailand and Brazil, and in reservoirs for cage culture in South Africa. The

findings can be formatted as best management practices (BMPs) to facilitate their presentation to and implementation by farmers. Workshops on general aspects of aquaculture BMPs were held in South Africa and in São Paulo State, Brazil in 2005 and 2006. Experiences from those workshops will be useful in organizing the proposed workshops on bottom soil BMPs in Thailand and BMPs for cage culture in South Africa. The general BMP workshop will be presented again in the Amazon region of Brazil, for producers there have little experience with the topic.

In summary, the significance of this effort would be to: (1) present BMPs for sediment and water quality management in reservoirs for cage culture to fish farmers in South Africa; (2) present guidelines for developing aquaculture BMPs to a group of stakeholders in the Amazon region of Brazil; (3) provide fish and shrimp farmers in Thailand the latest information on pond bottom soils and their management.

Quantified Anticipated Benefits

These workshops are expected to improve the level of awareness of better practices in aquaculture for a range of stakeholders. This achievement should, in turn, lead to a better understanding by all stakeholders of the methods of reducing negative environmental impacts of aquaculture. Guidance on implementation of BMPs will be particularly valuable to extension biologists and farmers.

The specific expectations vary among countries because the workshops have different themes:

(1) The workshop in South Africa will provide farmers and other stakeholders an overview of water quality issues in cage culture, and specific recommendations will be presented on how to avoid sediment and water quality problems in small reservoirs used for cage culture.

(2) A workshop similar to the one organized by the PIs in São Paulo State in 2006 will be held in Manaus in the Amazon region. Fish farmers in that region have no experience with BMPs, and this workshop will provide guidelines for developing BMPs through a transparent process involving a wide range of stakeholders.

(3) The workshops in Thailand will provide small-scale, fish and freshwater prawn farmers information on bottom soil quality that was obtained in previous ACRSP work in that country. The workshops will present the basic information needed for implementing pond bottom soil BMPs.

Workshop Design or Activity Plan

South Africa

The workshop in South Africa will be entitled "Water and Sediment Quality Management in Reservoirs for Cage Culture." The workshop will be held at Stellenbosch University in Stellenbosch in March 2006. The workshop will consist of 2 days of presentations and a 1-day tour of nearby cage culture operations and university facilities. The main focus of the workshop will be to develop best management practices for cage culture. Participants will include researchers, extension workers, and graduate students from the university, fish farmers, government scientists, environmentalists, representatives of the governmental environmental management agency, feed producers, and possibly others. The participants will be expected to cover their own expenses, but lunch will be provided for participants. The Host Country PI thinks that an attendance of 35 to 50 individuals is a reasonable expectation.

The tentative outline for the workshop follows:

Day 1

Welcome and introductions
An overview of cage culture in world aquaculture*
Review of water and sediment quality issues in cage culture*
Cage culture in South Africa – status and future prospects
Environmental issues related to cage culture in South Africa

- Site selection considerations
- Production level
- Off-site effects
- Multiple-use reservoirs
- Regulatory and other legal issues
- Multi-trophic species

Roundtable discussion

Day 2

Guidelines for developing BMPs
Group discussions on BMPs:

- Stock density and carrying capacity calculation
- Feeds and feed management
- Prevention of escapes and management of predation
- Managing dissolved oxygen and occurrence of algal blooms
- Monitoring water and sediment quality*

Evaluation and response to water and sediment monitoring data*
Workshop summary with list of cage culture BMPs*
Roundtable discussion

Day 3

Farm tour and facilities at Stellenbosch

The US PI will make presentations indicated in the outline by an asterisk. The Host Country PI will present some of the other topics and arrange invited speakers to cover the remaining topics.

Brazil

A workshop entitled "Guidelines for Developing Aquaculture BMPs" will be held at the Embrapa facilities at Manaus, Brazil or at the National Institute for Amazon Research – INPA in May 2007. It will be 3 days in length – 2 days of presentations and a 1-day tour. Embrapa and INPA are well known and respected by local and national aquaculture industries. Moreover, these institutions have adequate facilities for convening the workshops, and the locations can be easily reached by travelers in the region.

Embrapa has devoted considerable effort towards development of good agricultural practices for traditional crops. This organization plans to extend the effort to aquaculture. Following the aquaculture BMP workshop supported by ACRSP funds in 2006, the Brazilian participants organized some committees to work on aquaculture BMPs in São Paulo State. The current proposal to hold a BMP workshop in the Amazon is based on Embrapa's desire to extend the BMP effort to other regions. Moreover, there is enthusiasm within the private aquaculture sectors and several other government agencies to participate in the effort.

ACRSP collaborators at other institutions in Brazil will be invited to participate in the workshop. They will be asked specifically to apply the findings of previous ACRSP research in the country to the development of aquaculture BMPs.

It is anticipated that about 50 people will attend the workshop. The stakeholders will be fish farmers, feed producers, aquaculture researchers, extension workers, and administrators, scientists from governmental environmental agencies, representatives of environmental NGOs, and media specialists. In addition, aquaculture, fisheries, and environmental science graduate students from host universities will be urged to participate. Participants will be required to cover their own expenses. Preliminary contacts by the Host Country Collaborator suggest that this requirement will be acceptable and adequate attendance can be achieved. However, Embrapa, Special Secretary for Aquaculture and Fisheries – SEAP/PR, and the Cooperative Program for Research and Technology Transfer for South American Tropics – PROCITROPICOS/IICA will likely cover travel costs for some of their employees to attend the workshop. The participation of PROCITROPICOS/IICA will be very important because it will make it possible to invite and support the participation of some researchers from countries located at the Amazon region, such as Peru, Ecuador, Colombia, Venezuela, and others.

The tentative outline for the workshop follows:

Day 1

Introduction
Aquaculture and the environment
Codes of conduct and BMPs: An introduction
Presentations about national aquaculture

- Production statistics and future trends
- Market considerations
- Culture systems
- Environmental impacts
  - Aquaculturist's opinion
  - NGO concerns
- Aquaculture regulations

Day 2

Aquafeeds
Feed management
Developing draft BMPs to prevent or mitigate impacts

Involving stakeholders in review and refinement of BMPS
Guidelines for implementation of BMPs
Application of BMPs
Questions and answers

Day 3

Tours of nearby aquaculture projects

One of the US PIs (CEB) will make the presentation on aquaculture and the environment and introduce the topic of codes of conduct and BMPs. The other US PI (CL) will present the feed and feed management material. The part of the workshop presented in English by the US PIs will be translated to Portuguese by Dr. Julio Queiroz who has much experience in research on aquaculture and the environment. National speakers will be identified to present information on aquaculture in Brazil. On the second day, the US and Host Country PIs will be responsible for presenting information on the process of BMP development.

Thailand

A 1-day workshop entitled "Pond Bottom Soils: Importance, Characteristics, and Application of BMPs" will be presented at three places. It will be held at Kasetsart University in Bangkok, at Sumat Prakarn, and at Suphan Buri. Fish farmers, feed producers, extension workers, scientists from universities and government agencies, and aquaculture graduate students will be invited. Dr. Wudtisin will work with colleagues at Kasetsart University and in the Thailand Department of Fisheries to select and invite participants.

There has been a large ACRSP effort in Thailand and neighboring countries that was lead by researchers at the Asian Institute of Technology (AIT). Participation of ACRSP researchers from AIT will be requested, and they will be asked to provide comments on pond soil management to supplement the workshop material.

It is anticipated that 50 to 70 participants will be obtained for each workshop. The workshops will begin about 9 am and end at about 3 pm to facilitate travel by participants. Lunch will be provided as part of the program, for participants will be responsible for their other travel expenses.

The workshops will each have four sessions: (1) overview of pond bottom soil dynamics; (2) presentation of soil quality data for freshwater aquaculture ponds in Thailand collected in previous ACRSP efforts (Thunjai et al. 2004; Wudtisin and Boyd 2006); (3) discussion of BMPs for maintaining soil quality and preventing off-site impacts from soil particles suspended in effluents; (4) farmer question-answer-dialogue period.

The outline follows:

Introduction
Pond soils in aquaculture – an overview (by CEB)
Soil quality of freshwater ponds in Thailand:
    Tilapia ponds (probably by Dr. Taworn Thunjai)
    Carp, catfish, and freshwater prawn ponds (by Dr. Idsariya Wudtisin)
Best management practices:
    Introduction to topic (by CEB)
    Pond bottom soil BMPs (by Dr. Idsariya Wudtisin)
Comments by ACRSP researchers from AIT (TBA)
Questions/Answers/Dialogue (all)

Dr. Wudtisin developed a list of BMPs for pond bottom soil as part of her dissertation research. These BMPs were translated to Thai, and copies will be provided to participants in the workshop.

Impact Indicators

The impact of the workshops will be assessed by the following indicators:

1. Total number of participants.

2. Number of fish or freshwater prawn farmers in attendance.

3. Number of requests to PIs for further information on BMPs.

Regional Integration

Cage and pond culture are conducted in all ACRSP regions. There also is interest in aquaculture BMPs in all regions. The bottom soil BMPs to be presented in Thailand and the recommendations for

sediment and water quality management in small, South African reservoirs would be of interest to pond culturists or to those operating cage culture operations in other nations or regions. The guidelines for developing BMPs also are general ones that are widely applicable. The effort has great prospects for regional integration in all ACRSP regions.

Schedule

The tentative schedule follows:

South Africa

November 2006 – February 2007	Planning, speaker, selection, participant invitations, preparation of materials.
March 2007	US PI to SA, final arrangements for workshop, presentation of workshop. US and HC PI work on report.
April – June 2007	Prepare final report.

Brazil

November 2006 – February 2007	Planning, speaker, selection, participant invitations, preparation of materials.
April 2007	US PI to Brazil, final arrangements for workshop, presentation of workshop. US and HC Collaborator work on report.
June 2007	Prepare final report.

Thailand

November 2006 – February 2007	Planning, speaker, selection, participant invitations, preparation of materials.
May 2007	US PI to Thailand, final arrangements for workshop, presentation of workshop. US and HC Collaborator work on report.
June 2007	Prepare final report.

Literature Cited

Avnimelech, Y. and G. Zohar. 1986. The effect of local anaerobic conditions on growth retardation in aquaculture systems. Aquaculture 59=8:167-174.

Boyd, C. E. 1999. Codes of practice for responsible shrimp farming. Global Aquaculture Alliance, St. Louis, Missouri, USA.

Boyd, C. E. 2003a. The status of codes of practice in aquaculture. World Aquaculture 34(2):63-66.

Boyd, C. E. 2003b. Guidelines for aquaculture effluent management at the farm level. Aquaculture 226:101-112.

Boyd, C. E. and P. Munsiri. 1997. Water quality in laboratory soil-water microcosms with soils from different areas of Thailand. Journal of the World Aquaculture Society 28:165-170.

Boyd, C. E. and J. Queiroz. 2001. Feasibility of retention structures, settling basins, and best management practices in effluent regulation for Alabama channel catfish farming. Reviews in Fisheries Science 9:43-67.

Boyd, C. E. and C. S. Tucker. 1998. Pond Aquaculture Water Quality Management. Kluwer Academic Publishers, Boston, Massachusetts, USA.

Boyd, C. E. A. A. McNevin, J. Clay, and H. M. Johnson. 2005. Certification issues for some common aquaculture species. Reviews in Fisheries Science 13:231-279.

Chamberlain, G. W. 2005. Consumers speak, aquaculture responds. Global Aquaculture Advocate 8(6):2.

Chamberlain, G. W. 2006. Controversial to inevitable. Global Aquaculture Advocate 9(2):2.

Clay, J. 2004. World Agriculture and the Environment. Inland Press, Washington, D.C., USA.

Federal Register. 2004. Effluent limitation guidelines and new source performance standards for the concentrated aquatic animal production point source category. Final rule. Federal Register:

August 23, 2004, Volume 69, Number 162, pages 51892-51930. Office of the Federal Register, National Archives and Records Administration, Washington, D.C., USA.
Hajek, B. F. and C. E. Boyd. 1994. Rating soil and water information for aquaculture. Aquacultural Engineering 13:115-128.
Kitamura, P. C. J. F. Queiroz, R. B. Lopes, F. G. de Castro, Jr. and C. E. Boyd. 2002. Environmental and economic assessment of fee-fishing in São Paulo State, Brazil. Journal of Applied Aquaculture 12(4):23-41.
Naylor, R. L., R. J. Goldburg, H. Mooney, M. Beveridge, J. Clay, C. Folke, N. Kautsky, J. Lubchenco, J. Primavera, and M. Williams. 1998. Nature's subsidies to shrimp and salmon farming. Science 282:883-884.
Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsky, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. Effect of aquaculture on world fish supplies. Nature 405:1017-1024.
Schmittou, H. R. 1993. High density fish culture in low volume cages. American Soybean Association, South Asia Office, Singapore.
Schwartz, M. F. and C. E. Boyd. 1994. Channel catfish pond effluents. Progressive Fish-Culturist 56:273-281.
Thunjai, T., C. E. Boyd, and M. Boonyaratpalin. 2004. Bottom soil quality in tilapia ponds of different age in Thailand. Aquaculture Research 35:698-705.
Wudtisin, I. and C. E. Boyd. 2006. Physical and chemical characteristics of sediments in catfish, freshwater prawn, and carp ponds in Thailand. Aquaculture Research 37:1202-1214.

Building the Capacity of Moi University to Have a Working GIS Lab and First Generation GIS Model of the Nzoia River Basin

Aquaculture and Human Health Impacts (12E1A8) / Activity / Kenya

Collaborating Institutions

University of Georgia, USA
- E. W. Tollner, Herbert Ssegane (Graduate Student)

Moi University, Kenya
- Mucai Muchiri, Department of Fisheries and Aquatic Sciences
- Odipo Osano, School of Environmental Studies
- Geoffrey Karanja, Department of Wildlife Management
- James Kiyiapi, Department of Forestry
- Ruth Kinagwi, School of Environmental Sciences
- Frank Masese (Graduate Student)
- Bilha Saina (Graduate Student)
- Naomi Chebet (Graduate Student)

GoK, Kenya
- Rodrick Kundu, Department of Fisheries (Graduate Student)

Objectives

- The over arching objective is to develop a functioning watershed assessment center at Moi University with a GIS-equipped laboratory to integrate water, soils and social indicators needed for assessing the Nzoia river basin and subsequently other important watersheds in Kenya and the surrounding region. A functioning watershed assessment center consists of a GIS-integrated facility that supports the following knowledge and outreach areas:
    - Hydrological and water quality determination
    - Land use identification
- Research objective: To enable students at Moi University and at the University of Georgia to complete their degree under the mentorship of CRSP Researchers. Herbert Ssegane and students at Moi as related to hydrological and water quality determination and to land use identification
- Outreach objective: To accelerate the delivery of research results to key leaders in the form of an outreach workshop. (See appendix 1)

Significance

A major barrier to socio-economic development in sub-Saharan Africa, including Kenya, is food inadequacy. Some of the more important factors that have led to this status are rapid population growth outstripping food production capacity, post-harvest losses, land degradation that leads to further decline in soil fertility, and climatic changes, particularly periodic droughts and subsequent flooding. This food shortage coupled with high poverty rates that diminish people's ability to afford the ever-increasing food prices, has led to related health problems especially in rural areas. In the effort to meet the required food supplies to feed the growing population, forestlands have been cleared for small scale agriculture. Inevitably, a major challenge to economic developing in Kenya is, therefore, the sustained increase of food production without compromising the integrity of the environment within which that much required food is produced. As such the project seeks to complement other projects that seek to "improve the productivity and sustainability of land use systems in Nzoia, Yala and Nyando river basins through adoption of an integrated ecosystem management approach" through development of on-farm and off-farm conservation practices and increased local capacity (Global Environmental Facility 2004:3). Desired outcomes include increased biodiversity and reduced erosion (GEF 2004).

Such a balance reflects decision making regarding risk. People must balance the need for meeting food, housing and health needs with an interest in protecting the environment (Smith et al. 2000). Risk approaches require an integration between positivist and constructivist approaches (Rosa 1998). Risk not only appears as a function of probability-consequence dynamics, but also as a function of risk perception and responses to risk perception (Cohen 2000; Rosa 1998).

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

The major new work proposed in this extension is a more detailed GIS – based model that integrates climatic and physiographic data to do a detailed analysis of sediment pollution potential for the Nzoia basin.

Anticipated Benefits

We anticipate this project to lay the foundation for protecting the Nzoia basin from nonsustainable development. This will be protective of the Lake Victoria and will synergize with in-country efforts to nurture fish production in the region. By building the capacity of Moi University to replicate the effort in other watersheds of Kenya, Moi University can develop a regional reputation as a watershed assessment center that can positively impact the environment in and around Kenya. Physical science skill development would concentrate on developing hydrological dimensions while adding to existing ecological, water quality, forestry, agronomic and Geographic Information System (GIS) skills. Social science would draw from and further develop existing anthropologists and teacher trainers and incorporate sensitivity to gender dynamics and other anthropogenic issues.

A watershed assessment study yields benefits in a hierarchy based on geographic/geomorphic scaling considerations (WEF, 1998). A key feature of watershed management is the use of models to understand the amount of pollution generated and the subsequent distribution and fate of pollutants throughout the watershed (Korfmacher 2001). Typically scientists build watershed models that focus on bio-physical processes. However watershed management involves a greater reliance on social processes than other resource management foci. Therefore models should reflect that social process (Korfmacher 2001; Paolisso and Maloney 2001; Lazo et al. 1999). For example, "cultural models are presupposed, taken-for-granted models of the world that are widely shared (although not necessarily to the exclusion of other, alternative models) by members of a society and that play an enormous role in their understanding of that world and their behavior in it." (Paolisso and Maloney 2001). Conceptual models serve as vehicles to build system understanding from qualitative data collection efforts (Soulliere et al. 2001).

Development projects can incorporate participatory approaches to watershed management (GEF 2004; Wangila and Swallow 2001; Kerr et al. 2000; Estrella and Gaventa 1998). However, previous experience suggest various factors that influence success. The most effective efforts foster collaboration among local communities, national and international agencies, lay and techno-scientific knowledge. Financial and technical investments must exist complementarily and reflect local conditions to ensure sustainability. Efforts must identify, involve and incorporate diverse stakeholders using stakeholder appropriate policy solutions. Watershed efforts need to acknowledge heterogeneity within watersheds. While watersheds fit nicely into physical and hydrologic boundaries, watersheds rarely provide the appropriate social scale for management (Kerr et al. 2000). Lastly, communities with previous experience in community-based or cooperative efforts in other areas and without inconclusive or problematic property rights conditions, provide the best chance of success (Wangila and Swallow 2001; Kerr et al. 2000).

Deliverables from the watershed as a whole include an inventory of resources, statement of environmental endpoints and quality targets, list of Best Management Practices (BMPs) and mitigating measures and location, list of impact statements and uncertainties to be addressed in future monitoring programs. A workshop on watershed assessment and integration of data into a GIS database is planned. From the social perspective, the center should be able to identify a meaningful set of indicators for measuring group activity related to key social goals and then track changes in social organization as part of project monitoring.

Research Design

A detailed literature review and reconnaissance has been completed. The watershed is currently broadly zoned based of survey map of Kenya and focused and targeted field visits to cover key system characteristics have occurred. We are working with key government officials in various districts within the basin. The methodology in Table 1 is currently underway. Students at UGA and at Moi University are currently working toward MS degrees.

The end goal of a watershed assessment effort is to comprehensively model water quantity and quality delivered to the discharge. Modeling, while not necessary to complete an assessment, enables a structured approach to planning an assessment process in that they specify the nature of the data needed. Available models then enable the watershed planner to evaluate management strategies to provide guidance for policy decisions.

Table 1. Steps in completing a watershed assessment

Step	Item
1	Identifying and networking with local agencies and citizens (social inventory)
2	Getting to know the watershed (agronomic, hydrologic, river morphology, ecological inventories); Income sources, Watershed goals
3	Defining the critical areas, including stream and wetlands physical condition assessment
4	Surveying and inventorying key features (Mapping, field visits, etc.); identify reference streams for desired ecological, hydrological, and water quality conditions
5	Prioritizing pollutants, sources and causes
6	Determining objectives for further action (education, research) based on reference metrics
7	Identifying potential best management practices needed based on reference metrics
8	Identifying and analyzing existing local projects, programs and ordinances; promote a few self perpetuating practices
9	Informing and involving the public
10	Developing an evaluation process in light of watershed goals
11	Assembling the work plan

Perhaps the single most important variable in achieving sustainable watershed management is understanding and underpinning key land use practices that directly or indirectly affect ecological processes and system functioning. The reliance on land for agrarian production in rural Kenya coupled with dependence on land resources for economic livelihood places enormous premium on resources derived from land and as a consequence leads to degradation and hence loss of ecological integrity of the system (GEF 2004; Githaiga et al. 2003; Osano et al. 2003). A sustainable land management strategy requires not only intervention at site specific but also the landscape level. A system approach is needed to disentangle critical landscape components and linkages and will more likely to lead to overall positive impacts on the watershed. The Nzoia watershed system transcends a broad range of land use systems and practices ranging from small-scale holder farmland to large scale mechanized agriculture, and cuts a cross a tenure regime of private ownership to public land – e.g., forest reserves and national parks. The watershed produces 30% of Kenya's maize and sugar (Osano et al. 2003). The watershed occurs in generally high potential and high population region of the country and therefore the influence of land use on the system is extremely important (Osano et al. 2003). Eldoret serves as the largest population center (234,000) followed by Kitale (88,100), Kakamega (86,500), Webuye (45,100), Mumias (36,200) and Bungoma (32,900) (Osano et al. 2003). Although agriculture comprises the major land use, textile, paper, sugar and coffee processing comprise major point source pollutants (Osano et al. 2003).

A GIS-based framework will be established to manage the watershed descriptive data. The GIS approach is a layered data management approach (Haan et al., 1994). GIS enables one to identify selected parameters. DeBarry (2004) provides an exhaustive listing of possible GIS layers for watershed assessment. He also provides an orderly approach towards the development of a GIS database. Sayer et al. (2000) provide an excellent set of forms and tables for terrestrial ecological assessments. Canter (1996) is but one example of a compendium of techniques for assessing land and water resources. He provides matrix, network and checklist tools for impact identification related to surface water, soil and groundwater environments (Table 1, items 3, 4). Poor hydrologic conditions of watersheds are known to contribute greatly to the deterioration of watersheds particularly with respect to the water quality and quantity. It is necessary to understand the interrelationship of these processes in order to suggest interventions that will lead to the arresting of these conditions and possibly reversing them. River morphology methods such as the Rosgen (1996), while not developed in the same physiographic soil group, can nevertheless provide valuable indications as to what increased development in the watershed can do to the river. Similarly, these methods can provide valuable insights into how damaged areas can be rehabilitated. Because of the above facts, it is important to understand the various physical aspects of the watershed and their contribution to the overall hydrologic status i.e., its water quality and quantity conditions. By carrying out an in-depth inventory/characterization of the hydrological condition, it is possible to identify pressure points, which ultimately form the entry avenues for the interventions (Table 1, items 5, 6). The rehabilitation as a goal for most elements of the watershed presupposes knowledge of

the current and reference conditions of both functioning and nonfunctioning watershed processes. Thus, both qualitative and quantitative data will be a prerequisite for the watershed rehabilitation. Mapping and initial feature identification will be completed in conjunction with the capacity building objective (GEF 2004).

The GIS lab is a significant facility at Moi University. The facility has been slow in coming due to physical security and other infrastructural issues. The strategy for maximizing the chances for continuation of the lab include the following steps: 1) integrate the lab into the activities of the environmental sciences department at Moi, which broadens the scope of potential funding they may be able to attract from the HC side; and 2) we will together explore additional opportunities relating to the Nile basin.

Regional Integration

The project is targeting the development of a watershed and basin assessment center at Moi University by building a physical science and social science interdisciplinary center to complement such centers at Egerton and Nairobi universities. This project is inherently integrative as it initiates and increases cooperation among diverse interests with the common thread of maintaining the health of a common benefit, the community river. The concept is replicable in other parts of Kenya as well as other developing countries. Close working collaboration will be maintained with the Sustainable Management of Watershed – CRSP (SUMAWA) project that studying the River Njoro watershed. The concept is replicable in other parts of Kenya as well as other tropical regions. The CRSP student at UGA is a Ugandan student, who looks forward to applying the results learned in Uganda.

Students at Moi University, funded by the project via the Moi subcontract and the Kenya Department of Fisheries are:

Frank Masese	Moi University (Graduate Student)
Bilha Saina	Moi University (Graduate Student)
Naomi Chebet	Moi University (Graduate Student)
Rodrick Kundu	Department of Fisheries, GoK (Graduate Student)

Schedule

RESEARCH ACTIVITY PLANS	Responsible Person(s)	Personnel	Timeline
Development of key measurement capabilities and GIS integration	Tollner, Muchiri	Karanja, Odipo	March, 2007
Watershed assessment and GIS data integration workshop	Tollner, Muchiri	Odipo, Muchiri, Tollner	March 2007
Graduate students training at Moi University	Muchiri	Tollner, Nyandat, Odipo, Kiyiapi, Khamasi, Muhia,	June, 2007
Graduate student training at UGA	Tollner	Tollner, Ssegane	June, 2007
Complete resource inventory	Muchiri, Tollner	Tollner, Nyandat, Odipo, Kiyiapi, Khamasi, Muhia	April, 2007
Statement of key environmental endpoints and quality targets	Muchiri, Tollner	Tollner, Nyandat, Odipo, Kiyiapi, Khamasi, Muhia	April, 2007
BMPs and mitigating measures for identified key locations	Muchiri, Tollner	Tollner, Odipo, Kiyiapi, Khamasi, Muhia,	April, 2007

Literature Cited

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, 2nd Ed. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, DC.

Canter, L.W. 1996. Environmental impact assessment (2nd Ed.). McGraw-Hill Publishing Co., New York, NY.

Cohen, M.J. (editor). 2000. Risk in the modern age. MacMillan.

DeBarry, P.A. 2004. Watersheds: Processes, assessment and management. John Wiley & Sons, New York, NY.

Estrella, M. and J. Gaventa. 1998. Who Counts Reality? Participatory Monitoring and Evaluation: a Literature Review, IDS Working Paper 70. Institute of Development Studies. University of Sussex.

Githaiga, J.M., R. Reid, A. Muchiru, S. van Dijk. 2003. Survey of Water Quality Changes with Land Use Type, in the Loitokitok Area, Kajiado District, Kenya. Land Use Change Impacts and Dynamics (LUCID) Working Paper Series Number 35. Nairobi, Kenya: International Livestock Research Institute.

Global Environmental Facility (GEF). 2004. Western Kenya Integrated Ecosystem. Project Executive Summary. http://www.gefweb.org/Documents/Council_Documents/GEF_C23/MFA_-_Kenya_-_Executive_Summary.pdf

Haan, C.T., B.J. Barfield and J.C. Hayes. 1994. Design hydrology and sedimentology for small catchments. Academic Press, New York, NY.

Kerr, J., with G. Pangare, V.L. Pangare and P.J. George (2000). "An evaluation of dryland watershed development projects in India." EPTD Discussion Paper No. 68. International Food Policy Research Institute, Washington DC. USA.

Korfmacher, K.S. 2001. The politics of participation in watershed modeling. Environmental Management 27:161-176.

Lazo, J.K., J. Kinnell, T. Bussa, A. Fisher and N. Collamer.1999 in Risk: Health, Safety and Environment 45:45-64.

Osano, O., D. Nzyuko, M. Tole and W. Admiraal. 2003. The Fate of Chloroacetanilide Herbicides and Their Degradation Products in the Nzoia Basin, Kenya. Ambio 32:424-427.

Paolisso, M.J. and R.S. Maloney. 2000. "Recognizing Farmer Environmentalism: Nutrient Runoff and Toxic Dinoflagellate Blooms in the Chesapeake Bay Region." Human Organization 59(2):209-21.

Rosa, E.A. 1998. Metatheoretical foundations for post-normal risk. Journal of Risk Research 1:15-44.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology. Pagusa Springs, CO.

Sayer, R., E. Roca, G. Sedaghatkish, B. Young, S. Keel, R. Roca and S. Sheppard. 2000. Nature in focus: Rapid ecological assessment. Island Press, Washington, DC.

Smith, K., C.B. Barrett and P.W. Box. 2000. Participatory risk mapping for targeting research and assistance: with an example from East African pastoralists. World Development 28:1945-1959.

Soulliere, D., D.W. Britt and D.R. Maines. 2001. Conceptual modeling as a toolbox for grounded theorists. The Sociological Quarterly 42:253-269.

Wangila, J. and B. Swallow. 2001. Design principles for land and watershed management in Western Kenya, Proceedings of a workshop held on 9th April 2001, Kisumu, Kenya. Natural Resource Problems, Priorities and Policies Programme Discussion Paper 2001-1. International Centre for Research in Agroforestry (ICRAF).

WEF. 1998. Urban runoff quality management. WEF Manual of Practice No. 23. (ASCE Manual and report on engineering practice No. 87). Water Environment Federation, Alexandria, VA.

Aquaculture Outreach in the Amazon Basin

Sustainable Development and Food Security (12SDF7) / Activity / Amazon

Collaborating Institutions

Southern Illinois University at Carbondale, USA
Christopher C. Kohler, Susan T. Kohler, and William N. Camargo
Instituto Nacional De Investigaciones Agricolas (INIA) Amazonas, Venezuela
Karen Graterol, Otto Enrique Castillo González, and Trinidad Urbano de Sarco
Instituto Nacional de Pesquisas da Amazônia (INPA), Brazil
Manoel Pereira Filho, Cristhian Castro Pérez, Flávio Leão da Fonseca, Daniel Rabello Ituassú, Fábio Wegbecher, Fábio Soller Dias da Silva
Universidad Federal do Amazônia (UFAM), Brazil
Marle Angélica Villacorta Correa , Bruno Sagratzki
Secretaria Especial de Acuicultura e Pesca/SEAP/PR, Brazil
Rodrigo Roubach
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil
Levy Caraballo
Instituto de Investigaciones de la Amazonía SINCHI, Colombia
Juan Carlos Alonso and Rosa Machoa
Instituto de Investigaciones IMANI, Leticia, Colombia
Santiago Dúque, Miguel Angel Landines, Cesar Bonilla
Instituto de Investigaciones de la Amazonia Peruana (IIAP), Peru
Fernando Alcántara
Universidad Nacional de la Amazonia Peruana
Marina Del Aguila
Fondo Nacional del Desarrollo Pesquero (FONDEPES), Peru
Guillermo Alvarez
Universidad Mayor de San Simón, Bolivia
Mabel Magariños, Danny Rejas Alurralde, Francisca Acosta Cárdenas, Huáscar Muñoz Saravia Rosmery Ayala Lozada, Mirtha Rivero Lujan
Universidad Autonoma del Beni (UAB), Bolivia.
Luis Torres Velasco
Comunidad Indígena Sarayaku, Ecuador
José Machoa
Fundación Arcoiris, Ecuador
A Luis Arevalo, M Ricardo Burgos
Instituto Tecnológico Saleciano, Ecuador
M Galo Plaza
Peace Corps, Ecuador
Leach Kirk

Objectives

- Provide extension services to the community to promote sustainable aquaculture in the Amazonian region.
- Maintain the specialized website developed in WP10 on Amazonian aquaculture to provide for information exchange and networking.

Significance

Fish culture has been practiced for over five decades in the Amazon region. The countries comprising the Amazon region are linked by major river systems, particularly the drainages comprising the Amazon and Orinoco Rivers. The largest diversity of freshwater fishes in the world is contained within these drainages. In the Peruvian Amazon, the food security program (PROSEAL) created in 1999 and directed by Terra Nouva (Italian NGO, Marco Colace) and IIAP, provided significant extension service (five extension agents) for several communities along the Iquitos-Nauta Road and the Santa Helena and Huayococha indigenous communities in Tigre River (Maynas Province, Loreto Department, Peru). After Terra Nouva completed its prime goals in December 2001, CRSP and IIAP took over this important task through a transitional period in 2001 by rehiring up to 2 of the 5 extension agents, and by enrolling a third extension agent in a Ph.D. program at SIUC. Results from research conducted at our host

country facilities provided much of the information that PROSEAL extended to farmers. Thus, at the outset in 1999, PROSEAL was a direct beneficiary from the CRSP program in Peru. As a result of the technical support and outreach efforts of the CRSP/IIAP team in WP 9, WP 10, WP 11, and WP 11.5 valuable information has been transferred to the Iquitos and Tigre River area fish farmers.

In the Amazon Department (Colombia) a new aquaculture association (Acuiamazonas) was integrated during a visit by one of our Peruvian extensionists (Carlos Chavez). Acuiamazonas has more than 50 members, who live along the Leticia-Tarapacá Road. Additionally, several indigenous groups also inhabit this road and they have demonstrated interest in aquaculture related activities as part of a food security program. In Brazil, a project under the direction of Prof. Marle Villacorta (Universidad Federal Do Amazonas) with the financial support of the Brazilian government titled: "Family fish culture and food processing in the Sateré-Mawé indigenous communities along the Marau and Urupadi Rivers" is underway. The main objective is to implement ethnodevelopment activities of the Sateré-Mawé indigenous communities (32 communities with 4,160 inhabitants) to guarantee food security. The Sateré-Mawé indigenous community inhabits the area between the Amazonas and Pará States (middle region of the Amazon River). Fishing is the main source of animal protein for the Sateré-Mawé, but the Marau River is overfished and aquaculture is seen as a means to ensure food security for the rural poor.

Quantified Anticipated Benefits

The development of sustainable aquaculture will benefit many sectors throughout the Amazon region. Rural farmers and indigenous communities will benefit from the addition of an alternative form of agriculture. Aquaculture production requires considerably less land than that needed for cattle ranching. Moreover, ponds can be used year-after-year whereas rain forest lands converted to traditional agricultural practices are rarely productive for more than a couple of seasons. Such lands, once abandoned, usually can no longer support normal jungle growth. Both rural and urban poor will benefit by the addition of a steady supply of high quality protein in the marketplace. Aquaculture of *Colossoma* and *Piaractus* should relieve some of the fishing pressure on these overharvested, native species. The two frugivorous fishes have been suggested to play a crucial ecological role in disseminating seeds from the flooded forest (Goulding 1980; Araujo-Lima and Gouling 1997; Chu, dissertation in progress). Accordingly, the aquaculture of *Colossoma* and *Piaractus* may be ecologically as well as economically and nutritionally beneficial to the inhabitants of the Amazon region. Host country consumers and fish farmers, researchers, extensionists and planners, local and foreign Latin-American governmental organizations and/or NGOs and users of global CRSP- sponsored models and data will benefit from this activity. Development of a Latin American network of Amazonian species producers and researchers has begun to catalyze regional efforts to fortify the growing industry and to explore new aquaculture candidates to diversify production in this highly productive and species-rich region. Specifically, we will quantify the following:

1. Number of fish farmers receiving extension services.
2. Number of training participants (extension agents, students and experts from Amazon region).
3. Number of hits at Amazonian aquaculture web page.

Activity Plan

1. *Location of work*

This work will be conducted and/or directly impact Colombia, Ecuador, and Peru.

2. *Methods*

Objective 1: Provide extension services to the local community to promote sustainable aquaculture in the Amazon region. We will continue to reinforce extension activities with the local farmers that were previously served (WP11.5) in the Cahuide and 12 de Octubre communities, both located in Itaya river (Peru), Leticia (Colombia) and El Puyo and Macas (Ecuador). This will continue facilitating the expansion coverage to other countries of the vast Amazonian region (see list of collaborators above). Farmers will be provided with knowledge gleaned from the CRSP sponsored studies with *Colossoma* and *Piaractus* conducted in Workplans 8, 9, 10, 11 and 11.5 and with new cultured species (*Prochilodus nigricans, Arapaima gigas*, *Brycon nigricans*, Churo and Congonpe). Accordingly, we will:

1. Provide workshops to existing and prospective fish farmers, to students from local high schools and to technical (vocational) schools in Colombia, Ecuador and Peru. Specifically, we will update the Spanish-language production manual for *Colossoma* and *Piaractus* compiled by the WP 10 and WP 11 to accompany the reproduction manual completed in Workplan 9. These companion manuals will be used in workshops to be conducted in Leticia (Colombia), El Puyo (Ecuador) and Iquitos (Peru) for teaching prospective farmers the basics for pond culture. The workshops will also include orientation on the business aspects of aquaculture.
2. Provide aquaculture advisement via site visits to local farmers. We will continue to make bi-monthly site visits to fish farms in the Cahuide and 12 de Octubre communities, both located in

Itaya river (Peru), and Leticia (Colombia) and initiate extension activities in El Puyo and Macas (Ecuador). Farms will be visited on a rotational basis so that every farm is visited at least once each quarter. Farmers will be provided with information on fish husbandry and pond maintenance, as well as with any new developments learned through our research activities. Standard water quality parameters (temperature, dissolved oxygen, pH, total ammonia nitrogen, and nitrite) will be measured at representative farms throughout the region whenever required (i.e. massive fish mortalities, etc.)

3. Evaluate the extension service through a questionnaire pilot tested and administered by the extensionists themselves to all clientele receiving extension services to assess quality of extension provided and to obtain suggestions on how to improve the program.

Objective 2: Maintain and expand the specialized website on Amazonian aquaculture and species to provide for information exchange and networking. A web site (http://fisheries.siu.edu/amazonia/index.html) on Amazonian aquaculture and species will be maintained and expanded to allow for information exchange and networking. The web site will contain information on all CRSP-sponsored research and outreach activities in the Amazon region. It will also provide links to other agency activities in the region such as USAID, World Wildlife Fund, etc. An 'AquaForum' will allow for discussions on Amazonian aquaculture and species by interested participants. The web site will contain a specialized bibliography on publications on research and outreach activities related to Amazonian aquaculture and species. An up-to-date list of announcements concerning related workshops and meetings will be maintained on the site. A list-serve will be established and maintained for the purpose of relaying relevant information on Amazonian aquaculture and species. The number of hits to the site will be enumerated to determine the site's exposure.

Regional and Global Integration

An objective of the Regional Plan is to maintain and expand outreach and networking activities in the Amazon region. This proposal expands on this objective by training more personnel in neighboring countries as well as enhanced training in Colombia, Peru and Ecuador. The proposal begins to build the network of mentors by certifying additional "Master Aquaculturists." It extends knowledge through on-farm trials and demonstration research. Lastly, the website on Amazonian aquaculture will facilitate networking both within and outside of the region.

Schedule

All activities will take place from 1 October 2006 through 30 June 2007. The final report will be submitted by June 30, 2007.

Literature Cited

Araujo-Lima, C. and M. Goulding. 1997. So Fruitful a Fish: Ecology, Conservation, and Aquaculture of the Amazon's Tambaqui. Columbia University Press, New York. 191pp.

Goulding, M. 1980. The Fishes and the Forest. University of California Press. London. 78 pp.

Molnar, J. Alcántara, F. and Tello Salvador. 1999. Identifying Goals and Priorities of Fish. Farmers in the Peruvian Amazon. *Workplan 8, Socioeconomic Study3 (8ADR1-3). Final Report.* Department of Agricultural

Economics and Rural Sociology International Center for Aquaculture and Aquatic Environments. Auburn University. Auburn, USA. Instituto de Investigaciones de la Amazonía Peruana. Iquitos. Perú. 12 pp.

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

Sustainable Development and Food Security (12SDF8) / Activity / Mexico

Collaborating Institutions

University of Arizona, USA
Kevin Fitzsimmons
Universidad Juárez Autónoma de Tabasco (UJAT), Mexico
Wilfrido M. Contreras Sánchez, Ulises Hernández-Vidal

Objectives

The exchange program builds the initial foundation to further build upon the following components:

- Appropriate aquaculture models and technology
- Appropriate Indigenous economic and community development pathways
- Aquaculture's role and contribution to biodiversity, sustainability, food security and community wellness
- Aquaculture and the environment and Indigenous traditional ecological knowledge
- Aquaculture information transfer and network building between the North and the South
- Organization of aquaculture
- Indigenous aquaculture and the non-indigenous world
- Aquaculture in the context of aquatic resources management
- Planning for aquaculture development
- Expanding educational and training opportunities

Significance

All Indigenous Peoples and cultures communicate with the water world. Water life has supported Indigenous Peoples for all time. Many Indigenous People recognize the turtle, whale or salmon as their crest, totem, or clan. Fish, shellfish and other aquatic life remain an integral part of Indigenous Peoples life-way and culture.

Today the water life is threatened. There are many reasons, including industrial development, urban expansion, agriculture, and colonial western forms of governmental laws and regulations. Aquaculture, the controlled cultivation of aquatic organisms, offers promise for expanding upon Indigenous Peoples' health and sustainability of the water world. Properly developed, aquaculture enhances core cultural objectives such as biodiversity, sustainability, food security and community wellness.

While Indigenous People have practiced aquaculture for thousands of years, the modern science of aquaculture is relatively recent. In North America there are about 50 active aquaculture projects being undertaken by Indigenous Peoples, primarily as projects through tribal governmental initiatives. These projects are primarily economic development oriented (providing jobs) with some traditional cultural values incorporated into aquatic rearing practices. The potential for further integration of the controlled cultivation of aquatic organisms (aquaculture) into Indigenous culture can directly address biodiversity, sustainability, food security and community wellness. Further exploration of these issues has not been pursued to any great degree in the North as well as the South. Indigenous aquaculturists work in relative isolation from each other and other non-Indigenous aquaculture-oriented organizations.

The Indian Nations component of Heifer Project International (HPI) and the Indigenous Environmental Network proposes development of a collaborative relationship with Oregon State University (OSU). This collaborative work is intended to serve as a future link to other Indigenous and non-Indigenous organizations that work with aquaculture. It is with the intent that this collaboration creates an opportunity for Indigenous individuals representing tribal governmental projects, universities, organizations and community-based groups, to participate in an exchange training program in regards to aquaculture. Because this exchange takes place in the western hemisphere between the north and south this exchange would be called an "Exchange between the Eagle of the North and the Condor of the South." It is with hope that this training reinforces Indigenous Knowledge and the cosmovision of Indigenous Peoples.

Anticipated Benefits:

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

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

Criteria

The Indian Nations component of Heifer Project International (HPI) and the Indigenous Environmental Network proposed that approximately 15 participants from the Northern hemisphere travel to meet and exchange information with Southern Indigenous aquaculturists from Peru and Mexico. Seven "eagles" participated in the Peru portion and eleven will participate in the Mexico portion. We expect eight to ten "condors" from Mexico or Central America to participate at Villahermosa. These participants will be selected by a committee of Indigenous Peoples, including Lacandones, Tzotziles, and Tsetsales and include the following minimum qualifications:

- Active work, career goals in aquatic resources management/aquaculture
- Active work, career goals in health, nutrition, community development related to fisheries/aquaculture
- Active work, career goals in Indigenous planning/development with understanding of project management

Activity Plan

Site: The project will take place in Villahermosa, Tabasco, Mexico, as well as include visits to surrounding aquaculture facilities including those in the Lacondon National Reserve, in the Chontal communities in Nacajuca and Camellones.

Methods: The exchange activity will primarily involve informal and formal discussions as well as touring of aquaculture facilities in order to facilitate further exchange of ideas.

Regional and Global Integration

An objective of the Regional Plan is to maintain and expand outreach and networking activities in the Mexican/Central American region. This activity expands on this objective by linking indigenous peoples from North and Central America.

Schedule

(Tentative Agenda) March 7 – March 14, 2007

March 7

Travel and arrival of participants

March 8

Visit to the Biological Sciences Division Facilities
Visit to the Laboratory of Aquaculture facilities
Presentation of the Dynamics of the workshops (Objectives, Goals, Methods)
Presentation of the indigenous groups of Tabasco
Seminars
Discussion

March 9

Visit to the Chontal communities in Nacajuca, Tabasco
Visit of the Camellones Chontales area
Visit of aquaculture facilities in the area
Exchange of experiences
Discussion

March 10

Visit to the Pantanos de Centla aquaculture projects
Simon Sarlat

Exchange of experiences
Discussion
March 11
Visit to the Ejido Rio Playa and Zapotal projects
Exchange of experiences
What have we learned
March 12
How to prepare projects for indigenous aquaculture development workshop
Where to get funding
Exchange of experiences
How can we help each other
What have we learned from this workshop?
Discussion
March 13
Departure

Reports
The final technical report will be submitted by 30 June 2007.
A final annual report will be submitted by 30 June 2007.

Sixth International Aquaculture Training Course in the Amazon Region

Sustainable Development and Food Security (12SDF9) / Activity / Venezuela, Brazil

Collaborating Institutions

Southern Illinois University at Carbondale, USA
Christopher C. Kohler, Susan T. Kohler, William Camargo
Instituto Nacional De Investigaciones Agricolas (INIA) Amazonas, Venezuela
Karen Graterol, Otto Enrique Castillo González
Instituto Nacional de Pesquisas da Amazônia (INPA), Brazil
Manoel Pereira Filho
Universidad Federal do Amazônia (UFAM), Brazil
Marle Angélica Villacorta Correa, Bruno Sagratzki

Objective

- Train participants on the use of technological tools, facilitate the exchange of strategies, experiences, learned lessons on rural aquaculture extension for the management and reproduction of native Amazon species.

Significance

Fish culture has been practiced for over three decades in the Peruvian Amazon and for over fifty years in Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, and Venezuela (the Amazon region). The countries comprising the Amazon region are linked by major river systems, particularly the drainages comprising the Amazon and Orinoco Rivers. The largest diversity of freshwater fishes in the world is contained within these drainages.

A 6th International Aquaculture Extension Course in the Amazon Region and the 2nd Meeting for The Amazon Region Aquaculturists is one of the CRSP Workplan 12 Amazon Basin Aquaculture Research and Outreach (11.5SDF1) activities that Southern Illinois University proposes in collaboration with Universidad de la Amazonia Peruana (UNAP, Peru), La Universidad Nacional de Colombia (UNAL, Colombia), Peace Corps Ecuador, USAID Ecuador, Arcoiris (Ecuadorian NGO), Instituto Nacional De Investigaciones Agricolas (INIA-Amazonas), Venezuela, Universidade Federale Do Amazonas (UFAM-Brazil), Instituto Nacional de Pesquisas da Amazónia (INPA-Brazil), Instituto de Investigaciones de la Amazonia Peruana (IIAP, Peru) and Universidad Mayor de San Simón (Cochabamba, Bolivia). This Project has been carried out since 1 July 2004 through 31 August 2006 with the funding provided by Aquaculture CRSP/USAID.

The 5th International Aquaculture Extension Course in the Amazon Region and the 1st Meeting for The Amazon Region Aquaculturists are part of a series of events that have been successfully organized in the Amazon region by a group of institutions since 2002, with the following schedule:

I Curso internacional de acuicultura para productores y extensionistas en la Amazonía. Iquitos (Perú). 25-30 April, 2002. Sponsors/Organizers: CRSP (USAID), IIAP, UNAP y Gobierno Regional. Participating countries: Brazil, Colombia, Ecuador and Peru (19 participants).

II Curso internacional de acuicultura para extensionistas de la Amazonía. Iquitos (Peru). 25-30 August, 2002. Sponsors/Organizers: CRSP (USAID), IIAP, UNAP y Gobierno Regional. Participating countries: Bolivia, Brazil, Colombia, Ecuador and Peru (23 participants).

III Curso internacional de acuicultura para extensionistas de la Amazonía. Pucallpa (Perú). 18 to 21 August 2003. Sponsors/Organizers: CRSP (USAID), IIAP, UNAP, Gobierno Regional, Marina de Guerra Participating countries: Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela (63 participants).

I Curso Internacional de Nutrición de Peces Tropicales. Pucallpa (Perú). 22 August 2003. Sponsors/Organizers: CRSP (USAID), IIAP, UNAP, Gobierno Regional, University of Arkansas-Pine Bluff. Participating countries: Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela (63 participants).

IV Curso internacional de acuicultura con especies promisorias de la Amazonía – Professional, large-scale producers and students. Leticia (Colombia) / Benjamín Constant (Brasil) 21 to 24 July 2004. Sponsors/Organizers: CRSP (USAID), UNAL, Alcaldía y Gobernación, Sinchi, Acuarios Leticia, INPA, Incoder, Acuiamazonas, IDAM. Participating countries: Brazil,

Colombia, Ecuador, Peru and Venezuela (57 participants).

IV Curso internacional de acuicultura con especies promisorias de la Amazonía – Small-scale producers, NGO's and indigenous communities. Leticia (Colombia), 22 to 24 July 2004. Sponsors/Organizers: CRSP (USAID), UNAL, Alcaldía y Gobernación, Sinchi, Acuarios Leticia, INPA, Incoder, Acuiamazonas, IDAM. Participating countries: Brazil and Colombia (20 participants).

I Curso internacional de Cultivo de Peces Ornamentales. Leticia (Colombia), 25 to 27 July 2004. Sponsors/Organizers: CRSP (USAID), UNAL, Alcaldía y Gobernación, Sinchi, Acuarios Leticia, INPA, Incoder, Acuiamazonas, IDAM. Participating countries: Brasil and Colombia (18 participants).

V Curso internacional de acuicultura con especies promisorias de la Amazonía – Small-scale producers, NGO's and indigenous communities. Macas, Ecuador, 11-15 April 2006. Sponsors/Organizers: SIUC, CRSP-USAID, Fundación Arcoiris, USAID Ecuador, CARE, PSUR, Plan Binacional, Instituto Tecnológico Salesiano de Sevilla Don Bosco, Global Water for Sustainability (GLOWS) Program, Municipio de Huamboya, Peace Corps Ecuador, COMAGA,FUNDACYT, OPIP, Consejos Provinciales de Morona Santiago, Sucumbios y Napo, Alcaldía de Macas, Gobernación, Museo Ecuatoriano de Ciencias Naturales (MECN), Fundación Universitaria San Martín, Organizaciones de Productores Rurales y Asociaciones/Colegios Profesionales. Participating countries: Colombia, Ecuador, Peru, and United States (65 participants).

V Curso internacional de acuicultura con especies promisorias de la Amazonía – Professional, large-scale producers and students, and I Encuentro de Acuacultores de la Región Amazónica. Macas, Ecuador, 11-15 April 2006. Sponsors/Organizers: SIUC, CRSP-USAID, Fundación Arcoiris, USAID Ecuador, CARE, PSUR, Plan Binacional, Instituto Tecnológico Salesiano de Sevilla Don Bosco, Global Water for Sustainability (GLOWS) Program, Municipio de Huamboya, Peace Corps Ecuador, COMAGA, FUNDACYT, OPIP, Consejos Provinciales de Morona Santiago, Sucumbios y Napo, Alcaldía de Macas, Gobernación, Museo Ecuatoriano de Ciencias Naturales (MECN), Fundación Universitaria San Martín, Organizaciones de Productores Rurales y Asociaciones/Colegios Profesionales. Participating countries: Bolivia, Brazil, Colombia, Ecuador, Peru, United States and Venezuela (59 participants). Southern Illinois University Carbondale (USA) will be the international coordinating institution for both proposed events and the Instituto Nacional de Investigaciones Agricolas (INIA) Amazonas - Venezuela, Universidad Federal do Amazônia (UFAM) – Brazil, and Instituto Nacional de Pesquisas da Amazônia (INPA) - Brazil, will be the three national coordinating institutions.

Quantified Anticipated Benefits

The development of sustainable aquaculture will benefit many sectors throughout the Amazon region. Rural farmers will benefit from the addition of an alternative form of agriculture. Aquaculture production requires considerably less land than that needed for cattle ranching. Moreover, ponds can be used year-after-year whereas rain forest lands converted to traditional agricultural practices are rarely productive for more than a couple of seasons. Such lands, once abandoned, usually can no longer support normal jungle growth. Both rural and urban poor will benefit by the addition of a steady supply of high quality protein in the marketplace.
Aquaculture of *Colossoma*, *Piaractus,* and *Arapaima* should relieve some of the fishing pressure on these overharvested, native species. The two former genera have been suggested to play a crucial ecological role in disseminating seeds from the flooded forest (Goulding 1980; Araujo-Lima and Gouling 1997). Accordingly, the aquaculture of *Colossoma* and *Piaractus* may be ecologically as well as economically and nutritionally beneficial to the inhabitants of the Peruvian Amazon. Host country consumers and fish farmers, researchers, extensionists and planners, local and foreign Latin-American governmental organizations and/or NGOs and users of global CRSP- sponsored models and data will benefit from this activity. Development of a Latin American network of Amazonian species producers and researchers has begun to catalyze regional efforts to fortify the growing industry and to explore new aquaculture candidates to diversify production in this highly productive and species-rich region. Specifically, we will quantify the following:

- Number of training participants (extension agents, students and experts from the Amazon region).

Activity Plan

1. ***Location of work***

The 6th International Aquaculture Extension Course in the Amazon Region and 2nd Meeting for The Amazon Region Aquaculturists will be tentatively held in Manaus (Balbina), Brazil, from 21-25 May,

2007.

2. *Methods*

Objective 1: Train participants on the use of technological tools, facilitate the exchange of strategies, experiences, learned lessons on rural aquaculture extension for the management and reproduction of native Amazon species.

Two intensive training courses (one for small-scale producers/NGO personnel / indigenous communities and another for large-scale producers/professionals/students) for a large group (~100 participants) of governmental and non-governmental personnel conducting aquaculture research and/or extension activities in the Amazon Basin will be offered in Brazil. This training plan will continue with the very successful program that has so far trained over 300 extensionists from Bolivia, Brazil, Colombia, Ecuador and Peru. The courses will be conducted by the Southern Illinois University Carbondale Project Coordinator, our extensionists, instructors/ researchers from Instituto Nacional de Pesquisas da Amazônia (INPA, Brazil), instructors/ researchers Universidad Federal do Amazônia (UFAM, Brazil), instructors/researchers from Universidad Nacional de Colombia (UNAL, Colombia), and other instructors from other HC institutions such as local government agencies and NGO's. For each course, fifteen qualified candidates from Amazon countries will be invited to participate. The courses will be offered to train aquaculturists, students and experts in aquaculture related degrees in extension techniques. Techniques which have been practiced successfully by IIAP and Terra Nuova, including CRSP's new experiences in the region through WP 11.5. Extension personnel will also learn pond construction, broodstock selection and handling, spawning techniques, incubation, larviculture, grow out, disease prevention and treatment, all specifically related to native cultured species of *Colossoma sp.*, *Piaractus sp.*, *Arapaima sp.*, *Prochilodus sp.* and *Brycon sp.* (fish), and Congompe and Churo (mollusks) to teach hormone injection, spawning, fertilization, incubation and larviculture techniques. A CD-ROM displaying all the course material for the Amazon aquaculture-training course will also be produced.

Regional and Global Integration

An objective of the Regional Plan is to maintain and expand outreach and networking activities in the Amazon region. This proposal expands on this objective by training more personnel in the Amazon region.

Schedule

Workshop planning/preparation: November 2006-March 2007. The workshop 6 has tentatively being programmed for 21-25 May 2007. The final report will be submitted by June 30, 2007.

Literature Cited

Araujo-Lima, C. and M. Goulding. 1997. So Fruitful a Fish: Ecology, Conservation, and Aquaculture of the Amazon's Tambaqui. Columbia University Press, New York. 191pp.

Goulding, M. 1980. The Fishes and the Forest. University of California Press. London. 78 pp.

Egg Hatching Quality of Amazonian Fishes

Indigenous Species Development (12ISD5) / Study / Columbia

Collaborating Institutions

Southern Illinois University at Carbondale--Lead US Institution
Christopher C. Kohler, Susan T. Kohler, William Camargo
Universidad Nacional de Colombia (UNAL), Columbia
Miguel Angel Landines, Santiago Dúque, Cesar Bonilla
Instituto de Investigaciones de la Amazonía SINCHI, Leticia, Columbia
Juan Carlos Alonso

Objective

- Improve egg hatching quality and larval survival by manipulating water quality for gamitana (*Colossoma macropomum*) and/or paco (*Piaractus brachypomus*).

Significance

Considering fish are a major part of the diet of Amazon communities (Brazil and Peru; Eckmann 1983), aquaculture will serve to maintain their consumption without overfishing natural populations and, in effect, promote the utilization and conservation of wild stocks in the Amazon rainforest. Studies on propagation of gamitana and paco (frugivorous fishes) are important because the commercial fisheries over-exploits them; thus, the populations are severely affected as gamitana and paco are commanding increasingly high prices. There is also increasing pressure in the conversion of the flood plains to rice paddies and cattle pastures (Achard et al., 2002), and viable aquaculture may prevent this disturbing trend.

The Quaternary history of the Amazon lowlands is characterized by deposition of sediments of Andean origin and by the influences of changing sea levels (Irion et. 1995). Amazon fish have evolved in an environment characterized by the low hardness and alkalinity waters of the basin, which are a consequence of its geologic constitution (Sioli, 1957). $Ca2+$ and $Mg2+$ are important for ionic regulation of freshwater fish because both ions influence the permeability of biological membranes, preventing diffusive flow and high ionic loss to water (Alderdice, 1988; Eddy et. al., 1990; Bijvelds et. al., 1998). Hardness has been reported to affect fish egg hatchability and larvae survival in fresh water in teleosts fish (Tucker and Steeby, 1993; Hwang et. al., 1996; Molokwu and Okpokwasili, 2002; Townsend et. al., 2003; Silva et al., 2003); however, no data are available regarding the effect of this parameter, and more specifically $Ca2+$ and $Mg2+$ ions, on hatchability of Amazon fish eggs and subsequent survival. Previous studies on other tropical fish eggs (silver catfish) have demonstrated that increasing water hardness to 70 mg/L $CaCO3$, using either $Ca2+$ or $Mg2+$ improved hatch rate (Silva et al., 2003).

Quantified Anticipated Benefits

The proposed study aims to investigate key aspects of the reproductive biology of gamitana and/or paco, through our collaborative effort with Colombian investigators in order to improve or develop sustainable aquaculture technology for these species. The main beneficiaries of this research will be the fish producers in the Amazon region.

Development of the technology of intensive growth of these species and stocking 4 to 6 week-old fingerlings will dramatically increase their survival and efficiency of production. More importantly, this study will also contribute towards institutional strengthening by providing training on various aspects of fish reproduction for staff of the Universidad Nacional de Colombia (Instituto de Investigaciones IMANI) and Instituto Amazónico de Investigaciones Científicas-SINCHI (Programa de Ecosistemas Acuáticos, Colombia), as well as serving as a thesis project for a student.

Research Design

1. Location of work

Experiments will be conducted in La Terraza Aquaculture Research Facility of the Universidad Nacional de Colombia (Meta, Colombia), as part of the thesis work on a Colombian student under the supervision of Universidad Nacional de Colombia and SINCHI. Universidad Nacional de Colombia and SINCHI are non-profit research institutions that are charged to alleviate the socio-economic conditions of the Amazonian farmers by conducting research on sustainable development and protection of natural resources.

2. Methods

This study will be carried out Colombia in La Terraza Aquaculture Research Facility of the Universidad Nacional de Colombia, (Meta, Colombia). Gamitana and/or paco broodstock will be maintained under standard culture conditions (pH near 7, temperature between 25 to 28±1 ºC, alkalinity near 50 mg/L-measured as CaCO3, and hardness near 100 mg/L). Fish will be induced to spawn by hormonal injections (Woynarovich, 1986). To evaluate Mg2+ and Ca2+ as egg hatching success factors, oocyte masses from each female broodstock will be divided by weight into four equal parts and placed in four containers. Milt from a single male will be added to each container for fertilization. Five hundred ml of water maintained at the same temperature as that of the broodstock from each treatment will be added to each container to hydrate the eggs for 10 min. Dead or unfertilized eggs will be removed by separating them manually in Petri dishes and viable fertilized eggs will be separated by observation of the initial cell division on a stereoscope and placed randomly in the 2 L cylindroconical aerated hatching jars (four hardness with three replicates per treatment: 30, 60, 90 and 120, with different Mg2+ and Ca2+ proportions: 0:100, 50:50, 80:20 and 100:0, obtained by the addition of a stock solution previously prepared with analytical grade CaCl2 and/or MgCl2 to the standard hatchery water) connected to a temperature controlled system (maintained at 26±1 ºC). After hatching, larvae will be maintained in the incubators for 48 h to calculate the post-hatch survival (PHS). Eggs from each treatment will be evaluated to determine egg consistency (soft vs. hard), percentage eyed embryos (13 h after fertilization), hatching rate (HR), PHS and larval length; all of these parameters will be considered as a final indicator of eggs and larval quality. The HR and the PHS will be calculated by the method of Geertz Hansen and Rasmussen (1994): HR = (number of incubated eggs - number of dead eggs) x 100 (number of incubated eggs) PHS = (number of incubated eggs - number dead eggs - dead larvae) x 100 (number of incubated eggs). New water will be replenished (100%) daily in each hatching jar, maintaining the original ion proportion for the respective treatment. Mg2+ and Ca2+ ions in each treatment will be analyzed by flame atomic absorption spectrophotometer to maintain the Mg2+ and Ca2+ content for each treatment. Temperature, pH, CO2, conductivity and alkalinity will be monitored daily in the hatching jars, while ammonia, nitrite and nitrate will be monitored three times (7:00, 12:00 and 17:00) daily.

3. Statistical Analysis

Analyses will be performed using the Statistical Package for the Social Sciences Version 10.1 (SPSS 10.1). The correlation between Ca2 + and Mg2 + water levels and hatching rate and post-hatch survival will be calculated. Data on egg consistency, HR and PHS will be subjected to one-way analysis of variance (ANOVA) followed by a comparison of means using chi square test (Steel and Torrie 1980). The mean total lengths of larvae will be compared by one-way analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) to test for significant differences in larval development among various water hardnesses. Normality and homogeneity of variance tests will be performed on raw data. All differences will be regarded as significant at $P < 0.05$.

Regional Integration

Colossoma spp., and *Piaractus spp.* are economically important in several countries in South America, especially in Colombia, Brazil, Peru, Argentina, Bolivia and Guyana. Studies refining the artificial propagation of these fishes will improve the profitability of aquaculture operations of fish farmers and consequently economic conditions of rural communities in these countries. In addition, readily available techniques of farming these fishes will reduce the pressure of catching fish from the wild. Results from these studies will be published as fact sheets and distributed to key academic and research institutions in the region to promote interests among researchers in working with these fishes.

Schedule

November-December 2006: Selection and preparation of broodstock.
January-February 2007: Induction to spawn for gamitana and/or paco. Evaluation of gamitana and/or paco egg hatching performance.
March-May 2007: statistical analysis and preparation of manuscripts.
June 2007: Final report.

Literature Cited

Achard, F., Eva, H.D., Stibig, H.-J., Mayaux, P., Gallego, J., Richards, T., and Malingreau, J.-P. 2002. Determination of deforestation rates of the World's Humid Tropical Forests. Science 297:999-1002.

Alderdice, D.F. 1988. Osmotic and ionic regulation in teleost eggs and larvae. In: Hoar, W.S., Randall, D.J. (Eds.), Fish Physiology: V. XI-Part A. Eggs and Larvae. Academic, San Diego, pp. 163-165

Bijvelds, M.J.C., Van Der Velden, J.A., Kolar, Z., and Flik, G. 1998. Magnesium transport in freshwater teleosts. Journal of Experimental Biology 201: 1981– 1990.

Eckmann, V.R. 1983. The fisheries situation in the Peruvian Amazon Region. Arch. Hydrobiol. 97: 509-539.

Eddy, F.B., Ward, M.R., Talbot, C.P. and Primmett, D. 1990. Ionic movement across the chorion in newly shed salmon eggs (*Salmo salar* L.). Journal of Comparative Physiology 159: 771– 776.
Geertz Hansen, P. and Rasmussen, G. 1994. Influence of ochre and acidification on the survival and hatching of brown trout eggs (*Salmo trutta*). In: Müller, R., Lloyd, R. (Eds.), Chronic Effects of Pollutants on Freshwater Fish. FAO-Fishing New Books, Cambridge. 317 pp.
Hwang, P.P., Tung, Y.C. and Chang, M.H., 1996. Effect of environmental calcium levels on calcium uptake in tilapia larvae (*Oreochromis mossambicus*). Fish Physiology and Biochemistry 15 (5): 363– 370.
Irion, G., Müller, J., Nunes de Mello, J. and Junk, W.J. 1995. Quaternary geology of the Amazonian Lowland. February 25, 2005. Geo-Marine Letters 15(2-4):172-178.
Molokwu, C.N. and Okpokwasili, G.C. 2002. Effect of water hardness on egg hatchability and larval viability of *Clarias gariepinus*. Aquaculture International 10(1): 57–64.
Silva, L.V.F., Golombieski, J.I., and Baldisserotto, B.. 2003. Incubation of silver catfish, *Rhamdia quelen* (Pimelodidae), eggs at different calcium and magnesium concentrations. Aquaculture 228: 279–287
Sioli, H. 1957. Sedimentation im Amazonasgebiet: Geologische Rundschau 45: 608–633.
Steel, R.G.D. and Torrie, J.H. 1980. Principles and Procedures of Statistics. McGraw-Hill Book Company, New York.
Townsend, C.R. and Silva, L.V.F., Baldisserotto, B. 2003. Growth and survival of *Rhamdia quelen* (Siluriformes, Pimelodidae) larvae exposed to different water hardness levels. Aquaculture 215: 103–108.
Tucker, C.S. and Steeby, J.A. 1993. A practical calcium hardness criterion for channel catfish hatchery water supplies. Journal of the World Aquaculture Society 24 (3): 396– 401.
Woynarovich, E. 1986. Tambaqui e pirapitinga, propagação artificial e criação de alevinos. Companhia de Desenvolvimento do Vale de São Francisco, Publicação 2/86, Brasilia, Brasil, 68 p.

Influence of Dietary Fatty Acid Composition on Reproductive Performance of *Colossoma macropomum*

Reproduction, Native Species (12ISD6) / Study / Peru

Collaborating Institutions
Southern Illinois University Carbondale, USA
Christopher C. Kohler, Susan T. Kohler, Jesse T. Trushenski, William Camargo
Instituto de Investigaciones de Amazonia (IIAP), Peru
Fred Chu-Koo and Luis Campos-Baca

Objectives

- Quantify the effect(s) of dietary highly unsaturated fatty acid (HUFA) content on fecundity of female *C. macropomum*; egg lipid content and fatty acid (FA) composition; as well as egg fertilization and hatching rates.
- Compare results of objective 1 with gametes from broodstock reared in Iquitos, Peru.
- Quantify the effect(s) of dietary HUFA content on semen volume and spermatozoan density; as well as spermatozoan motility, lipid content, and FA composition.
- Assess 10-day survival of resultant larvae under normal culture conditions and after temporary heat stress.

Significance

Success of commercial aquaculture is dependent on numerous factors, but perhaps the greatest limitation to industry growth and diversification is availability of viable fry and fingerlings. Although year-round, bulk availability of ongrowing livestock has been achieved in some established sectors, such as the U.S. catfish industry, limited volume and/or temporal availability remain problematic for many species. Methods to optimize broodfish performance and ensure robust offspring must be developed to overcome bottlenecks in fingerling production. As a tolerant, fastgrowing, highly-sought food fish species, *Colossoma macropomum* is an excellent candidate for aquaculture and is raised commercially in Latin America. However, complications in propagation of *C. macropomum* and restricted availability of progeny impede expansion of this emerging aquaculture industry.

Nutrition is widely-recognized as a determining factor in reproductive health and performance of vertebrates. Poor nutrition, either generally or with respect to certain critical dietary components, can impair reproductive output or result in complete loss of reproductive competence. Dietary lipid source, or more specifically, the fatty acid (FA) composition of the diet, has been shown to dramatically impact gamete production and offspring viability.

Reproductive performance of broodfish is enhanced by dietary long-chain highly unsaturated fatty acids (HUFA), particularly arachidonic (20:4n-6, ARA), eicosapetaenoic (20:5n-3, EPA), and docosahexaenoic (22:6n-3, DHA) acids (Watanabe et al. 1984; Watanabe et al. 1985; Mourente and Odriozola 1990; Fernández-Palacios et al. 1995; Bell et al. 1997; Fernández-Palacios et al. 1997; Navas et al. 1997; Almansa et al. 1999; Bruce et al. 1999; Mazorra et al. 2003; Lane and Kohler 2006). Moreover, survival and vigor of offspring have been improved through maternal transfer of long-chain HUFA to developing fry (Fernández-Palacios et al. 1995; Lane and Kohler 2006).

Although the relationship between dietary FA composition and reproductive success is relatively well-established, the influence of dietary lipid source on *C. macropomum* reproduction has not been addressed. Adult *C. macropomum* have been described as predominantly frugivorous, and, accordingly, most prepared feeds used in *C. macropomum* culture have relatively low nutrient density (14-35% crude protein, 3-10% crude lipid) and are largely comprised of carbohydrate-rich, plant-derived feedstuffs (Araujo-Lima and Goulding 1997). However, zooplankton consistently represents a substantial portion of the natural adult diet (Campos-Baca and Kohler 2006) and may represent as much as 95% of the diet during the dry season when fruits and seeds are unavailable (Oliveira et al. 2006). Fruits and seeds of terrestrial plants do not contain long-chain HUFA, and thus zooplankton consumed during the dry season serve as the primary source of intact HUFA for *C. macropomum*. Zooplanktivory associated with the dry season coincides with the period of gonadal maturation in the wild (da Silva et al. 2000), suggesting nutrients of animal origin support reproduction of *C. macropomum*. Given the fundamental relationship of HUFA and reproductive competence of vertebrates and the temporal link between HUFA consumption and spawning in the wild, it is reasonable to assume dietary HUFA content is functionally related to reproductive performance of *C. macropomum*. Supplementing broodstock diets for *C. macropomum* with long-chain HUFA may enhance production of quality gametes

and survivability of resultant fry, however, the effect(s) of dietary FA profile on reproduction of this species has not been quantitatively assessed. Accordingly, our objectives are to quantify the reproductive performance and gamete quality of *C. macropomum* broodfish fed diets containing different levels of HUFA, and to assess the viability and stress tolerance of the resultant progeny. Comparison will be made in gamete fatty acid compositions between broodstock raised in the USA and Peru.

Quantified Anticipated Benefits

We expect dietary HUFA content to modulate reproductive performance of *C. macropomum*. If inclusion of marine-derived lipid enhances performance of broodfish and progeny, inclusion of these high HUFA-content products may increase productivity of *C. macropomum* hatcheries. If increased HUFA content does not improve performance, producers and feed manufacturers will have more information to facilitate least-cost diet formulation for these fish.

Research Design or Activity Plan

1. Location of work: Fisheries and Illinois Aquaculture Center (FIAC)

FIAC has over 15,000 square feet of floor space in the Life Science II and Life Science III buildings located on the campus of Southern Illinois University Carbondale. Of Dr. Kohler's laboratories, the proximate analyses laboratory is fully equipped for the project to perform all of the necessary methods to estimate crude protein, crude fat, moisture, crude fiber, and ash of feeds. His biochemistry laboratory is fully equipped with modern instrumentation with analytical software to perform all of the lipid and fatty acid assays for the project, which include a Shimadzu gas chromatograph (GC-FID) and Shimadzu highpressure liquid chromatograph (HPLC), an Iatroscan (TLC-FID), and developing chambers for HPTLC plates. The biochemistry laboratory also houses analytical balances, spectrophotometers, a freeze dryer, and a -80°C freezer.

An 8,300 square-foot, temperature-controlled wet laboratory building houses more than thirty 2000-L tanks, fifteen 1200-L tanks, eighteen 1200-L raceways as well as approximately 100 flow-through aquaria varying in size.

At least 15 recirculating systems are employed allowing for numerous studies to be conducted simultaneously. Most of the aforementioned recirculating systems are equipped to manipulate temperature and photoperiod. One recirculating systems was designed especially as a hatchery, consisting of over 10 hatching jars, 4 hatching trays, and twelve 350-L tanks. In addition, this wet laboratory building houses feed storage and feed manufacturing rooms, a water chemistry laboratory, a large workshop, and a small toxicology laboratory.

In Peru, .*C. macropomum* broodstock will be raised in three ponds at the IIAP Quistococha Aquaculture Station and fed the standard diet (Table 1).

Table 1. Composition (%) of diets for Colossomid broodstock in Peru.A

Ingredient 30% ProteinB
Fish meal 20.0
Soybean meal 30.0
Wheat husks 28.0
Corn flour 16.0
Vitamin/Mineral premix 1.95
Vitamin C 0.05
Palm Oil 4.0

A The calculated energy to protein ratios of the diet is 10.7 kcal/gram dietary protein, respectively, based on digestible energy values for channel catfish.
B Total dietary protein levels calculated using analyzed protein content of the individual ingredients.

2. Methods

Two iso-caloric, iso-nitrogenous (45% crude protein, 12% crude lipid, dry matter basis) practical diets will be formulated, differing only in primary lipid source and HUFA content. One diet will be formulated as a high-HUFA content diet and will contain menhaden fish oil (FO) as the primary lipid source, whereas the other will be formulated as a low-HUFA content diet and will contain canola oil (FO). Both diets will be produced as floating, extruded feeds by a commercial aquafeed manufacturer, and stored refrigerated prior to use. Crude dietary composition will be confirmed according to standardized methods for animal feeds (AOAC 1995). Diet samples will be prepared for FA analysis according to the methods of Folch et al. (1957) and Christie (1982), and analyzed according to standard gas chromatography procedures used in our laboratory.

Mixed-sex groups of adult *C. macropomum* will be stocked in 10, 1900- L tanks within a recirculation system. Each diet will be assigned to 5 tanks each, individual tanks serving as experimental

units. For 9-12 months prior to spawning, fish will be fed assigned feeds to apparent satiation. Broodstock at the IIAP field station will be fed their standard diets (Campos-Baca and Kohler 2006; Table 1). Induction of gonadal maturation and collection of gametes, facilitated by use of exogenous hormone preparations, will be conducted as described by Campos-Baca and Kohler (2006). Both groups will be spawned in spring or early summer, 2007.

Individuals in the USA and Peru will be weighed and manually stripped of their gametes. After recording total gamete mass/volume, subsamples will be collected, flash-frozen in liquid nitrogen, and stored (-80°C) for subsequent lipid and fatty acid analyses according to procedures described for diet samples. Peruvian samples will be packed in dry ice and shipped to the USA for fatty acid analysis. Additional subsamples of semen in the USA will be collected, extended, and held on ice for subsequent determination of spermatocrit (percent cellular fraction of packed volume) and motility (total motile time post-activation, assessed microscopically). Each clutch of eggs will be divided equally into two groups (USA studies only), and fertilized using extended semen from the FO or CO dietary treatments to produce all four sex/dietary treatment crosses. Fertilized eggs will be incubated at 27-28ºC in MacDonald jars until hatch and reared in separate tanks by group in a separate recirculation system. At hatch, subsamples of larvae will be collected for FA analysis and to determine average total length (mm). Four hours postfertilization, 1.0 mL sub-samples will be removed from each MacDonald jar, counted, and observed microscopically to calculate fecundity (eggs/kg female) and percentage of non-fertilized eggs. Replicate groups of ten viable embryos collected from these subsamples will be transfer to 250 mL beakers and monitored to calculate hatchability and survival to 5 days post-hatch (DPH). At 5 DPH, one half of replicates will be challenged with heat stress (exposure to 30ºC water, total duration to be determined). After the heat stress challenge, survival of control and stressed larvae will be assessed daily until 10 DPH.

3. Statistical Analyses

All data on will be subjected to analysis of variance (ANOVA) using the General Linear Model of the Statistical Analysis System, version 9.1 (SAS Institute, Cary, North Carolina, USA) Differences will considered significant at $p < 0.05$.

Regional Integration

C. macropomum is economically important food fish in several countries in South American, especially in Colombia, Brazil, Peru, Argentina, Bolivia, and Guyana. Increasing broodfish performance and availability fry and fingerlings will improve the profitability of aquaculture operations of fish farmers and, consequently, economic conditions of rural communities in these countries. In addition, expansion of *C. macropomum* culture will reduce harvest pressure on wild populations of this species. Results from these studies will be published as fact sheets and distributed to key academic and research institutions in the region to promote interest among researchers in working with *C. macropomum.*

Schedule

November 2006: Stocking of broodfish.
November 2006-April 2007: Feeding trial.
May 2007: Data collection and analyses.
June 2007: Preparation of manuscripts, fact sheets, and final report.

Literature Cited

Almansa, E., M.J. Pérez, J.R. Cejas, P. Badía, J.E. Villamandos, and A. Lorenzo. 1999. Influence of broodstock gilthead seabream (*Sparus aurata* L.) dietary fatty acids on egg quality and egg fatty acid composition throughout the spawning season. Aquaculture 170:323-336.

AOAC (Association of Official Analytical Chemists). 1995. Official methods of analysis, 15th edition. Association of Official Analytical Chemists, Washington, D.C.

Araujo-Lima, C., and M. Goulding. 1997. So fruitful a fish: ecology, conservation, and aquaculture of the Amazon's tambaqui. Columbia University Press, New York, New York.

Bell, J.G., B.M. Farndale, M.P. Bruce, J.M. Navas, and M. Carillo. 1997. Effects of broodstock dietary lipid on fatty acid compositions of eggs from sea bass *(Dicentrarchus labrax*). Aquaculture 149:107-119.

Bruce, M., F. Oyen, G. Bell, J.F. Asturiano, B. Farndale, M. Carrillo, S. Zanuy, J. Ramos, N. Bromage. 1999. Development of broodstock diets for the European sea bass (*Dicentrarchus labrax*) with special emphasis on the importance of n-3 and n-6 highly unsaturated fatty acid to reproductive performance. Aquaculture 177:85-97.

Campos-Baca, L., and C.C. Kohler. 2006. Aquaculture of *Colossoma macropomum* and related species in Latin America. Pages 541-561 *in* A.M. Kelly and J. Silverstein, editors. Aquaculture in the 21st Century. American Fisheries Society, Bethesda, Maryland.

Christie, W.W. 1982. The preparation of derivatives of lipids. Pages 51-61 *in* W. W. Christie, editor. Lipid Analysis 2nd Edition. Pergamon Press, Oxford, United Kingdom.

da Silva, J.A.M., M. Pereira-Filho, and M.I. de Oliveira-Pereira. 2000. Seasonal variation of nutrient and energy in tambaqui's (*Colossoma macropomum* Cuvier, 1818) natural food. Reviews in Brasilian Biology 60(4):599-605.

Fernández-Palacios, H., M.S. Izquierdo, L. Robaina, A. Valencia, M. Salhi, and J. Vergara. 1995. Effect of n-3 HUFA level in broodstock diets on egg quality of gilthead seabream (*Sparus aurata* L.). Aquaculture 132:325-337.

Fernández-Palacios, H., M.S. Izquierdo, L. Robaina, A. Valencia, M. Salhi, and D. Montero. 1997. The effect of dietary protein and lipid from squid and fish meals on egg quality of broodstock for gilthead seabream (*Sparus aurata*). Aquaculture 148:233:246.

Folch, J., M. Lees, and G.H. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry 276:497-507.

Lane, R.L., and C.C. Kohler. 2006. Effects of dietary lipid and fatty acids on reproductive performance, egg hatchability, and overall quality of progeny of white bass *Morone chrysops*. North American Journal of Aquaculture 68:141-150.

Mazorra, C., M. Bruce, J.G. Bell, A. Davie, E. Alorend, N. Jordan, J. Rees, N. Papanikos, M. Porter, N. Bromage. 2003. Dietary lipid enhancement of broodstock reproductive performance and egg and larval quality in Atlantic halibut (*Hippoglossus hippoglossus*). Aquaculture 227:21-33.

Mourente, G., and J.M. Odriozola. 1990. Effect of broodstock diets on lipid classes and their fatty acid composition in eggs of gilthead sea bream (*Sparus aurata* L.). Fish Physiology and Biochemistry 8:93-101.

Navas, J.M., M. Bruce, M. Thrush, B.M. Farndale, M. Bromage, S. Zanuy, M. Carrillo, J.G. Bell, and J. Ramos. 1997. The impact of seasonal alteration in the lipid composition of broodstock diets on egg quality in the European sea bass. Journal of Fish Biology 51:760-773.

Oliveira, A.C.B., L.A. Martinelli, M.Z. Moreira, M.G.M. Soares, and J.E.P. Cyrino. 2006. Seasonality of energy sources of *Colossoma macropomum* in a floodplain lake in the Amazon—lake Camaleão, Amazonas, Brazil. Fisheries Management and Ecology 13:135-142.

Watanabe, T., T. Takeuchi, M. Saito, and K. Nishimura. 1984. Effect of low protein-high calory or essential fatty acid deficiency diet of reproduction of rainbow trout. Nippon Suissan Gakkaishi 50:1207-1215.

Watanabe, T., T. Koizumi, and H. Suzuki. 1985. Improvement of quality of red sea bream eggs by feeding broodstock on a diet containing cuttlefish meal or raw krill shortly before spawning. Nippon Suisan Gakkaishi 51:1511-1521.

Pelagic (Fish) and Benthic Ecology of Selected Sub-Watersheds of the Nzoia River Basin

Water Quality and Availability (12WQA7) / Activity / Kenya

Collaborating Institutions

University of Georgia, USA
E. W. Tollner, Herbert Ssegane (Graduate Student)
Michigan State University, USA
Geoff Habron, Fisheries/Rural Sociology
Heather Patt (former graduate student)
Moi University, Kenya
Mucai Muchiri, Department of Fisheries & Aquatic Science
Odipo Osano, School of Environmental Studies
Geoffrey Karanja, Department of Wildlife Management
Frank Masese (Graduate Student)
Rodrick Kundu (Graduate Student)
Egerton University
William Shivoga, Department of Environmental Studies

Objectives

Research objective: To enable students at Moi University and at the University of Georgia to complete their degree under the mentorship of CRSP Researchers. The following work is on-going in that an additional subwatershed is being assessed:

1. Complete the assessment of aquatic ecological health of selected representative sub-watersheds on an additional subwatershed by
    - analysing biotic habitat characteristics
    - establishing fish and macroinvertebrate population characteristics
    - analyzing ecotoxicological characteristics of representative biota.
2. Relate land use to habitat and biotic assemblages characteristics based on data being collected and continuing analysis of field data that is in hand. The preliminary analyses is completed. We propose to apply some control theory and new ecological thermodynamic approaches to analyzing these data.
3. Complete the sampling expeditions in an additional subwatershed (Kapolet).

Outreach objective: To accelerate the delivery of research results to key leaders in the form of an outreach workshop and to develop key exhibit materials by which Moi and Egerton personnel could demonstrate the value of riparian barriers to local and national officials.

Significance

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

Protocols for monitoring biophysical characteristics of the landscape conditions at sampling sites will be developed throughout the watershed in order to capture the spatial distribution of landscape conditions as a function of biophysical and anthropogenic activities. These protocols will identify key indicator species, which must be identified for each physiographic region. UGA students are currently working on a GIS model for the Nzoia basin. Jensen and Bourgeron (2001) and IoEA (1995) have provided excellent guidelines for baseline determination and subsequent survey approaches. They discuss methods for prioritization of resources and time to achieve results appropriate to local and regional scales. Ludwig and Reynolds (1988) discuss techniques such as canonical correlation that are useful for exploring connections between ecological indicators and environmental variables that can be tailored to watershed assessment objectives. The work to date has confirmed and extended the excellent

in-country resources (e.g., http://www.iaia.org/Members/Publications/Guidelines_Principles; and http://www.kws.org/kwstidiploma.htm).

Both rural and urban land uses within watersheds invariably have effects on biodiversity. This includes terrestrial and aquatic biota. Habitats are altered leading to variation in biotic population structures. In streams the effects come in the form of variation in water quantity and quality. Land uses generate both organic and inorganic pollutants that alter the physicochemical quality of the water. Such altered water characteristics in turn influence changes in biological communities. Pollutants entering a river system at identifiable points are often evaluated using physical and chemical measurement techniques. However, in certain situations, particularly in rural agricultural areas, pollutant sources are more diffuse and thus lending it difficult to make direct measurements. Fish and macroinvertebrate communities are good indicators of ecosystems quality as the kinds and abundances of animals will vary according to a wide variety of physical habitat differences such as habitat size, temperature, stream flow or water depth, and pollution.

Objective 1 is nearly completed for the Moiben subwatershed, except for fish sampling, which proved to require additional equipment requested in the extension. The extension will enable assessment of an additional subwatershed, likely the Kapolet. Work to date suggests that the midge is an excellent genus for identifying the ecological health of a stream because it in effect develops an integrated response to the pollution load via key morphological changes as exposure to chemical pollution increases. This work is currently being prepared for publication.

As a component of the social analyses, the dataset assembled relating to social assessment will be further analyzed using canonical correlation and related statistical techniques used in participatory rural assessments (PRAs). Jacob Ng'etich, the assistant to Heather Patt (MSU graduate student) while Heather was in country, is now enrolling in Moi as an MS student. This well-trained assistant will also collect additional social science indicator data.

Anticipated Benefits

It is anticipated that by using ecological characterization techniques, appropriate species for assessment will be identified and results will be used to develop a rapid assessment model that can be used to rapidly indicate the ecological health of the selected sub-watersheds and by extension the whole of the Nzoia River basin. We will build on the finding that the Midge is a significant indicator. The GIS model will be left at the GIS lab of Moi University for continued development.

Research Design

The Nzoia basin contains a variety of geomorphic formations, ranging from pristine fast moving streams, wetlands, reservoirs and discharge into Lake Victoria. Selected stations will be characterized for selected indicator species of river health. At least one existing industry (sugar processor or paper mill), an upland wetland and reservoir will be assessed for species composition and diversity. These will be coordinated with water quantity/quality sampling expeditions. As with the hydrology and water quality objective, emphasis will be directed toward developing the capacity of Moi University in the course of accomplishing these goals. The initial goals will be developed with close cooperation and with coordination of goals from nearby watersheds such as the Njoro that are currently being studied. Over the life of this project, initial ecological characterization of these potentially sensitive areas is the expected outcome.

Proposed methodology: The Nzoia basin fish and macroinvertebrate biodiversity surveys is based at Moi University. For the most part, choice of sampling points will be determined by perceived impacts of the various land uses. In forested areas sampling stations will be influenced by accessibility on motorable roads. However, every effort will be made to access as many habitat types as possible even on foot where safety from wildlife permits. On reservoirs and the mouth of Lake Victoria a rubber dingy will be used to access the open water.

Fish

Sampling of fish will rely on several collection gear. Seine nets will be used in clear shallow banks, gill nets will be used in lagoons and other open water habitats while electric fishing apparatus will be used in habitats that netting would be difficult. A fry seine, a dip net and traps will also be used where appropriate.

Handling of fish after capture will be aimed at:

1. identifying, photographing, fixing and preserving representative specimens of all the species present in all the water bodies in the sampling areas.
2. describing population structures and basic biology and ecology of the species present. The fish collection was hampered by the lack of effective equipment for capturing the

fish. A sampler has been identified and is being shipped. Funding is included in the Moi budget for an improved fish sampler.

Participants in the fish surveys

To achieve the desired results, the following institutions will be involved in the survey.

- Moi University (MU-FISH) (Dr. Muchiri) will co-ordinate the fish ecology exercises.
- The Department of Fisheries, Ministry of Agriculture (FD-GoK).

The original plan was to sample inside the Mt. Elgon Wildlife preserve, involving the Kenyan Wildlife Service. However, due to some logistics considerations, this sampling zone will be located just outside the park, and will represent the pristine condition.

Macroinvertebrates

Macroinvertebrate collection in the river and its tributary streams will employ a Surber Sampler and D-frame net Sampler in different habitat types pre-identified along the selected parts of Nzoia River. In Lake Victoria and reservoirs within the basin, an Ekman grab will be used to collect bottom invertebrates. A hand net will also be used to collect invertebrates in vegetated areas.

Samples collected will be preserved to be later identified and counted in the laboratory. This survey is aimed at describing population structures and basic biology and ecology of the species present.

Participants in the macroinvertebrate survey

To achieve the desired results, the following institutions will be involved in the survey.

- Moi University
- Egerton University (Dr. Shivoga) will co-ordinate the macroinvertebrate ecology exercises.

The macroinvertebrate results have been collected by MS students. Results are now in preparation for publication, with preliminary results being submitted as an annual report.

Ecotoxicological studies

Representative samples from the fish and invertebrate surveys will be preserved for ecotoxicological analyses. Laboratory analyses will focus on heavy metals and pesticide accumulation and effects on fish and macroinvertebrates.

These studies will be co-ordinated by Moi University (Dr. Osano). These studies are in progress.

Appropriate statistical designs and analyses will be employed in the ecological studies.

Statistical Design, Null Hypothesis and Statistical Analyses

Fish and macroinvertebrate surveys will be collected using locations along the Nzoia (or tributaries) as reference locations. Key location attributes will be 1) distance from outlet; 2) water quality attributes; 3) key hydrologic descriptors and 4) season. The null hypothesis is that no differences in selected species exist across location. ANOVA techniques (Hintze, 2004) and paired t tests will be used as appropriate.

Based on the previous work on conservation practices, gender and livelihood insecurity, there remains a need to get the research findings to those that can benefit from the results through project implementation. The dissertation research requires distillation and reorganization to meet the needs of government and non-governmental organization extension staff and project-related staff and students at Moi University. We need to investigate the kinds of products and processes that would yield the most beneficial outcomes in terms of fostering improved natural resource conditions that fit within the social context and issues identified in the project. Michigan State University researchers frequently produce new materials based on academic research in order to fit different non-academic audiences, especially those within the organizations and agencies that hold the ability to affect change in natural resource settings. Possible deliverables include interactive website, fact sheets, posters, compact discs, maps and interactive workshop design materials and processes. The appropriateness of any deliverable requires close collaboration with the project team collaborators in Kenya.

Attempts are underway to analyze selected ecological and social datasets using some newly developed thermodynamics approaches (Tollner and Kazanci, 2007) and control theory approaches (Mathworks, 2006) for describing the effective time constants related to selected population dynamics. Emphasis is being directed in the extension to the Kapolet subwatershed.

Regional Integration

The project is targeting the development of a watershed and basin assessment center at Moi University by building a physical science and social science interdisciplinary center to complement such centers at Egerton and Nairobi universities. The centerpiece of the Moi center is a GIS laboratory, which is

now complete. This project is inherently integrative as it initiates and increases cooperation among diverse interests with the common thread of maintaining the health of a common benefit, the community river. The concept is replicable in other parts of Kenya as well as other developing countries. Close working collaboration will be maintained with the Sustainable Management of Watershed – CRSP (SUMAWA) project that studying the River Njoro watershed. This will be managed by continued involvement of Dr. William Shivoga in this activity. Dr. Shivoga is closely involved with the SUMAWA project and is providing liason. The concept is replicable in other parts of Kenya as well as other tropical regions.

Schedule

Due to logistical difficulties, field survey activity lagged the original schedule; however, they are now well underway. Additional field surveys are expected to take place between March and May 2007. Fish sampling will be carried out once every month for nine months. This will cover both the short and long rains periods. Each field sampling expedition will last four days.

Details of the outreach event are contained in Appendix 1. The event will include a demonstration of the benefits of riparian vegetation on soil retention.

Periodic reports of progress will be made in the course of the ecological surveys. Final data analyses and reporting (Oct. 06 – June 07).

Literature Cited

Hintze, J. 2004. NCSS and PASS. Number Cruncher Statistical Systems, Kaysville, UT.

IoEA. 1995. Guidelines for baseline ecological assessment. Institute of Environmental Assessment, Chapman and Hall, New York, NY.

Jensen, M.E. and P.S. Bourgeron (Eds.). 2001. A guidebook for integrated ecological assessments. Springer, New York, NY.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology. Wiley Interscience, New York, NY.

Tollner, E.W. and C. Kazanci. 2007. Discrete simulation approaches for analyzing ecological thermodynamics. Submitted to Ecological Modeling.

Mathworks, 2006. MatLab and Control Systems Toolboxes. Natick, MA.

Appendix I. Description of the concluding Outreach event. Date to be determined but late spring 07.

Agenda	Subjects covered	Needs Addressed	Goals	Audience	Expected impacts	
Day 1 AM	GIS Lab	Show MOI Univ and Gvt personnel the lab	Demonstrate the feasibility of assessing other watersheds	GVT, Moi Univ, Edgerton Univ	Interest in additional assessments	
Day 1 PM	Review of research	Present the MOI assessment	Demonstrate the potential seriousness of municipal contributions	GVT, Moi Univ, Edgerton Univ	Interest in additional assessments	
Day 2 AM	Field Demo	Show sampling techniques, soil transport demo, and conduct riparian demo	Field demonstration of how the data gathering occurs.	Same as above plus local officials and interested public	The benefits of watershed assessment and how that assessment need not be regarded as a threat	
Note: Efforts will be made to achieve gender diversity in all aspects of the workshop.						

Hydrologic Modeling in the Nzoia River Basin

Water Quality and Availability (12WQA8) / Study / Kenya

Collaborating Institutions

University of Georgia, USA
Ernest W. Tollner, Herbert Ssegane (Graduate Student)
Michigan State University
Geoff Habron
Moi University, Kenya
Mucai Muchiri, Bilha Saina (Graduate Student), Naomi Chebet (Graduate Student)
Kenya Department of Fisheries, Kenya
Betty Nyandat

Objectives

Research objective: To enable students at Moi University and at the University of Georgia to complete their degree requirements under the mentorship of CRSP Researchers. The following work is on-going:

- Evaluate the potential impact of streamside cultivation on water quality parameters
  a) improved riparian cultivation approaches based on computer modeling studies
  b) soil transport in on-the-ground studies. This objective proved not to be feasible due to the short duration of the project and uncertain long-term effects. We opted to instead rely on more extensive remote sensing approaches. The outreach demonstration will include a demonstration of how to launch a long-term soil transport study.
- Continue the water quality profile of the Nzoia
  a) winter (rain) conditions
  b) summer (dry) conditions
- Organize additional data to incorporate it into the GIS database

Outreach objective: To accelerate the delivery of research results to key leaders in the form of an outreach workshop which is to be integrated into the above-mentioned workshop.

- Apply a river model (QWAL2E) to selected stations of the Nzoia to assess natural attenuation possibilities.

Significance

The degradation of the Lake Victoria basin has received international attention (GEF 2004). The 184,400-km^2 basin drains 14 major rivers with an estimated population of 25 million people (Wangila and Swallow 2001). The Kenyan portion of the basin drains 42,000-km^2 with a population of 7.9 million people (Wangila and Swallow 2001). The Nzoia watershed comprises 12,000 km^2 of the Lake Victoria basin (United States Geological Survey 2004). Four main processes drive the degradation of the Lake Victoria basin: 1) loss of 89% of forest cover to poor agricultural practices causing erosion and sedimentation; 2) pollution from mines, urban areas and industry leading to sedimentation in eutrophication; 3) loss of lake fish species diversity due to introduction of the non-native Nile perch; and 4) poor fisheries management practices (Wangila and Swallow 2001). Sedimentation increased fourfold in the last 100 years with some areas demonstrating losses of 200 horizontal feet each year (GEF2004).

Kenya is on the verge of substantial agricultural development (GEF 2004) and urbanization especially in the Nzoia basin (Osano et al. 2003). A search of the literature reveals that virtually every agricultural enterprise from forestry production to container nursery production has specific Best Management Practices (BMPs) for water quality management with nonpoint source inputs. The NRCS has an exhaustive array of BMPs available for agricultural production (NRCS, 2004) nonpoint sources. BMPs have recently been published for urban storm water management (WEF, 1998). Except for specific cases not involving soil tillage (e.g., container nursery in greenhouses), sediment is the most significant pollutant. Sediments are significant in both urban and rural development because a host of chemical constituents adhere to sediment particles. BMPs for urban and rural environments focus primarily on sediment removal and handling. Increased urbanization and increased intensity of agricultural production results in increased magnitude and frequency of runoff events, reduction of base flow and increased stream velocities when flowing (WEF, 1998). These flow changes lead to increased cross sectional areas, significant down cutting (unless stream is already heavily armored), increased sediment loads due to bank erosion, urban construction or intensifying agricultural production, modification of

streambed to include more fine particles and subsequent stream modifications being required to reduce flooding risks.

Increased urbanization and agricultural development affect water quality as well. Urbanization causes an initial pulse of sediment which subsides as the development stabilizes. Increased agricultural production increases pesticide (Osano et al. 2003) and sediment loads which may remain high, depending on the degree of soil tillage. The sediment load and consequent increase in fines cause benthic ecology to become much less diverse. Streams generally shift from an external (leaf matter) to an internal (algal organic matter) food chain. The stream community loses diversity and wetlands, springs and riparian buffers are damaged or lost due to excessive sediment, toxic compounds or both. The effects on receiving bodies (e.g., Lake Victoria in this case) are felt over longer time frames. After visible refuse and damage to aesthetics, nutrient enrichment and the resulting increase in primary productivity is the most visible sign of development. Lakes act as sinks for sediment-laden materials and take longer to recover from contamination than do streams. Heavy metal absorption, sediment deposition patterns near the outlet, increased algae production in the lake (which indicates possible eutrophication that can in turn lead to fish kills), loss of desirable species and increased "trash" fish species are documented to occur with development. These documented trends will be pivotal in prioritizing the work on the Nzoia basin. It is not too late to avoid these effects in the Nzoia basin.

The Nzoia basin is in the initial phases of development. Much cultivation in rural areas is conducted by women of the families on soils at the river edge. Environmental legislation on the books provides 30 m buffers; however the exact point of measurement of the buffers is legally unclear and thus there is effectively not an enforced buffer. A buffer design is needed that will preserve some of the existing benefits of being near the river while achieving water quality goals. Environmental quality within and around the Lake Victoria basin, the location of this projected intervention, is closely linked to land use practices (GEF 2004). Some of the land uses have resulted in serious degradation of ecological integrity and hydrologic processes within the watersheds. This is shown by the loss of biodiversity and habitats as well as altered hydrologic regimes (GEF 2004). Consequently, the trend has resulted in declining livelihoods of the inhabitants. These factors have contributed to overall poverty in the region. With this background, there is a need to develop strategies and mechanisms to stabilize and rehabilitate the watersheds in the region. The proposed project will embark on a multidisciplinary approach to develop and demonstrate improved and integrated sustainable management of watershed resources at a watershed scale. The watershed assessment effort and subsequent demonstration projects will be coordinated with needs of the Kenyan Department of Fisheries in terms of fostering aquacultural enterprises along the river and preserving the Lake Victoria fishery. Overall, the proposed project will complement other efforts in the region in creating sustainable interdisciplinary, broad-based watershed rehabilitation models through technical, social and policy interventions in land use and natural resources management. The fisheries department can provide much helpful reference information to provide an objective standard by which improvements can be measured.

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

A watershed water resources assessment is the basis of determining the possibilities of water resource utilization, control and development. A proper assessment requires the determination of the sources, quantity and quality of water resources which In this study, the initial baseline data to assess the conditions in the watershed will be collected. First an inventory and mapping of the characteristics of the watershed will be undertaken. Next data collection stations will be established at key location for water quantity and quality measurements. The extended remote sensing analyses is showing much promise as a technique for rapidly assessing a small basin such as the Nzoia.

The US NRCS developed the Universal Soil Loss Equation (Wischmeier and Smith, 1978). The USLE predicts soil detachment. Soil delivered to some point below the erosion location may be predicted using a sediment delivery ratio. The US Forest Service (1980) published an approach for evaluating sediment delivery ratios through buffer strips. Coupling the NRCS soil loss equation with the Forest Service delivery ratio estimation approach enables the computer modeling of buffer strip scenarios that can prove efficacious for water quality preservation.

Herbert Ssegane (UGA MS student) has finished the model that couples the NRCS soil loss equation with the Forest Service delivery ratio estimation approach. A GIS based model is currently being constructed that will enable comprehensive modeling of the Nzoia basin as a whole. The comprehensive model was not anticipated but has become feasible with synergistic efforts with another UGA research effort. Additional details on the social analyses aspects applicable to Activity 3/3 are given in the discussion of social analyses under Activity 2/3.

Anticipated Benefits

Perhaps the single most important variable in achieving sustainable watershed management is understanding and underpinning key land use practices that directly or indirectly affect ecological processes and system functioning. The reliance on land for agrarian production in rural Kenya coupled with dependence on land resources for economic livelihood places enormous premium on resources derived from land and as a consequence leads to degradation and hence loss of ecological integrity of the system (GEF 2004; Githaiga et al. 2003; Osano et al. 2003). A sustainable land management strategy requires not only intervention at site specific but also the landscape level. A system approach is needed to disentangle critical landscape components and linkages and will more likely to lead to overall positive impacts on the watershed. The Nzoia watershed system transcends a broad range of land use systems and practices ranging from small-scale holder farmland to large scale mechanized agriculture, and cuts a cross a tenure regime of private ownership to public land – e.g., forest reserves and national parks. The watershed produces 30% of Kenya's maize and sugar (Osano et al. 2003). The watershed occurs in generally high potential and high population region of the country and therefore the influence of land use on the system is extremely important (Osano et al. 2003). Eldoret serves as the largest population center (234,000) followed by Kitale (88,100), Kakamega (86,500), Webuye (45,100), Mumias (36,200) and Bungoma (32,900) (Osano et al. 2003). Although agriculture comprises the major land use, textile, paper, sugar and coffee processing comprise major point source pollutants (Osano et al. 2003).

Given the character of the Nzoia watershed, the emphasis in this initial project will be to focus on BMPs for mitigating agricultural impacts. A desired outcome of this study is to develop a buffer design that will preserve some advantages of cultivation near the river while also providing water quality benefits. The more extensive remote sensing will enable a richer transfer of information from UGA to the Moi GIS laboratory.

Research Design

1) Physical condition classification of watershed

The map reconnaissance will be completed as part of Activity 1. A physical condition checklist (Prichard et al., 1998, 1999) will be completed at some key locations to be coordinated with identified riparian buffer sites (see objective 2).

A thorough literature review will be conducted to gather data from previous hydrological studies and reports. Information on location of existing rainfall, river gauging and water quality measurement stations in the selected watershed will be obtained. Data from existing rainfall and river gauging stations will be obtained from Kenya Meteorological Department and Ministry of Water Resources Management and Development . Topographic maps of the watersheds at scales of 1:50,000 will be purchased at Survey of Kenya. Satellite data from Landsat TM will be acquired to prepare a land use and land cover map of the watershed. Soils and geology data will be obtained form Kenya Soil Surveys Department. All the data collected will be input in a GIS. GIS will be used to perform spatial and temporary data analysis and information extraction and improve the efficiency and quality of the watershed assessment.

Physical condition checklist results will be coordinated with water quantity/quality sampling expeditions. As with the hydrology and water quality objective, emphasis will be directed toward developing the capacity of Moi University in the course of accomplishing these goals. The initial goals will be developed with close cooperation and with coordination of goals from nearby watersheds such as the Njoro that are currently being studied using Participatory Rural Appraisal (PRA) in conjunction with the University of Wyoming, Egerton University, and Moi University. The Western Kenya Integrated Ecosystem project will continue the PRA to address watershed conservation in the Nzoia and two other watersheds (GEF 2004) with the help of a trained assistant of Ms Heather Patt, the Michigan State student who completed the primary PRA analyses. These data would be integrated into the GIS database discussed above.

These protocols will identify key indicator species, which must be identified for each physiographic region. Resources such as Barbour et al., 1999, Jensen and Bourgeron (2001), Sayer et al. (2000) and IoEA (1995) provide excellent guidelines for baseline determination and subsequent survey approaches. They discuss methods for prioritization of resources and time to achieve results appropriate to local and regional scales. Ludwig and Reynolds (1988) discuss techniques such as canonical correlation that are useful for exploring connections between ecological indicators and environmental variables that can be tailored to watershed assessment objectives. Excellent in-country resources exist for ecological assessment (e.g., http://www.iaia.org/Members/Publications/Guidelines_Principles; and http://www.kws.org/kwstidiploma.htm).

The first step in the assessment is to spatially segregate the area into manageable unit areas. The division into such units will be done systematically to define the watershed boundaries, hydrogeological, administrative and water management characteristics. Each unit will represent an area such that it is possible to collect and analyze the required data for purposes of water balance studies. The units should

be able to be aggregated in a hierarchy manner to determine information at watershed, sub-basin, basin or regional level.

The selection of measurement stations for the project extension will be focused toward those needed for providing input information for the water quality modeling work.

2) Evaluate the potential impact of streamside cultivation on water quality parameters

A computerized version of the USLE will be developed and coupled with the Forest Service sediment delivery ratio to predict relative soil loss from buffer configurations. The following buffer scenarios will be modeled:

* Forested buffer 30 m wide
* Grass buffer 30 m wide
* Completely disturbed buffer zone
* Grass buffer with alternating 5 m cultivated strips and grass within 10 m of the river
* Grass buffer with alternating 5 m cultivated strips and forest within 10 m of the river
* Forest buffer with alternating 5 m cultivated strips and forest within 10 m of the river

These practices are being evaluated with the remote sensing techniques completed in the original project. This objective was modified due to the short duration of the project and uncertain long-term effects. We opted to instead rely on more extensive remote sensing approaches. The outreach demonstration will include a demonstration of how to launch a long term soil transport study.

3) Water quality profile of the Nzoia

Stations along the Nzoia will be equipped with staff gauges and surveyed cross sections for water quantity measurements. Sites will be coordinated with the sites of objective 2. Selected water quality measurements (such as N, P, BOD, turbidity) will also be taken (Githaiga et al. 2003) in winter and summer conditions in order to gauge the general water quality in a range of rainfall conditions. These data would be collected as part of Activity 1.

For water quality, groundwater quality may change relatively slowly while surface water quality changes much more rapidly. Moreover the quality of water discharge from point sources may change quickly and similarly water quality can change with time depending on the parameter being measured. In this study the quality parameter to be observed are N,P,BOD and turbidity. Groundwater and water from springs will be monitored on monthly basis while surface water will be monitored on weekly or bi-monthly basis. The project extension will enable modeling of water quality, as dicussed above.

The data collection, storage, analysis and presentation methodologies of the above mentioned monitoring scheme will follow already developed methodologies (eg UNSECO 1988). It is assumed that the methodologies are adequate and can be implemented easily at the sub-watershed level.

4) Organize data to incorporate it into the GIS database

This will be completed under 12E1A8.

5) Statistical Design, Null Hypothesis and Statistical Analyses

The sediment delivery model will be evaluated via sensitivity analyses by setting envelopes for rainfall, soil type, slope lengths, slopes, prevailing cropping practices and prevailing conservation practices to arrive at a distribution of expected soil loadings via the universal soil loss equation to which the buffer designs would be subjected. A worst case and best case of each parameter would be determined and modeled, requiring 25 or 64 erosion loadings. Each of the 64 erosion loadings would be evaluated with the 6 buffer designs. This would be repeated for each of the three regions of the Nzoia.

The null hypothesis, stated in a positive sense here, is that one or more of the designs will provide a reduction in soil loading equivalent to generally accepted soil loss tolerances for a field size typically found in the respective region. In other words, the goal is to use the buffer to enable soil conservation expected for good agricultural practices in the region.

The data will be analyzed following regression approaches and ANOVA approaches. Regression relations will be established for buffer strip widths with the forest and grass conditions. Soil losses from the 64 soil erosion runs will be grouped into three equal sized groups and mean soil loadings for the groups determined. This will be done by test region. These will form the basis for a randomized complete block ANOVA assessing buffer attributes. The emphasis of the analyses will be on relative benefits of the buffer.

Regional Integration

This project is inherently integrative as it initiates and increases cooperation among diverse interests with the common thread of maintaining the health of a common benefit, the community river. The concept is replicable in other parts of Kenya as well as other developing countries. We will

collaborate with other participatory watershed efforts such as those facilitated by the Kenya Agricultural Research Institute (KARI) through the Global Environmental Facility (GEF) and The World Bank, The International Centre for Research in Agroforestry (ICRAF), the Ministry of Agriculture and Rural Development (MoARD), and Egerton University (Wangila and Swallow 2001), as well as the Lake Victoria Improved Land Management Program. The Soil and Water Conservation Branch of the Ministry of Agriculture has implemented Participatory Rural Appraisal (PRA) in several watersheds in an ongoing basis (Thompson 1995). Colleagues at Michigan State University also co-direct the Land Use Change Impacts and Dynamics (LUCID) project in Kenya and Uganda in conjunction with the International Livestock Research Institute in Nairobi and the University of Nairobi. The LUCID project also addresses socioeconomic drivers of land use, gender dynamics, erosion and water quality.

Students from Africa will be involved in the effort, including

Herbert Ssegane	Graduate Student	University of Georgia
Bilha Saina	Graduate Student	Moi University
Naomi Chebet	Graduate Student	Moi University

Schedule

RESEARCH ACTIVITY PLANS Activity 3 (Study)	Responsible Person(s)	Personnel	Timeline
Erosion workshop and assessment workshop	Tollner	Team	May 2007
Computer modeling	Tollner	Graduate student	March-June 2007
Monitoring of gauging stations	Tollner	Karanja, 1 graduate student	July 2005-Jan 2007
Organize data	Muchiri	Kenyan Team	Feb 2007

Literature Cited

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, 2nd Ed. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, DC.

Global Environmental Facility(GEF). 2004. Western Kenya Integrated Ecosystem. Project Executive Summary. http://www.gefweb.org/Documents/Council_Documents/GEF_C23/MFA_-_Kenya_-_Executive_Summary.pdf

Githaiga, J.M., R. Reid, A. Muchiru, S. van Dijk. 2003. Survey of Water Quality Changes with Land Use Type, in the Loitokitok Area, Kajiado District, Kenya. Land Use Change Impacts and Dynamics (LUCID) Working Paper Series Number 35. Nairobi, Kenya: International Livestock Research Institute.

ILACOBC. 1981. Agricultural compendium for rural development in the tropics and subtropics. International Land Development Consultants, Arnhem, The Netherlands, Elsevier Scientific Publishing Co., Amsterdam, Netherlands.

IoEA. 1995. Guidelines for baseline ecological assessment. Institute of Environmental Assessment, Chapman and Hall, New York, NY.

Jensen, M.E. and P.S. Bourgeron (Eds.). 2001. A guidebook for integrated ecological assessments. Springer, New York, NY.

Lal, R. 1994. Soil Erosion research methods, 2nd ed. St. Lucie Press, Delray Beach, FL.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology. Wiley Interscience, New York, NY.

NRCS. 2004. National Conservation Practice Standards. Available at http://www.nrcs.usda.gov/technical/Standards/index.html. National Resource Conservation Service, United States Department of Agriculture, Washington, DC.

Osano, O., D. Nzyuko, M. Tole and W. Admiraal. 2003. The Fate of Chloroacetanilide Herbicides and Their Degradation Products in the Nzoia Basin, Kenya. Ambio 32:424-427.

Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell and J. Staats. 1998. Riparian area management: A user guide to assessing proper functioning condition and the supporting science for lotic areas. TR 1737-15, US Dept. of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO.

Prichard, D., F. Berg, W. Hangenbuck, R. Krapf, R. Leinard, S. Leonard, M. Manning, C. Noble, and J. Staats.1999. Riparian area management: A user guide to assessing proper functioning condition and the supporting science for lentic areas. TR 1737-16, US Dept. of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO.

Sayre, R., E. Roca, G. Sedaghatkish, B. Young, S. Keel, R. Roca and S. Sheppard. 2000. Nature in focus: Rapid ecological assessment. Island Press, Washington, DC.

Thompson, J. 1995. Participatory approaches in government bureaucracies: facilitating the process of institutional change. World Development 23: 1521-1554.

Tollner, E.W. 2002. Introduction to Natural Resources Engineering, Iowa State Univ. Press, Ames, IO.

Wangila, J. and B. Swallow. 2001. Design principles for land and watershed management in Western Kenya, Proceedings of a workshop held on 9th April 2001, Kisumu, Kenya. Natural Resource Problems, Priorities and Policies Programme Discussion Paper 2001-1. International Centre for Research in Agroforestry (ICRAF).

WEF. 1998. Urban runoff quality management. WEF Manual of Practice No. 23. (ASCE Manual and report on engineering practice No. 87). Water Environment Federation, Alexandria, VA.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. USDA Handbook 537. United States Dept. of Agriculture, Washington, DC.

Workshops for the cultivation of new species in Brazil and Peru

Fish Nutrition and Feed Technology (12ATE16) / Activity / Brazil, Mexico, Peru

Collaborating Institutions

Ohio State University, USA
Konrad Dabrowski and Marta Jaroszewska
Sao Paulo State University, Brazil
Maria Celia Portella
Universidad Nacional Agraria de la Selva, Peru
Manuel Sandoval
Universidad Juárez Autónoma de Tabasco, Mexico
Wilfrido M. Contreras Sánchez and Arlette Hernandez Franyutti

Objectives

- Accelerate the delivery of research results to people, in the form of outreach and extension modules (workshop in Maringa, Parana State, Brazil, and in Tingo Maria, Peru, in May 2007) .
- Continue long-term training of graduate students and carry out workshops on reproduction and nutrition of tropical fishes, and a new challenging aquaculture species in tropical Amazon region, piraruku (paiche) and arowana (*Arapaima* and *Osteoglossum*).

Outreach Activities

Brazil: The goal of the first workshop is to accelerate the delivery of research results to researchers, students, farmers and extension personnel in the form of outreach and extension modules. This workshop will be organized in Maringa, Parana State, Brazil, in May 2007. As part of this initiative, a graduate student Rodrigo Takata will spend 4-6 months at Ohio State University. Specifically, this will allow him to become a major contributor to the workshop. This long-term training of graduate students and getting them involved in the workshop will make information transfer far more informal.

A scientific collaboration between Konrad Dabrowski (OSU) and Maria Celia Portella (UNESP) was started to develop the project entitled "Mass production of juveniles of subtropical fish (*Piaractus* and *Pseudoplatystoma* sp.) with natural and artificial diets in different production systems". Funding was provided by The National Council for Scientific and Technological Development– CNPq, Brazil, a foundation linked to the Ministry of Science and Technology, to support Brazilian research. The Aquaculture CRSP (USAID) through the project "Broodstock development and larval feeding of Amazonian fishes", also supported part of this research. Based on experiences in 2006 when a workshop was organized in Jaboticabal on August 12, on "Larviculture of Neotropical Fish", we would expect more than 100 participants to attend. Graduate students, fish producers, extension personnel and researchers, from several states of Brazil, including researches from Amazonas, Minas Gerais, Rio de Janeiro, Paraná, Mato Grosso do Sul, Goiás, São Paulo and Brasília participated. The workshop planned in 2007 will be a part of larger event, AquaCiencia 2008 in Maringa, and even more participants may be expected.

In the program an overview of the state-of-art of the larval rearing techniques of paku and surubim and new results related to nutrition and feeding of these species will be presented. In the sequence, we anticipate Rosângela Kiyoko Jomori, who recently graduated with her PhD at CAUNESP, to present the results of the performance and economic evaluation of paku juveniles production. Rodrigo Takata, a MSc student at CAUNESP, will present recent advances in the use of live food for spotted surubim (*P. fasciatum)* and the potential of the rearing of several neotropical fish species in low salinity (2 – 4 ‰) water. Dr. M. Tesser from University of Baha will present research on live food replacement with formulated diets in larval/juvenile intensive rearing condition.

Peru: The purpose of this workshop is to explore applications of CRSP research to a new challenging aquaculture species in tropical Amazon region, piraruku (paiche) and arowana (*Arapaima* and *Osteoglossum*). Dr. Manuel Sandoval has several years of experience working with paiche in Iquitos and Tingo Maria, Peru and would be the ideal leader to hold and coordinate the workshop.

Paiche (Spanish) or pirarucu (in Portuguese), is the largest freshwater fish in the world (measuring up to 10 ft. long and weighing up to 200 kg) and has been listed in the *2000 IUCN Red List of*

Threatened Species since 1996 (Hilton-Taylor 2000). It is naturally found only in the Amazon and Essequibo River basins surrounding Peru, Guyana and Brazil. In the last 30 years, illegal fishing and poaching have drastically reduced the populations of *Arapaima* in their local habitats. Studies on artificial propagation of this fish are important to alleviate the condition of poverty-stricken rural areas by providing food and a source of income for the Amazon people (Gram et al. 2001). Being a top-of-the food web species, maintaining paiche populations in the wild will also contribute toward ecological balance in the Amazon rainforest.

In 2001, the first batch of paiche matured in IIAP Pucallpa and Iquitos, Peru and observations on spawning behavior (nesting), duration and frequency of breeding, fecundity were made (R. Mariano and F. Alcantara, IIAP-Pucallpa and Iquitos, personal comm.). Part of the progenies were removed after a few days (as early as 6-7 days old) from parental care and raised in captivity (hatchery tanks). Development of larval feeds for raising *Arapaima* in captivity will resolve the problem of providing natural food for these fishes and developing domesticated stock that relies on formulated diets. Interestingly, information on natural spawning in ponds was made available in Brazil during the same year (Imbiriba 2001).

The workshop will facilitate transfer of information on paiche reproduction and nutrition in a manner similar to the gathering in 2003 (Alcantara and Montreuil, 2003), however, new aspects and trends in nutrition research, as well as reproduction physiology will be considered when applicable to resolve shortcomings in culture of this species. Specifically, experiences with diet formulations for juveniles of surubim and pacu, rainbow trout and yellow perch (Dabrowski and Portella, 2005), in order to address nutrient requirements in paiche, will be discussed. One of the options to be discussed during the workshop will be to initiate research using arowana as a surrogate species for paiche, and by these means to avoid a controversy of studies carried out with CITES protected species.

ACRSP Support for Development of Aquaculture Economics

Economic Risk Assessment and Social Analysis (12ATE17) / Activity / Vietnam

Collaborating Institutions

Agricultural and Resource Economics Dept., Oregon State University, USA
Richard Johnston and Ann Shriver
Nha Trang University, Vietnam
Kim Anh Nguyen
St. Mary's University, Canada
Tony Charles

Objectives

a. To strengthen and develop the application of economic analysis to global aquaculture problems and issues surrounding farm management, aquaculture sector development, and marketing, by enabling and facilitating peer scientific exchange

b. To strengthen the development and coverage of aquaculture topics at the IIFET Conference in Nha Trang, Vietnam

c. To support participation by developing country scientists who lack the resources to travel to the conference, enabling mutual benefit from peer interaction on research and extension methods

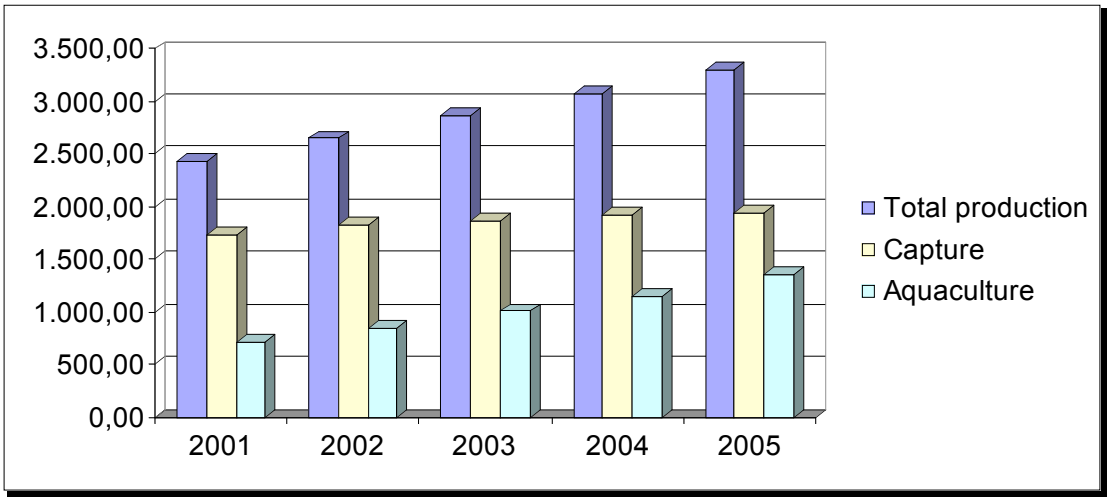
d. To develop networks to support these scientists, and others interested in aquaculture economics and related social science applications, in the future

Significance

The Importance of Aquaculture: The UN Food and Agriculture Organization's recently released "State of World Aquaculture 2006" report indicates that 43% of fish consumed today is produced by aquaculture—up from just 9% in 1980. This statistic provides evidence of significant changes in the structure of the world's consumable fish supply—the analysis of which IIFET conference participants have been involved in for some time. These changes will affect both subsistence and commercial economic activity in many countries throughout the world, especially in those with significant fish consumption and production activities. These are sometimes among the world's most poverty stricken societies, where the balance between wise management of natural resources and society's economic and social needs for food production is at its most delicate and debates take on an extraordinary significance in terms of social welfare.

IIFET's Role: IIFET is the world's only global organization of fisheries and aquaculture economists. In existence since 1982, the organization has held thirteen biennial international conferences, gathering academic researchers and trainers, government resource managers, and industry practitioners in a single global forum. Individuals from over 65 countries, covering all of the world's major fishing and aquaculture regions, have presented research and exchanged ideas, information, and potential solutions to fisheries management, seafood trade, and aquaculture issues and problems. IIFET Conferences provide opportunities for participants from all over the world, and from varied professional orientations, to gather current information on how issues are being tackled in other countries, successful and unsuccessful strategies and methods, and varied perspectives. In addition conference participants develop critical peer networks which enable future research collaboration.

Vietnam as a Focal Point: The graph below, taken from the presentation made by Dean Kim Anh Nguyen of the Nha Trang University's Faculty of Economics illustrates the significance and growth of both capture fisheries and aquaculture production in Vietnam over the past five years.



Source: Nguyen, Kim Anh: Presentation to the IIFET Executive Committee in support of Nha Trang University's bid for the right to organize IIFET's 2008 Conference, Portsmouth, UK, July 9, 2006

Graphs of the growth in fisheries products exports, proportion of fisheries products in total GDP, number of jobs created in fisheries, and other data (available on request) all tell the same story. Vietnam is both an increasingly significant actor in the world's fish production and trade, and also a microcosm of the economic and social issues facing all seafood producers today; balancing the needs and interests of fishing vs. aquaculture, dealing with the ecological problems surrounding competing uses of resources, and management of sectoral development where employment issues are crucial to the economic well being of large sectors of the populace.

These developments and trends put Vietnam on the cutting edge of fisheries and aquaculture today, and make it an ideal location to examine some of the issues facing policymakers and industry members today.

ACRSP support will enable the conference organizers to broaden the coverage of aquaculture related issues examined at our upcoming fourteenth international conference, IIFET 2008 Vietnam. It is our goal to make the issues surrounding aquaculture's ability to meet the world's future demand for fish one of the major themes for this conference. Themes suggested by ACRSP staff will also be added to the list of topics, which will attract the submission of presentations from a variety of countries. Submitted papers will then be organized into sessions during which participants will have opportunities to interact both in larger groups, and one on one, creating a positive professional dynamic for future interactions.

Benefits

Benefits from this project will accrue to several diverse groups:

1. Aquaculture economics graduate students and their institutions: prizes offered to this group are often beneficial in a degree disproportionate to their size. That is, it is not the amount of money which is offered, but the international recognition which a prize brings to them and to their institutions which determines the real value of the award. 1-3 graduate students and their institutions will benefit.

2. Aquaculture economists: the 3-5 who will be funded to participate in the conference will receive obvious benefits, including the opportunity to participate in an international conference, meet and interact with their peers from around the world, exchange views, information, and experiences on the value and usefulness of a variety of analytical techniques and methods, and present their work for constructive review by senior and world-renowned economists. In addition, the other 300+ conference participants will receive the benefit of the increased breadth of coverage in terms of numbers of countries represented, and variety of analytical methods applied to an equal variety of problems and situation. The resulting publication of their results in both the conference proceedings, and in peer-reviewed journal literature outside of the conference, will extend the results to an even broader group. 3-5 conference participants will benefit directly, 300+ conference participants will benefit indirectly.

3. Further downstream benefits will eventually be felt by aquaculture practitioners in the countries where the researchers and managers participating in the IIFET conference are working. Past papers presented have, for example, applied and developed economic techniques to evaluate the profitability, efficiency, and yield of aquaculture farms, assessed the effectiveness of traditional vs. modern production methods, evaluated the economic potential of the culture of new species, and suggested new marketing strategies for rural enterprises. All of this information, properly extended to rural populations, could provide aquaculture farmers with information and techniques they need to improve their operations. An unknown number of aquaculture managers, extension agents, and practitioners will benefit from the peer review, improvement, and use of the research presented.

4. ACRSP Management Entity will receive benefits of improved visibility and public perception as a result of acknowledgement of ACRSP support for the IIFET conference and program, in all printed conference materials, on the conference website, and in the conference proceedings.

Activity Plan

a. Conference theme planning and coordination: IIFET staff at Oregon State University will coordinate with a variety of entities in an effort to develop the most comprehensive and interesting possible group of conference themes related to aquaculture. Individuals and agencies will include:

i. IIFET President, Dr. Cathy Roheim (University of Rhode Island) and other IIFET members with expertise and knowledge of the most important current economic issues facing aquaculture

ii. IIFET Executive Committee members, who will be asked to review the report of the FAO Subcommittee on Aquaculture, which calls for further economic analysis and possibly an expert consultation, to glean the most important 2-3 aquaculture related themes for consideration by the conference organizers for inclusion in the program

iii. The conference organizers at Nha Trang University

iv. ACRSP management entity staff at Oregon State University

v. ACRSP collaborating scientists in Vietnam

vi. FAO fisheries and aquaculture staff involved in the Italy-FAO Hue Lagoon program in Vietnam, to examine the potential for collaboration and support for a pre-conference extension-related workshop, and/or special conference sessions

b. Award program development: IIFET staff at Oregon State University will develop and begin implementation of a program similar to that used in previous years to partially or fully fund 3-5 conference participants from developing countries. At least one of these will be a student. In addition, at least one prize will be offered for the best student paper or poster on a developing country/aquaculture related topic. An abstract and paper collection and review system and review committees will be established as described below.

Funds in the amount of $6,000 to support travel expenses of the selected participants will be transferred to the Vietnamese Host Country collaborating agency, Nha Trang University of Fisheries, prior to the end date of the project. Prior to the transfer of the funds, the IIFET Executive Director will work with the Dean of the Faculty of Econmics (and Conference Host) Dr. Kim Anh Nguyen to develop an MOU detailing exactly how these funds will be used to support travel and lodging expenses of 3-5 selected participants. To leverage the amount of funds available, the Nha Trang University of Fisheries has agreed to subsidize the awards by providing free conference registration for the recipients.

The review committee for selection of the aquaculture awards and grants will be chaired by the IIFET Executive Director and include three internationally recognized experts in the field of aqauculture economics. Two of these will be named by the IIFET Executive Director, and one by Nha Trang University of Fisheries. The primary criterion for selection will be excellence in the application of economic theory and analytical method to an important aquaculture problem or issue, relevant to developing countries. Applicants will be limited to developing country scientists. Participants will be asked to submit either a fully developed paper (in the case of the student prize) or a longer abstract 4 months in advance of the conference for review by the committee.

Communication in the form of internet and email announcements describing the availability of the prizes will be generated and distributed through all of the usual channels, including electronic mail and websites, used to communicate with IIFET conference participants, to solicit participants.

Printed fliers and brochures will also be distributed at various international meetings and conferences, and by selected IIFET members who act as ambassadors to various international organization, to ensure an appropriate degree of access to the awards.

The contribution of the Aquaculture CRSP will be acknowledged in all appropriate conference-related printed materials. The awards themselves will also bear the ACRSP name. Awards, and ACRSP support, will be acknowledged during an awards ceremony to be held during the conference.

Schedule

December 1, 2006	beginning of project activities
February 1, 2007	basic award program plan will be developed so that information fliers can be distributed by CRSP Management Entity staff at the World Aquaculture Society meetings.
May 1, 2007	review committee will be set up, initial communication distributed soliciting applications by potentially fundable participants
June 30, 2007	Project completion; conference theme development results will be submitted to conference organizers, final schedule and processes for submission and review of supported participant applications will be established, final technical report due in management entity office.

Special Sessions, Travel and Poster Awards at 2007 World Aquaculture Conference, Site Descriptions Update

Applied Technology and Extension Methodologies (12ATE18) / Activity / Philippines

Collaborating Institutions

University of Arizona
Kevin Fitzsimmons
Central Luzon State University, Philippines
Remedios Bolivar

Objectives

1. Organize a special session at the 2007 (San Antonio) World Aquaculture Meetings. This session would focus on Sustainable Aquaculture Research conducted in Aquaculture CRSP countries.
2. Provide travel support for four international contributors from Aquaculture CRSP countries to attend the 2007 World Aquaculture Conference.
3. Provide two student travel and three poster awards to present Aquaculture CRSP results and/or recognize research that addresses goals of sustainable aquaculture in developing countries at 2007 San Antonio meeting.
4. Complete the updated version of the ACRSP Site Description Booklet.

Significance

The Aquaculture CRSP will sponsor a special session focused on research conducted by Aquaculture CRSP scientists. The conference in San Antonio, Texas, scheduled for Feb 27-March 3, 2007, will focus on aquaculture in the developing countries supported with A CRSP funds. Many of the A-CRSP host countries will be heavily represented at the meeting. Findings from this research will benefit fish producers in developing and developed countries. The focus of the session will be the use of tilapia and native species in developing countries for sustainable production systems.

The conference in San Antonio is a triennial meeting with the Fish Culture Section of the American Fisheries Society and the US Shellfish Association. It will be heavily attended by Latin American farmers and academics in aquaculture.

Travel support is critical to the ability of scientists from developing countries to present their findings in an international forum. Host country CRSP scientists benefit from the opportunity to discuss their work amongst themselves, with their US colleagues as well as the rest of the international community.

The effort within this proposal fits the Activity description of conference organisation.

Anticipated Benefits

Target groups

1. Host country scientists.
2. Our target group is the international community devoted to development of sustainable aquaculture technologies in developing countries.

Quantifiable direct benefits from the conference

1. Have a special session at the World Aquaculture Meetings that presents a comprehensive overview of the research contributions of the Aquaculture CRSP; and have a tilapia session where CRSP research can be presented
2. Ensure a strong participation of Aquaculture CRSP host PI's in the World Aquaculture meetings
3. Through the technical sessions, present a large body of information generated by Aquaculture CRSP researchers

Quantifiable indirect benefits from the conference

1. Establish relationships between CRSP research community and international aquaculture scientists, producers, and development community
2. Have a strong program with informative presentations and good networking

Activity Plan - Awards

Location of work

WAS 2007 - Arizona and San Antonio, Texas

Methods

Fitzsimmons has already been asked by the program committee planning the San Antonio conference to organize the tilapia and A CRSP sessions. The sessions have been approved and are in the schedule.

An A-CRSP committee has been formed to determine the selection of visiting scientists and students who will be awarded the travel support. The selection criteria will be based on contributions of papers to the conference, past participation in Aquaculture CRSP projects and other available support. If partial support can be generated from other sources, the funds may be split to support additional participation.

Specifically for the scientist and student travel awards:

1. Announcement of the grants was distributed by e-mail to the A-CRSP list serve and posted on a webpage.
2. The application form required a copy of the abstract submitted to the conference, description of past involvement with the A CRSP, and description of matching support available.
3. The selection committee(Fitzsimmons, Kosciuch, Nelson, and Gonzalez) ranked the proposals based on quality of abstract, contribution of the work to sustainable aquaculture, degree to which the presentation was supported by A CRSP funds, and amount of matching support available.

The committee will also evaluate student posters to determine student poster awards based on the quality of the work and its applicability to the A-CRSP goals. The posters are judged during the conference and the award checks are provided at the final reception on the last evening of the conference.

Specifically for the student poster awards:

1. Announcement of the awards was distributed by e-mail to the A-CRSP list serve and posted on a WAS student webpage.
2. A list of all student abstracts was obtained from the WAS administrative office.
3. The selection committee (Fitzsimmons, Kosciuch, and Bowman) evaluated the abstracts based on contribution of the work to sustainable aquaculture. The selection committee thereby culled the number of posters to a reasonable number with a focus on the A CRSP goals.
4. Judging – The judges (Fitzsimmons, Kosciuch, Bolivar,Contreras, and Bowman) used a score sheet based on scientific content, visual appeal, degree of effort demonstrated by the work, and use of graphics to transfer the information.
5. The scores were averaged with the highest score receiving the First place award ($400 and certificate) and the next two places given second place awards ($200 and a certificate).
6. The awards are announced and given to the student at their reception during the WAS meeting.

Regional and Global Integration

- Local participation on organising committee
- Regional participation on organising committee
- International participation on organising committee
- Local, regional and international co-sponsors and vendors for trade show
- Strong international representation in papers presented

Schedule

Nov. 2006 – Announce travel award grants for scientists and students
Jan. 2007 – Write additional letters if needed for obtaining visas
Feb. 25-26 2007 – Participate in ACRSP TC meetings immediately prior to conference
Feb. 27- Mar. 1 2007 – Judge student posters
Mar. 2 2007 – Announce student winners and present checks at final reception
April 2007 – Prepare final reports for ACRSP annual and final techinal reports

Application for Aquaculture CRSP San Antonio Pre-conference Awards
ACRSP Annual Meeting February 25-26 and WAS February 26-March 2, 2007

This award is open to all individuals who will be presenting research historically or currently funded by the Aquaculture CRSP. It is open to those students, researchers, producers, and others who are principal authors of an accepted WAS presentation regarding CRSP research.

All applications should be returned to Kevin Fitzsimmons at kevfitz@ag.arizona.edu by end of day October 31, 2006. Evaluations will be completed and awardees notified by December 1, 2006. Criteria to be used will be 1) scientific quality, 2) financial need and 3) regional representation. In an effort to simplify the application, please complete the four sections below.

1. Applicant Information
   Name:
   Highest degree:
   Current title:
   Institution:
   Mailing Address:
   Email:
   Telephone:

2. Past/Present role as an Aquaculture CRSP participant:

3. Attach an electronic copy of your presentation abstract or insert below (follow instructions for 'a' or 'b' but not both).

a) If your presentation has already been accepted by WAS, please provide the title and session below. Please attach a copy of your submitted abstract as part of your completed application.
Title:
Session:
Abstract:

b) If you have not yet submitted an abstract to WAS, you unfortunately missed the deadline for general sessions. In this case, immediately submit your abstract to WAS through the WAS website. Specify that you wish the paper to be accepted in the special "tilapia session." Provide a duplicate of your abstract for evaluation for this competitive pre-conference award.
Title:
Session:
Abstract:

4. Please provide a statement outlining your specific need for conference preparation funds to the WAS annual conference in San Antonio.

IMPORTANT NOTES:

Recipients of Aquaculture CRSP pre-conference awards are required to attend the Technical Committee meeting on Sunday, February 25 and Monday February 26, 2007. If you receive an Aquaculture CRSP pre-conference award then you are expected to make your travel plans to attend this TC meeting. Not attending the ACRSP meeting will invalidate your travel award.

Recipients of Aquaculture CRSP pre-conference awards are expected to obtain VISAS for travel to the US. Verifying visa status with Kevin Fitzsimmons is necessary prior to acceptance of awards.

Invitation letter to Honors and Awards Committee

11 January 2007

Dr. Kevin Fitzsimmons
Environmental Research Lab
University of Arizona
2601 E Airport Dr
Tucson, ZA 85706-6985

Dear Dr. Fitzsimmons,

I am writing to invite your participation on a special committee that will reward students for excellence in research. The Aquaculture CRSP is pleased to be the sponsor of three student poster awards at the upcoming World Aquaculture Society (WAS) Conference in San Antonio, Texas. The awards provide an opportunity for students working in the international aquaculture field to be recognized for their efforts and to raise awareness of the CRSP in the greater aquaculture community. Please consider being part of this CRSP Honors and Awards Committee.

The award is open to any student presenting a poster at WAS 2007 that addresses the topic "Low-cost strategies for increasing pond production in low-income countries." The posters will be judged and the winners determined by the Honors and Awards Committee. Members of the Committee will initially meet on 27 February at WAS 2007 in San Antonio.

I appreciate your close association with the Aquaculture CRSP. I look forward to hearing if you are willing to serve the CRSP as a member of the Honors and Awards Committee. If you are available, I will send you additional details.

Sincerely,

Hillary Egna, Ph.D., Director

Example Poster Judging Sheet

Aquaculture CRSP Student Poster Award Criteria - 2007

Student author Family Name: _____
Title: _____
Board number: _____

	Value (15 points) Is this topic of importance to sustainable aquaculture development?
	Poster title (5 points) Does the title accurately and concisely describe the subject?
	Abstract content (10 points) Is the abstract well organized and interesting? Does it adequately summarize the *project*, the *results*, and a *discussion* of their relevance?
	Scientific and research value (20 points) How much effort was involved to complete the study (2 weeks, 6 months, 2 years)? Is the study innovative? Is there evidence of careful planning and conduct of the study?
	Application potential (20 points) Do the results constitute new knowledge? Are the conclusions important? Can findings be applied to maintain or improve present production or harvest practices?
	Scope (10 points) Are findings of general interest to the broad aquaculture community as opposed to findings relating to a special situation and relevant only to a limited locality? Can the abstract be understood by those not engaged in the particular specialty and by those without competence in narrow fields?
	Visual Presentation (10 points) Is the poster well laid out? Is it easy to read? Are the tables, graphs, and figures appropriate and easy to understand?

Comments:

Total:

Reviewer's name:_____

Activity Plan – Site Description Booklet

The Aquaculture CRSP Site Description Booklet was last published 1999. With the expansion of ACRSP projects into new Host Countries and the continued interest in global aquaculture, an updated version of the booklet is warranted. The booklet provides important background information and detailed descriptions of the different sites where Aquaculture CRSP research has been conducted. The updated version will compliment the version published in 1999.

The ACRSP Site Description Booklet will be published as an on-line booklet. The work will involve compiling, editing, and design of the site description booklet.

Location of work

Work will be complete at Central Luzon State University, Philippines.

Schedule

March 2007 – compile all site descriptions from Host Country PIs
April 2007 – Lay-out booklet
June 2007 – Publish final version of booklet on-line

References

www.was.org Program and call for papers website

Improvement of Tilapia Fingerling Production and Availability in Central America

Seed Stock Development and Availability (12SDA6) / Study / Costa Rica, Panama

Collaborating Institutions

Auburn University, USA
Joseph J. Molnar
Panamerican Agriculture School, Zamorano, Honduras
Daniel E. Meyer

Objectives

- Train extension agents, farmers and interested individuals from Costa Rica and Panama on the techniques of tilapia reproduction, sex reversal and distribution of fingerlings.
- Translate from English to Spanish 130 abstracts from ACRSP research corresponding to the period 1996-2005
- Contribute to developing a new source of fingerlings for distribution in southern Honduras to support interest in tilapia culture regionally.

Significance

The availability of good quality seed is often a factor limiting aquaculture development (PD/A CRSP 2002, Egna and Boyd 1997). The lack of adequate supplies of all-male tilapia fingerlings has been identified as a principal limiting factor to small-scale fish culture development in Honduras (Meyer 1988; Triminio 2001; Triminio et al in print). Procuring reliable supplies of high quality seed for stocking local and remote sites is critical to continued development of the industry. Previous ACRSP research in Honduras evaluated tilapia fingerling production and examined factors that influence the way farmers produce and distribute fingerlings (Triminio et al. in print). The study considered three indicators of fingerling quality (uniformity of color, size and male gender).[1] Sixteen farmers were identified and interviewed for the study during the period from September 2003 to July 2004. Seed production is concentrated in valley areas in the departments of Olancho, Comayagua, and Cortes. The results show that there is higher variability for color and gender than for size among the fingerling batches evaluated. This variability suggests that the quality of fingerling delivered to tilapia farmers is not consistent. Most of the fingerling batches evaluated fall below the 90 percent level of uniformity of size, color, and gender.

Tilapia culture continues to expand in Honduras and neighboring countries. The production of cultured tilapia in Honduras will surpass 30,000 metric tons in 2006. Most of this production comes from two large commercial farms that supply fresh fillets to North American markets. These large commercial farms are self-sufficient in tilapia fingerling production and occasionally sell excess fingerlings to small-scale producers. Cultured tilapia for distribution in Honduran domestic markets is estimated at approximately 2500 metric tons for 2006. Much of this production comes from small and medium-scale producers located throughout Honduras. The popularity of tilapia is increasing throughout Central America and several Honduran farmers are exporting fish to Guatemala and El Salvador.

There is a perceived growing interest among shrimp farmers and local residents of southern Honduras to begin tilapia culture (personal communication with Grupo Granjas Marinas, Choluteca, Honduras). World wholesale prices for commodity shrimp have been depressed for more than five years. In previous CRSP research only a single fingerling producer was identified in the region (Triminio et al. in print).

---

[1] Fingerling sex reversal with hormone-treated feed was practiced by 14 of the 16 farmers. Seven fingerling farms are family-owned, four are private companies, one is a cooperative, one is operated by a non-profit organization, and another run by a university and two are government stations. From each of the farms and in the manner that would be used by a typical producer, a minimum of 1000 fingerlings were purchased and transported to the aquaculture station at Zamorano for evaluation (count, uniformity of size, and uniformity of color). A sub-sample of 250 fingerlings purchased from each farm was reared to a size when sex identification was possible. The sex of each adult fish was determined by visual examination of the genital papilla to ascertain the percent of males in each sub-sample. In aggregate, the sample produces approximately 15.3 million fingerlings a year. Most (75 percent) of the fingerling producers interviewed also raise tilapia, produce other aquaculture species, and have other farm enterprises. Fingerling farmers have at least 4-6 years of formal education and fingerling production experience on average of 6.7 years and a range 0-25.

Small and medium-scale Central American fish farmers often have difficulties in obtaining tilapia fingerlings for stocking their ponds following each harvest due to logistic problems, and many are dependent on subsidies from NGOs for assistance in obtaining fingerlings, paying for transportation costs and for other inputs (Meyer 2001). There are several private farms, national fish culture stations and universities in Honduras that specialize in tilapia reproduction and distribution of sex-reversed fingerlings (Green and Engle 2000). The quality and sales price of fingerlings available in Honduras is variable (Aceituno et al. 1997; Triminio et al. 2004).

The inadequate availability and poor quality of tilapia seed was identified as a major constraint to fish culture for regional development (Aceituno et al. 1997; Triminio 2001). The lack of information, especially pertinent information in Spanish, and insufficient training opportunities, have also been identified as constraints to improving farmers capabilities to culture tilapia more efficiently and profitably (Triminio 2001).

The development of a second fingerling production capability in southern Honduras will provide a greater degree of independence for the farmers to obtain seed locally. This should also contribute to the elimination of subsidies from NGOs. Our efforts should contribute substantially to make tilapia culture more viable and sustainable in southern Honduras and in other parts of Latin America thru our training events.

Our work on WP 12, and other studies, has shown that production of all-male tilapia fingerlings can be a profitable business for local fish farmers in Central America (Engle 1986; Popma and Green 1990). The level of profitability in fingerling production is dependent on the use of appropriate technologies and the proper management of fish and other inputs (= costs). There is a documented unsatisfied demand for tilapia seed in many areas of Honduras (Triminio 2001; PD/A CRSP 2002). All of the proposed activities will enhance the knowledge and capabilities of local and regional farmers, provide greater access to CRSP generated research results and to other information on tilapia culture and fingerling production, to broaden the impacts from our previous efforts in the region.

Quantified Anticipated Benefits

Direct target groups of the study will be:

1. A minimum total of 60 individuals (fish farmers, extension agents, students and interested individuals) from Costa Rica and Panama will be trained on technical aspects of tilapia biology and culture techniques, reproduction and sex reversal procedure, and marketing of fish in Central America.

2. Spanish speaking farmers, extension agents, government and NGO officials, students and other interested individuals in Latin America and in other Spanish-speaking areas of the world, will have available Spanish translations of CRSP research results to enhance their understanding, knowledge and decision-making capabilities.

3. A local institution in southern Honduras will have a defined idea as to the required resources (physical and human) and capabilities they need to acquire in order to implement a tilapia fingerling production and distribution unit.

Indirect target groups will be:

1. Thru our CRSP supported training efforts in Costa Rica and Panama, we expect that there will be an increased interest in promoting and developing tilapia culture among NGOs and increased awareness among government officials, of the potential that tilapia culture may play in local, regional and national development programs.

2. The family members of the persons trained in Costa Rica and Panama will indirectly benefit from our efforts thru the adoption of tilapia culture that can contribute to improved family nutrition and additional income from sales.

3. A potential enormous audience of Spanish speaking people will be able to access and understand CRSP supported research results via web pages and the internet.

4. These activities will strengthen and enhance Zamorano's, University of Georgia and Auburn's institutional understanding of the needs and aspirations of rural farmers, extension agents and others residing in southern Honduras, Costa Rica and Panama, which are critical understandings for proposing activities to help alleviate poverty and increase rural incomes while protecting the local natural resources.

Activity Plan

Training Events to Sustain, Enhance and Expand Program Impact

Our proposed work is focused on training events that incorporate and extend the broader impact of the research and outreach activities achieved in Work Plan 12. We plan to organize and carry out two training events in Central America (in Costa Rica and in Panama) during May or June of 2007.

The two three-day long training events will be designed for tilapia farmers and NGO extension agents. The training events will offer CRSP generated information and research results on methods of producing tilapia fingerlings (including mixed-sex culture, hand sorting, and sex-reversal), managing ponds, feeds and nutrition, marketing and other topics. We will invite farmers, extension agents, students and other interested persons from Costa Rica and Panama to participate in each event, expanding the regional reach of the project. We will attempt to find collaborators in each country to facilitate acquiring of a meeting room, assist with local logistics and publicizing each event.

The participants in each of the training events will be evaluated to determine the effectiveness of our technology transfer and demonstrate their level of learning by answering a series of questions at the start and finish of each event.

Translation to Spanish of abstracts from CRSP publications 1996-2005

We will translate into the Spanish language a series of approximately 130 abstracts in English of published CRSP research results. These abstracts will be down loaded and translated by students and staff of the English as a Foreign Language program at Zamorano. Each translated abstract will be proof read by a HC-Co-PI and sent to be posted on the CRSP web page and on the www.acuacultura.org web page managed by Zamorano and supported by CRSP.

Establishing a center for production and distributing tilapia fingerlings in southern Honduras

We will train two staff members from the Luis Landa Vocational High School (LLVHS), Nacaome, Honduras, during a two-week long practicum at the Zamorano Aquaculture Station. Additionally, these individuals will participate in a scheduled training program (July 5-7, 2007) to gain theoretical knowledge and enhance learning acquired in the practicum. The LLVHS staff members will also be invited to attend the Central American Symposium on Aquaculture in Tegucigalpa in August of 2007.

LLVHS is a public school that includes aquaculture in its academic programs and many of their graduates have done well working in the marine shrimp farming industry and as students in formal academic programs at Zamorano and other universities in Honduras. We will make several visits to their campus in Nacaome to evaluate the aquaculture infrastructure and support installations. We will discuss with school officials the advantages and disadvantages, limitations and perceived needs, to implement a tilapia reproduction and fingerling production unit on their campus.

Regional and Global Integration

The proposed work will provide opportunities to extend awareness, knowledge and understanding of CSRP generated research and outreach efforts to interested individuals and groups in Costa Rica and Panama. This will effectively expand the impact of CRSP activities in the region.

The translated abstracts will be posted on the CRSP's home office operated web page and also on the www.acuacultura.org web page operated and managed by Zamorano with support from the CRSP. The Zamorano web page provides information in Spanish to a wide audience from throughout Latin America.

The HC PIs will coordinate preparation of training materials and logistics for the training events with collaborators in Costa Rica and Panama. Patricio Paz will assist with preparing documents and presentations, and participate in the instruction to be given at each site.

The training events will contribute to strengthening our contacts in countries where we have previously not had activities. They will provide opportunities for establishing new contacts in countries that have not had prior relations with the CRSP.

Our efforts will strengthen the aquaculture program at Luis Landa Vocational High School and the capabilities of their staff and serve to improve their ties with Zamorano, UGA and Auburn.

Schedule

- The two three-day long training events will be held in Costs Rica and Panama during May or June of 2007. We will schedule the specific dates for these events while consulting with potential collaborators in each country.

- The abstracts to translate will be down loaded from the CRSP web page, translated by students and staff at Zamorano, proof read by the HC-Co-PIs, and a final report prepared by April 30, 2007.
- The two-week long practicum/training of LLVHS staff will be done in May of 2007 and the theoretical training in July. A written evaluation of their infrastructure and needs to implement a tilapia reproduction unit will be completed by June 30, 2007.

Report Submission

All reports and results corresponding to the work proposed herein will be submitted by June 30, 2007.

Literature Cited

Aceituno, C., D.E. Meyer, A. García Y. J. Barrera. 1997. Evaluación de alevines de tilapia roja adquiridos en diferentes centros de producción en Honduras, p. 206-208, in: D.E. Alston, B.W. Green, and H.C. Clifford (editors) IV Simposio Centro-americano de Acuacultura, Tegucigalpa, Honduras. Latin American Chapter of the World Aquaculture Society (WAS), Asociación Nacional de Acuicultores de Honduras (ANDAH).

Egna, H.S. and C.E. Boyd (editors). 1997. Dynamics of Pond Aquaculture. CRC Press, New York, USA. 437 pp.

Engle, C. 1986. Costos de producción de semilla de entrega en Panamá. Rev. Lat. Acui. 30:43-57.

Green, B.W. and C.R. Engle. 2000. Commercial tilapia aquaculture in Honduras. Pages 151-170 in B.A. Costa-Pierce and J.E. Rakocy, eds. Tilapia Aquaculture in the Americas, Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana, USA.

Lutz, C.G. 2001. Practical Genetics for Aquaculture. Blackwell Science, Ames, Iowa, USA. 235 pp.

Meyer, D.E. 1988. Realidad de la acuicultura en Honduras y sus limitaciones. CEIBA 30(2):9-15.

Meyer, D.E. 2001. Technology for the successful small-scale tilapia culture, p. 97-106 in: D.E. Meyer (editor), Proceedings of the Sessions on Tilapia. 6th Central American Aquaculture Symposium, August 22-24, Tegucigalpa, Honduras. Asociación Nacional de Acuicultores de Honduras (ANDAH) and the Pond Dynamics/ Aquaculture Collaborative Research Support Program (PD/A CRSP).

PD/A CRSP. 2002. Latin American and the Caribbean Region Expert Panel Meeting, Pond Dynamics Aquaculture Collaborative Research Support Program. February 1, San Diego, California. 20p.

Popma, T.J. And B.W. Green. 1990. Sex reversal of tilapia in earthen ponds. International Center for Aquaculture Research and Development Series No. 35, Auburn University, Alabama, USA. 15 pp.

Triminio, S. 2001. Report of the PD/A CRSP Aquaculture Stakeholders Meeting. August 21, Tegucigalpa, Honduras. 9 p.

Triminio, S., J. Molnar and D. Meyer. 2004. Evaluation and improvement of tilapia fingerling production and availability in Honduras. A/CRSP WP11 Year One Final Report (in preparation).

Triminio, S., J.J. Molnar, D.E. Meyer and E.W. Tollner. (In print). Tilapia fingerling production in Honduras. Journal of Applied Aquaculture.

Reproduction of Pacu (*Piaractus mesopotamicus*) and Surubim (*Pseudoplatystoma tigrinum*) and New Paradigm in Nutrition of Tropical Fishes

Fish Nutrition and Feed Technology (12FNF4) / Experiment / Brazil, Mexico, Peru

Collaborating Institutions

Ohio State University, USA
Konrad Dabrowski and Marta Jaroszewska
Sao Paulo State University, Brazil
Maria Celia Portella
Universidad Nacional Agraria de la Selva, Peru
Manuel Sandoval
Universidad Juárez Autónoma de Tabasco, Mexico
Wilfrido M. Contreras Sánchez and Arlette Hernandez Franyutti

Objectives

- To enable students in long term training to advance towards completion of their degrees under the mentorship of CRSP researchers
- To complete a series of experiments on reproduction (USA) and nutrition (Brazil and Mexico) of tropical fish (surubim, paku, tropical garfish).

Rationale and Significance

1.1 Reproduction of tropical fish in captivity

In the Amazon River and its tributaries, many species of *Psudoplatystoma* catfishes reach the most frequently harvestable size of 15–20 lbs. These catfish attract high market values among consumers in South America, Brazil, Peru, Colombia, and Bolivia, making them economically important in the region. Unfortunately, the wild harvest of fish from the Amazon, Parana, or Orinoco rivers and tributaries has become increasingly limited in the face of these species' high nutritional value and market demand. As a result, aquaculture of these species is becoming a national priority. South American catfishes (e.g., *Pseudoplatystoma coruscans, P. fasciatum* and *P. tigrinum*) are already important species for commercial production in South America (Kossowski, 1996; Campos, 2004). Reproduction of doncella and tiger (*P. fasciatum* and *P. tigrinum)* occurs in Peru in February-March (Alcantara, F., IAAP, Iquitos, personal communication), in Brazil in January (Leonardo et al. 2004). Final maturation and ovulation were achieved in several catfish species from South America using carp pituitary extracts or pituitary hormones (Cardoso *et al*., 1995; Kossowski, 1996). However, to the best of our knowledge, no information is available on possibility to use captive broodstock in order to synchronize ovulation/spermiation in surubims as earlier described in other Amazonian fish (Dabrowski *et al*., 1996).

Research results from a collaboration between the aquaculture program at The Ohio State University's School of Environment and Natural Resources, The Sao Paulo State University (UNESP) in Jaboticabal, Brazil, The University of San Marcos (USM) in Lima, Peru, and Agriculture University at La Molina, Lima, Peru came to fruition recently when the first larvae from a species of Amazonian catfishes (genus *Pseudoplatystoma*) were born on February 14 at 11:00 pm, 2006 in Columbus, Ohio. This success is the result of nearly three years of research that began with funding from OSU and has garnered continuing support from the Aquaculture CRSP and the Peruvian Science Foundation (CONCYTEC). The research team gained initial knowledge in the larval rearing of the Amazonian catfish in the project when a batch of newly hatched larvae arrived from Brazil. Dr. Maria Celia Portella (UNESP) provided instructions regarding rearing conditions. In attempting to further unlock the secrets of surubim reproduction, we practiced monitoring of gonad development and profiling of blood steroid hormones, as well as mimic proper water temperature and light regimes. The final "resolving" dose of hormonal treatment induced female catfish to release the fertile eggs. Males were already releasing sperm for more than a year and successful fertilization followed. Finally, several thousand larvae 3.5 mm in length were hatched within 14 hours. Surubim has one of the fastest rates of embryonic development in vertebrates, and within the next several hours the larvae were ready to feed.

1.2. Larval rearing of native tropical fish in high density and with higher economic efficiency.

In Brazil it also becomes necessary to develop and implement better technology to produce juveniles of local catfishes and pacu as they are subject of considerable international trade (Taiwan,

China) and in high demand by domestic producers. For this reason, intensive larviculture is a good alternative to improve survival rates during the most critical larval stages. In the new system, culture is conducted indoor, where the larvae are kept in tanks without predators, being fed good quality live feed of right size and in predetermined amounts. Furthermore, when the fish are more agile and developed, they can be transferred to fertilized ponds, thus securing increased survival rates. For carnivorous species, such as the pintado (*Pseudoplatystoma coruscans*) or cachara (*P. fasciatum),* they need to be trained (habituated) to accept artificial diets before being transferred to ponds.

In a recent work, Jomori et al. (2003b) determined that the high productivity and economical viability of initial intensive larviculture are achieved when larvae of pacu were kept in the laboratory for 6 or 9 days before stocking in the outdoor ponds. However, the authors suggested that these results obtained during intensive experimental rearing should be validated at semi commercial scale with the objective to further increase survival and growth and shortening time of weaning from *Artemia* nauplii to formulated diets. Thus, the substitution of live *Artemia* nauplii by natural plankton and afterwards by formulated microparticulate diets should be the focus of further investigation in order to achieve cost reduction.

The commercial larval rearing of these species represents a great challenge to farmers because high mortality occurs in the larval phase, especially due to the feeding habits of the catfishes which include cannibalism, and could be associated with inadequate feeding strategy. Generally, *Pseudoplatystoma* sp. catfish juvenile producers use live *Artemia* nauplii for larvae initial feeding, followed by a feed training (habituation), when the fish are adapted to moist artificial diets and subsequently to dry diets. However, survival rates during this period are not satisfactory. This fact results in the raise of the price for juvenile pintado and surubim practiced by producers. Studies that were conducted in Dr. Portella's laboratory, aimed at better understanding of initial larvae development (Cestarolli et al., 2002; Furusawa et al., 2001), and adequate larval feeding management (Portella et al., 2002; Furusawa et al., 2002; Guerrero-Alvarado and Portella, 2002). Despite significant progress, an increased survival and growth rate at the early weaning from live feeds to formulated diets still needs improvements.

In Brazil, no commercial artificial diets were developed especially for fish larvae. Experiments were conducted with microbound diets for pacu (Jomori 1999 and 2001; Macedo–Viegas et al., *in press*) and pintado (Portella et al., 2002; Furusawa et al., 2002; Guerrero-Alvarado and Portella, 2002). Recently, Macedo-Viegas et al. (2005) used fish silage and fish protein hydrolyzates as components of diets for feeding pacu larvae and validated the possibility for their incorporation in larval feeds.

2.0 New paradigm in fish nutrition (CRTICAL RESEARCH)

Previous studies have shown that IDAA deficient diets decrease feed intake and change feeding behavior of rats, thus lowering growth rate and survival of animals. However, no information is available on how IDAA deficient/imbalanced diets affect feed intake in fish, feed utilization, and acute versus chronic effects on feed acceptance. It is likely that adaptive responses, in the short term (within hours) and during a long period (several weeks) depend on the fish species and ontogenetic stage. Our preliminary results show that fish fed interchangeably with two IDAA-imbalanced diets separated into different meals (i.e. complete daily IDAA ration) significantly increased their feed intake compared to the group fed IDAA-balanced diets. We propose to further investigate how IDAA deficient diets affect the free amino acid profile in fish, and particularly in muscle tissue. We hypothesize that the sequential use of IDAA-imbalanced rations will reduce or eliminate the negative effects of IDAA deficiency on fish growth and the resulting hyperphagia will increase growth rate.

There are 20 amino acids of nutritional importance in food and tissue proteins. The indispensable amino acids (IDAA) cannot be synthesized by the body and must be obtained from the diet (Fuller, 2000). The majority of IDAA are identical in all animals including fish (Dabrowski and Guderley, 2002). However, the requirements, for instance for arginine and proline (Dabrowski et al. 2005) among animals differ. The ontogenetical differences between young and adult fish and mammals were also documented. Non-ruminant animals must obtain sufficient IDAA from their diet to maintain normal growth and protein synthesis. Studies conducted in animals showed that an amino acid imbalanced diet reduced feed intake (Koehnle et al. 2004) and growth of animals (Harper et al. 1970; Gietzen 1993). In addition, studies also showed that rats could recover from such deficiency when fed with feed containing the specific IDAA they were lacking (Markison et al., 2000). Recently, Hao et al. (2005) argued that mammals recognize dietary IDAA deficiency in the brain's anterior cortex that is signaling diet rejection. However, there is no information available on how IDAA deficient diets affect fish.

We hypothesize that the use of sequential disproportionate amino acid rations will reduce or eliminate the negative effects of IDAA deficiency on fish growth. Specifically, we hypothesize that:

a) Following the first meal ingestion, fish feed intake will not be affected by IDAA-imbalanced diets and result in a dramatic decrease of free IDAA in fish body in comparison to pre-feeding levels;

b) Fish that will continue to be fed on IDAA-imbalanced diets (long term) are going to show further decrease of free IDAA to non-detectable levels;

c) Withdrawal of the set of 5 indispensable amino acids (out of 10 IDAA) from fish diets, named here either (-)Arg (deficiency in Arg, Thr, Val, Leu and Met) or (-)Lys diets (deficiency in Lys, His, Ile, Phe and Trp), will result in corresponding decrease or traceable amount of these amino acids in fish body;

d) "Switching" (or mixing) of (-)Lys and (-)Arg diets in a series of separate meals will allow complete recovery of FAA in fish body or "compensatory" response, i.e. higher levels of FAA than in control group of fish fed a balanced diet.

This project, for the first time, addresses amino acid imbalances in fish by using diets formulated in such a manner that will be favoring or minimizing the effect of feeding behavior. It aims to establish physiological regulatory mechanism that will govern diet acceptance or rejection. Using pacu (Brazil) and/or surubim (USA) in this study aims to develop feeding strategies for important species in aquaculture and seeks applications for IDAA-deficient diets in diets formulated based on plant proteins, i.e. replacement of fish meal in fish diets, the major task for aquaculture industry.

Quantified Anticipated Benefits

The proposed study aims to investigate key aspects of reproduction and larval nutrition of pacu and surubim (*Pseudoplatystoma s.)* in order to improve or develop sustainable aquaculture technology for these species that would aim at using recirculated, controlled systems. Through collaborative efforts with Brazilian, Mexican and Peruvian collaborators, we will be able (1) to develop breeding techniques for *Pseudoplatystoma sp*. and pacu in captivity, (2) to develop methods of rearing first-feeding larvae of pacu, surubim and tropical garfish, (3) to formulate protein/amino acid based diets that can be used in testing IDAA-imbalanced diet hypothesis and nutrient requirement studies. The main beneficiaries of this research will be the local producers in the Peruvian and Brazilian Amazon, garfish producers in Tabasco and surrounding states in Mexico, and farmers in neighboring countries (Colombia, Argentina, Ecuador, Bolivia).

This study will also contribute towards institutional strengthening by providing training for faculty and graduate students from Sao Paulo State University, Tingo Maria National University and University of Tabasco, and staff from IIAP, Iquitos, Peru, Fisheries Institute, Pirassanunga, Brazil, and many other local agencies in Brazil, Peru and Mexico. Development of methods that will increase the quality of progenies of *Pseudoplatystoma sp*., paku and tropical garfish will contribute significantly to the artificial propagation techniques of these South and Central America fish. The success of this project will be measured based on:

1. Training provided to 2-3 graduate students in host countries in respect to broodstock maintenance, larval rearing, juvenile diet formulation, familiarization with modern techniques and hypothesis in nutrition, new approaches to nutrient requirement studies, and exploration of practical applications of these finding in diet formulation for *Pseudoplatystoma* , pacu and tropical garfish. Results leading to improved growth performance will be recommended for practical farming.
2. Two workshops will be organized in Brazil and Peru devoted to reproduction and nutrition of tropical fish.
3. Two to three linkages with other organization in the host countries will be completed.
4. Four to five technical reports and/or peer-reviewed journal articles will be published.
5. One to two hundred researchers, students, farmers and technicians will be trained on various aspects of fish reproduction and nutrition techniques (workshops to be co-organized by M.C. Portella and M. Sandoval in Brazil and Peru, respectively).

We submit that a major undertaking in culture of tropical fish needs to include intensive methods of culture in recirculated, controlled condition, and in this respect OSU laboratory in Columbus will provide the opportunity to gather new information on species not raised thus far in laboratory conditions, outside of the native geographic zone. This would provide the opportunity for graduate students, research personnel, scientists to visit Columbus, collaborate and learn new techniques in reproduction and nutrient requirement experimental designs, diet formulation and biochemical analysis.

Research Design

1. Location of work

Reproduction of paku and surubim (OSU)

We achieved the first induced spawning of South American *Pseudoplatystoma* sp. on the North American continent. Furthermore, we accomplished spawning with fish maintained in captivity, in a recirculation system, under semi-controlled water temperature and light regime conditions. This is an achievement in its own right. The information generated in this project, in regard to surubim in captivity

will be relevant for comparison to fish in natural or semi-natural (pond rearing) conditions in the Peruvian Amazon and other subtropical locations in South America where interest in surubim aquaculture is booming (Brazil, Peru, Colombia).

This part of CRITICAL RESEARCH will be a continuation of the work reported in the Final Technical Report (2006). South American catfish surubim were imported from a fish farm in Brazil (Fazenda Santa Rosa, Mato Grosso do Sul) in December 2001 (Lima et al. 2006), and flown to Madison, WI, USA where they were acclimated to laboratory conditions. Fish were then transferred to the aquaculture facility at The Ohio State University in March 2003. Since then, the fish have been monitored in terms of growth and sexual maturation. The majority of the fish were PIT-marked and 3-5 samplings were performed between 2003 and 2006 (weighing, sexing, blood withdrawn, fish sacrificed for gonad histology). In March 2005, fish were transferred to larger tanks (200 L) where the 10-12 individuals were raised (biomass 12.5 kg / tank, water flow 6 L /min). Fish were fed pelleted feed (BioDiet Brood, Bio-Oregon, Inc., 5 mm) 0.5 – 1% body weight / day. The ovarian sample (catheter) will be fixed in Bouin's solution for histological examination. Gonad fragments fixed in Bouin's solution will be processed according to histological routine techniques as described earlier (Rinchard *et al*., 2002). They were embedded in paraffin, sectioned at 6 μm and stained with haematoxylin/eosin.

In February 2007, fish will be checked for signs of maturity (release of sperm by gentle pressure of the abdomen in males and oocyte biopsy using a catheter in females). Sperm will be collected from males and stored at 4-5°C. Prior to fertilization, sperm will be diluted in 0.3% sodium chloride. The six females varied from 1,936 to 4,605 g in mass in February 2006, and six fish released small amounts of eggs. Males will be injected with carp pituitary extract (0.5 mg/kg) to increase spermiation. Females will be injected with two doses of carp pituitary extract (0.5 and 5 mg/kg) at 11-h intervals. Then these fish will be observed regularly after treatment in accordance with the description given for propagation of *P. fasciatum* (Leonardo *et al*., 2004). Sperm from each individual male will be used to fertilize eggs sub-samples (2 g with 0.1 ml sperm) from individual females to estimate fertilization rates. The remaining eggs will be inseminated with a mixture of sperm. Temperature will be maintained above 25^{0}C at fertilization and from 25 to 27^{0}C during the incubation period. Embryo survival will be counted 9 h after fertilization.

Three days after hatching, following yolk sac absorption, larvae will be transferred and distributed into 12 aquariums with a semi-recirculated system at approximately 1,500 larvae per tank. Temperature will be adjusted to 28^{0}C. Salinity will be adjusted at 2 ppt by adding Instant Ocean (Aquarium Systems Inc., Mentor, OH, USA) salt to the system. Several groups of larvae will be fed with newly hatched *Artemia* nauplii at 2 h intervals. Fish will be kept in constant dark. Six-ten days after hatching, larvae will be provided with a formulated, commercial food (Aglo Norse, 500-710 μm, Norway).

1.2. Pacu (*Piaractus mesopotamicus*) reproduction for the first time in the North America

Pacu larvae were obtained in February 2003 from Argentina through our collaborative effort with an Argentinean farmer (N. Gromenida, Isla Pe, S.A. Formosa). Fish were of the Parana River system origin. Preliminary experiments with pacu larvae offered live Artemia or formulated diets were performed in 2003 and presented at WAS CRSP session in Hawaii. In 2003-4 several experiments with juvenile pacu were performed with participation of Brazilian, Peruvian, Turkish students and results were in part published (Tesser et al. 2005; Terjesen et al. 2005), in part were presented during the workshop organized in CAUNESP, Jaboticabal, Brazil, in May 2006.

Pacu was continued to be raised in recirculated system on OSU Columbus campus, and in 2004, 2005 and 2006 (October 13). The mean weight of fish increased from 917 $\pm$ 107, to 3,100 $\pm$ 470, and 3,821 $\pm$ 840 g, respectively. This size range and age of pacu suggest, based on our experience with pacu in Peru (Dabrowski et al. 2003), that fish are matured, and the experiments leading to final ovulation and spermiation are proposed to be carried out in the current project (February-March 2007). This will provide unique experience of maturation of pacu in captivity, and for the first tome, to the best of our knowledge (Kohler C., personal communication), in the Northern hemisphere.

Procedures leading to determination of the maturity, and then induction of ovulation and spermiation were described in detail earlier (Dabrowski et al. 2003). In brief, both genders will be catheterized to verify gonad status and then hormonal induction will be performed. Both genders will be injected with two doses of carp pituitary extracts (5 mg/kg female; 1.5 mg/kg male) (Leonardo et al. 2004) or luteinizing hormone-releasing hormone analogue (LHRHa) (Dabrowski et al. 2003) If the number of broodstock fish is sufficient, we will implement the standardized procedure described earlier in evaluation of gametes quality in rainbow trout, eggs and sperm separately (see Ciereszko and Dabrowski 1995; Blom and Dabrowski, 1995). We have already an experience with *Pseudoplatystoma* at OSU facility in Columbus that hormonally induced males are providing copious amounts of sperm

during prolonged periods (as it is the case in salmonids or percids). We will monitor the motility (duration and percent activation) of sperm prior to fertilization tests.

Sperm and ovulated eggs will be collected by stripping anesthetized fish. Eggs from each female will be fertilized with semen from three to four individual males and incubated in 9 cm diameter Petri dishes as well as in McDonald jars. Survival rates will be assessed at 1-2 hours (blastula) and at hatching (20 hours) (Cardoso et al. 1995; Kossowski 1996).

Larvae obtained from fish induced to spawn by hormonal injections in our laboratory or alternatively, larvae obtained from Aquaculture Center, Sao Paulo State University, Jaboticabal (Brazil) will be used. All required documentation will be completed (Fish and Wildlife Service permit, Ohio Department of Natural Resources permit, import permit, health certificate from Brazilian authority) prior to importation of larvae of exotic fish species to the United States. Dr. M.C. Portella, our Brazilian collaborator will be involved in planning the experiments to be carried out in Columbus. In addition, parallel studies with the same batches of fish will be carried out in Jaboticabal, to ensure viability of larvae, feed acceptance and growth rates.

2.2 Nutrition of tropical fishes (OSU, Columbus; CAUNESP Jaboticabal, Brazil; UJAT Villahermoza, Mexico)

This part of CRITICAL RESEARCH will be performed in parallel in 3 locations and provide opportunity for students Mr. Rodrigo Takata (UNESP, Jaboticabal, Brazil, advised by M.C. Portella) Ms. Yongfang Zhang (OSU, Columbus, advised by K. Dabrowski) to work collaboratively, obtain training in Columbus and prepare for outreach activity during the workshop in Brazil. Dr. Portella has received already funding for CAUNESP experiments from CNPq (Brazilian Science Foundation).

The feeding experiments will be also performed in the Laboratory of Aquaculture, Universidad Juarez Autonoma de Tabasco, Mexico, on juveniles of tropical gar. To examine feed intakes, two reference diets, amino acid-base and protein-based, and two experimental diets devoid of specific amino acids (Table 1) will be prepared according to our preliminary results (Dabrowski et al. 2003, 2005, 2006). Diets will be produced by mixing, pelleting, and freeze-drying followed by grinding and sieving to appropriate sizes and requirements of the species and different life stages. Diets will be stored at -20°C until use.

When fed carefully to satiation, we have observed rapid intake of diets discussed here by rainbow trout alevins, juveniles (Dabrowski et al. 2003) and cichlids, tilapia and midas (Dabrowski et al.. 2006), and leaching of diet components is unlikely to bias the results. Since nearly all amino acids in these diets will be given in the free form, some leacing may occur if intake is not immediate and may introduce bias. Still, this aspect and total leaching of amino acids will be tested according to Yufera et al. (2002). Briefly, 0.5 g diet will be added to 500 ml water (at 15°C) at time 0, stirring applied, and triplicate water samples taken out at times 5, 10, 20, 30, 60 and 120 minutes post immersion. Samples will be analyzed for free amino acids (Waters PicoTag HPLC) (see below). The amount of amino acids in the water will be compared with the original concentration of free amino acid levels in the diet. If leaching is found to be significant, we will modify diet production as described by Yufera et al. (2002).

The study will be conducted with juvenile pacu (Brazil) and/or surubim (USA). OSU has successfully spawn *Pseudoplatystoma* sp. in 2006 and no import of exotics is intended for the proposed project. Three replicate tanks per experimental group will be employed; pacu or surubim will be stocked with 100 larvae in 30 l tanks in flow-through, temperature (28ºC) regulated systems. Experimental diets will be given to fish over 14-28 days to satiation. Juveniles will be also fed live brine shrimp *Artemia franciscana* nauplii (methods as in Terjesen et al. 1997) as an additional control group. We will use juveniles of pacu or catfish of 100-200 mg individual weight. The survival of fish throughout the experiments will be monitored by counting dead individuals. Fish for sampling, each 2nd week from each tank, will be randomly selected from tanks within groups. Whole juveniles will be sampled on a custom made sampling device for small and fragile larvae enabling rapid collection (Terjesen et al. 1997), and frozen in liquid nitrogen for later storage at -80ºC. Three samples of pooled individuals will be collected per tank and per sampling point. Briefly, samples (1) for free amino acids and urea will be extracted in 0.1M final concentration HCl and 200 □M norleucine internal standard (TCA for HPLC pre-column derivatization, Terjesen et al. 2004) and 6% TCA, respectively, but otherwise according to Terjesen et al. 2002. Samples (2) for ammonia will be extracted after Wang et al. (1994) using grinding in liquid nitrogen, followed by weighing while still frozen, and homogenization in perchloric acid. Samples (3) for wet weight will be determined at sampling and dry weight after lyophilization. Free amino acid content will be assayed on a Waters PicoTag HPLC with pre-column derivatization.

Diets will be formulated isonitrogeneous and isolipidic (Table 1). In experiment 1, 4 diets will be used. They will be a casein-gelatin-based diet (protein control), FAA-based diet, (-)Lys and (-)Arg diets. For FAA, (-)Lys and (-)Arg diets, amino acids will be supplied by L-free amino acids. Juvenile catfish or

pacu amino acid requirement is assumed to be similar (NRC, 1993) to a cichlid fish, Nile tilapia (*Oreochromis niloticus*) (Santiago and Lovell, 1988). The casein-gelatin-based diet and FAA-based diet are amino acid balanced diets. The (-)Lys diet (Lys, His, Ile, Phe and Trp in the diet are omitted) and the (-)Arg diet (Arg, Thr, Val, Leu and Met in the diet are missing) are amino acid imbalanced diets All ingredients will be mixed, pelletized, freeze-dried and ground to particles with desired size (0.35-0.5 mm) (El-Saidy and Dabrowski, 1994).

The experimental procedures, feeding strategy and sampling methods to be used in the feeding experiments were described in Dabrowski etal. (2006). In experiment 1, fish will be fed restricted rations during the first 2 weeks. Food amounts will be adjusted to the least amount of feed consumed among all groups. At the end of the first week, the intermittent biomass will be measured. Fish will be fed *ad libitum* during the following two weeks. In experiment 2, fish will be fed restricted rations throughout the whole experiment (28-42 days). Feed will be adjusted every three days based on predicted weight gain and every week an intermittent biomass will be measured to adjust feed/biomass proportion accurately. Before the experiment start and at the end of the experiment, fish will be sampled at certain time points and frozen on dry ice immediately. Fish will be stored at -80°C for whole body free amino acid analysis.

Table 1. Composition of 4 experimental diets for experiment 1 and 2 (g/100g)

Ingredients	Protein	Free AA	(-)Lys	(-)Arg
Casein	29.6	4.5	4.54	4.54
Gelatin	2	2	2	2
Dextrin	23.8	25.6	24.68	26.59
Cellulose	30.1	30.1	30.1	30.1
AA mix*	0	23.3	24.2	22.3
CMC[1]	2	2	2	2
Phosphitan C[2]	0.05	0.05	0.05	0.05
Vitamin mix[3]	2.4	2.4	2.4	2.4
Mineral mix[4]	4	4	4	4
Cod liver oil	3	3	3	3
Soybean oil	3	3	3	3

AA mix * : See Lovell and Santiago (1988) and Dabrowski et al. (2006)
[1]Carboxymethylcellulose, MP Biomedicals, Aurora, OH, USA
[2]Mg-L-ascorbyl-2-phosphate, Showa Denko K.K., Tokyo, Japan.
[3]Roche Performance Premix composition (g/kg of vitamin mixture): vitamin A acetate, 7.56; cholecalciferol, 0.0055; α-tocopheryl acetate, 66.1; vitamin B_{12}, 0.0013; riboflavin, 13.2; niacin, 61.7; d-pantothenic acid, 22.1; menadione, 1.32; folic acid, 1.76; pyridoxine, 4.42; thiamin, 7.95; d-biotin, 0.31 (Hoffman-La Roche, Inc., Nutley, NJ).
[4] 5mg Se in the form of sodium selenite per kg Bernhart Tomarelli salt mixture (MP Biomedicals, Aurora, OH, USA).

Data will be presented as mean ± SD. FAA concentrations will be expressed in μmol/kg wet weight and μmol/100ml tissue water component. The fish group in one tank will be considered as experimental unit. The differences in FAA concentrations (a.) between pre-feeding and after feeding, (b.) among dietary treatments, and (c.) among different feeding strategies will be tested using one-way ANOVA at P = 0.05. All analyses will be performed using SPSS version 13.0 (Chicago, Illinois). If the fish fed long term (16 days) with IDAA-imbalanced diets have significantly lower level of body free IDAA compared to the fish in the control group (IDAA-balanced group), then fish metabolism will be

negatively affected by the IDAA-imbalanced diets intake. If there is no significant difference in the level of body free IDAA between the fish fed with "switching" IDAA-imbalanced diets and the fish fed with IDAA-balanced diets, fish will not be adversely affected by IDAA-imbalanced diets by the proposed strategies.

2.3 Development of purified juvenile diets and evaluation of potential action of feeding strategy in juveniles of pacu, surubim and tropical garfish (*Atractosteus tropicus*).

Experiments will be conducted in the laboratory at UJAT, Tabasco, Mexico. As a surrogate species, longnose gar (*Lepisosteus osseus*) from Ohio River or Lake Erie, Ohio, USA, can be used for some specific experiments with nutrient requirements. The OSU group has experience in working with longnose gar biochemistry (Moreau and Dabrowski 2000). Facilities to be used in Columbus for larval garfish rearing were described in detail previously (Dabrowski *et al.* 2003; Lee *et al.* 2004).

At UJAT, 5 rearing recirculating systems will be used combining 12, 20 L tanks each. Fish will be stocked at 20 per L and rearing with live and/or formulated diets is projected for 30 days after initiation of feeding. Water for rearing units will be reciculated using bio-filter and 25% of the volume will be exchanged twice a week. Live brine shrimp nauplii will be used as a control diet. The formulated diets will consist of an experimental casein-based diet (particle size 200-355 μm, enriched with attractants (soluble fish protein concentrate and/or maca meal; Lee *et al.* 2004), a salmonid starter diet (BioDiet Starter 1, BioOregon, particle size 0-600 μm), and a larval marine fish diet (AgloNorse Larva Feed, EWOS, Norway, particle size 300-600 μm and 2 mm. A preliminary test in Tabasco revealed that a casein/gelatin diet was not accepted by tropical garfish as the first food (Contreras, W. personal comm.). Therefore, we will use protein-amino acid based diet as a basis in our project. A sub-sample (10 fish) from each tank will be counted and weighed after 15 and 30 days. This sub-sample will be used to estimate the average weight of individual fish in each tank. Tanks will be cleaned twice daily with a siphon to remove any dead fish, feces, and uneaten food.

Alternatively, in these experiments fish will be fed live *Artemia* nauplii for 6-10days and then switched to either the experimental (particle size 355-500 μm) or commercial (Aglo Norse, Stavanger, Norway) juvenile diets for an additional 3-5 days. Triplicate tanks will be used for each treatment. Total experimental feeding for all treatments will be 30 days. The remaining fish will be weighed individually.

At the end of the feeding trial, growth performance will be evaluated in terms of individual body weight, survival, specific growth rate and weight gain as described earlier. Fish from each dietary treatment will be sampled for proximal body analysis (Lee and Dabrowski 2002a, b) and histological analysis. Digestive tract development and differentiation will be determined by histological analysis at 30 days (Rinchard *et al.* 2002).

Specific growth rate (SGR) will be calculated for each tank as SGR = {(ln (final weight)-ln(initial weight) x 100)/(number of days fed)} and expressed as a percentage day^{-1}. Daily survival rates will be calculated as the percentage of live larvae. Percentages will be arc sine transformed prior to statistical analysis. Feeding treatments will be compared by one-way analysis of variance (ANOVA) and Tukey's pairwise comparisons using Minitab 11.0 statistical software (Zar 1999) or followed by a comparison of means using Scheffe's F test. The Chi-square test will be used to determine alterations in sex ratios. Differences will be considered significant at $P<0.05$. Analyses will be performed using the Statistical Analysis System (SAS Institute, Inc., Cary, NC).

Regional and Global Integration

Aside from Brazil, *Pseudoplatystoma sp.* are economically important in other countries in South America, especially Peru, Colombia, Argentina, Bolivia and Guyana. It is evident that studies promoting the artificial propagation of these fishes will improve the profitability of aquaculture operations for fish farmers and, consequently, economic conditions of rural communities in these countries. In addition, readily available techniques of farming these fishes will reduce the pressure of catching fish from the wild. The studies we propose are consistent with the role of IIAP as an international center in the upper Amazon, and also include possible expansion into neighboring countries. Results from these studies will be published as fact sheets and distributed to key academic and research institutions in the region to promote interest among researchers in working with these fish.

Aquaculture represents an ideal model to explore a broad range of biological diversity, especially for developing an integrated approach that can be built into collaborative, multi-institutional partnership with access to species with a naturally limited geographical distribution. By establishing linkages between academic institutions in South America region and the USA, we can create an intellectually stimulating forum of research and educational exchanges, contribute to the unique teaching/graduate

programs of all partners, and address scientific questions which are the foundation of major change in the paradigm of the field of fish nutrition and metabolism.

This project would allow us to achieve two important goals that are not possible without A-CRSP specific objectives: (1) we intend to develop a research project to compare the responses of fish species of subtropical origin, pacu (*Piaractus mesopotamicus*), and tropical gar (*Atractosteus tropicus*), and (2) we will develop and implement a new educational system of graduate and undergraduate training. Specifically, we will foster exchanges that involve experiences among interdisciplinary OSU programs in comparative nutrition, applied aspects of aquatic ecology at Sao Paulo State University (UNESP), and the general biology and biotechnology program at UJAT, Mexico. Our masters and PhD students will have interchangeable field assignments and diverse experiences that best fit their individual projects, but still enforce diverse experiences in nutrition, ecology and biochemistry. The proposed project will build upon individual projects in partner countries, as well as earlier established collaborations funded between the USA and Brazil, and the USA and Mexico, that resulted in 6 peer-reviewed publications over the last 3 years. The project will reinforce the quality of graduate programs in all partner countries, expand their horizons, and provide a unique environment for students to have a meaningful international experience, practical training with advanced techniques, interdisciplinary course work at the graduate and undergraduate levels.

Among the States of Mexico, Tabasco is considered to have the greatest potential for both intensive and extensive aquaculture development. Moreover, fish consumption constitutes an important part of the rural lifestyle in the State of Tabasco. Therefore, the research efforts being proposed are logical initial steps towards developing sustainable aquaculture of native species in the region, in particular tropical garfish. The research will benefit the entire region by providing pertinent information on nutrition of garfish using purified diets.

Impact Indicators

1. Institutional Linkages

OSU will establish 2-3 formal linkages with domestic and international institutions.

OSU will establish 2-3 informal linkages with institutions worldwide (developing and developed countries farming tropical fish).

2. Training

At least 200 scientists, students, agency personnel and farmers in Brazil and Peru who will be provided with informal training on the use of new rearing technologies for larval/juvenile pacu and surubim.

3. Publications

At least four CRSP titles will be produced by the The Ohio State University (OSU), and collaborating academic institutions in Brazil, Peru and Mexico.

Four publications to be made available electronically via the OSU, CAUNESP (Brazil) and UJAT, and CRSP web pages.

Two fact sheets will be produced for this 6-month project.

Fifty individuals from the US and abroad will receive publications from this project.

Two doctoral dissertations will be completed (some work continues from previous cycle) during the following 6-month study.

Schedule

Study 1.) Reproduction of pacu (*Piaractus mesopotamicus*) and surubim (*Pseudoplatystoma tigrinum*) new paradigm in nutrition of tropical fishes

- January-March 2007, evaluation of pacu and surubim maturity;
- April-June 2007, eggs incubation and larval rearing;
- May-June, 2007, evalution of postspawning status of broodstock;
- June 2007, data analysis and preparation of reports and publications.

Study 2.) New paradigm in nutrition of tropical fishes, paku, surubim and tropical garfish (*Atractosteus tropicus*).

- January-March 2007, formulation and preparation of the experimental diets;
- April-June 2007, first set of feeding experiments and sampling in Brazil, Mexico and USA;

- May-June, 2007, measurement of free amino acids in pacu/surubim tissues
- March-June 2007, histological analyses of tropical gar
- May-June 2007, amino acid analyses in fish from Brazil, second set of experiments;
- June 2007, data analysis and preparation of reports and publications.

Literature Cited

Abucay JS, Mair GC. 1997. Hormonal sex reversal of tilapias: implications of hormone treatment application in closed water systems. *Aquacult. Res*., 28, 841-845.

Aguilera C, Mendoza R, Rodriguez G, Marquez G. 2002. Morphological description of alligator gar and tropical gar larvae, with an emphasis on growth indicators. *T. Am. Fish Soc*., 131, 899-909.

Bennetau-Pelissero C, Breton B, Bennetau B, Corraze G, Le Menn F, Davail-Cuisset B, Helou C, Kaushik SJ. 2001. Effect of genistein-enriched diets on the endocrine process of gametogenesis and on reproduction efficiency of the rainbow trout *Oncorhynchus mykiss*. *Gen. Comp. Endocrinol*., 21, 173-187

Blazquez M, Piferrer F, Zanuy S, Carillo M, Donaldson EM. 1995. Development of sex control techniques for European sea bass (*Dicentrarchus labrax* L.) aquaculture: effects of dietary 17α-methyltestosterone prior to sex differentiation. *Aquaculture*, 135, 329-342.

Blom, J.H. and Dabrowski, K. 1995. Reproductive success of female rainbow trout (Oncorhynchus mykiss) in response to graded dietary ascorbyl monophosphate levels. Biol.Reprod. 52, 1073-1080.

Campos, J.L., 2004. Pintado cutlture in Brazil. Global Aquaculture Advocate 7, 42-43.

Cardoso, E.L., Alves, M.S.D., Ferreira, R.M.A., Godinho, H.P., 1995. Embryogenesis of the neotropical freshwater siluriforme *Pseudoplatystoma coruscans*. Aquatic Living Resources 8, 343-346.

Cerdeira, R.G.P., Ruffino, M.L., Isaac, V.J., 2000. Fish catches among riverside communities around Lago Grande de Monte Alegre, Lower Amazon. Brazil. Fisheries Management and Ecology 7, 355-374.

Charlon, N., Bergot, P., 1986. An improved automatic dry food dispenser for fish larvae. The Progressive Fish-Culturist 48, 156-158.

Ciereszko, A. and Dabrowski, K. 1995. Sperm quality and ascorbic acid concentration in rainbow trout semen are affected by dietary vitamin C. Biol.Reprod. 52, 982-988.

Ciereszko R.E., Dabrowski, K., Ciereszko, A., Ebeling, J., Ottobre, J.S., 1997. Effects of temperature and photoperiod on reproduction of female yellow perch *Perca flavescens*: plasma concentrations of steroid hormones, spontaneous and induced ovulation, and quality of eggs. Journal of the World Aquaculture Society 28, 344-356.

Chen S, Kao YC, Laughton CA. 1997. Binding characteristics of aromatase inhibitors and phytoestrogens to human aromatase. *J. Steroid Biochem. Molec. Biol*., 61, 107-115.

Cicero AFG., Bandieri E, Arletti R. 2001. *Lepidium meyenii* Walp. improves sexual behaviour chromosome number in Maca, *Lepidium meyenii* (*Brassicaceae*). *Econ. Bot.*, 50, 216-223.

Contreras WM, Marquez-Couturier G, Feist GW, Hernandez-Franyutti A, Schreck CB, Giannico G. 2003. Diversification of aquacultural practices by incorporation of native species and implementation of alternative sex inversion techniques. Final Technical Report CRSP Appropriate Technology, 10ATR3, 14p.

Dabrowski, K., 1986. Ontogenetical aspects of nutritional requirements in fish. Comparative Biochemistry and Physiology 85A, 639-655.

Dabrowski, K., Ciereszko, R.E., Blom, J.H., Ottobre, J.S., 1995. Relationship between vitamin C and plasma testosterone in female rainbow trout, *Oncorhynchus mykiss*. Fish Physiology and Biochemistry 14, 409-414.

Dabrowski K, Lee KJ, Rinchard J, Ciereszko A, Blom JH, Ottobre J. 2001. Gossypol isomers bind specifically to blood plasma proteins and spermatozoa of fish fed cottonseed meal-containing diets. *Biochem. Biophys. Acta*, 1525, 37-42.

Dabrowski K, Lee KJ, Rinchard J. 2003. The smallest vertebrate, teleost fish, can utilize synthetic dipeptide-based diets. *J. Nutr*., 133, 4225-4229.

Dabrowski, K., Rinchard, J., Ottobre, J.S., Alcantara, F., Padilla, P., Ciereszko, A., De Jesus, M.J., Kohler, C., 2003. Effect of oxygen saturation in water on reproductive performances of pacu *Piaractus brachypomus*. Journal of the World Aquaculture Society 34, 441-449.

Dabrowski, K., Terjesen, F.B., Zhang, Y., Phang, J.M. and Lee, K.J. 2005. A concept of dietary dipeptides: a step to resolve the problem of amino acid availability in early life of vertebrates. J.exp.Biol. 208: 2885-2894.

Dabrowski, K., Arslan, M., Terjesen, B.F. and Zhang, Y. 2006. The effect of ietary indispensable amino acid imbalances on feed intake: Is there s sensing of deficiency and neural signaling present in fish. Aquaculture (submitted).

Feist G, Schreck CB. 1990. Hormonal content of commercial fish diets and of young coho salmon (*Oncorhynchus kisutch*) fed these diets. *Aquaculture*, 86, 63-75.

Ferrara AM, Irwin ER. 2001. A standardized procedure for internal sex identification in Lepisosteidae. *North Am. Fish Manag.* 21, 956-961.

Filip P, Lopez P, Gilberti G, Coussio J. Ferraro G. 2001. Phenolic compounds in seven South American *Ilex* species. *Fitoterapia*, 72, 774-778.

Froshauer J. 2004. Gamete quality and larval rearing in lake sturgeon (*Acipenser fluvescens*) from the Great Lakes region. MS Thesis, The Ohio State University, 71p.

Fujimoto, R.Y. and Carneiro, D.J. 2001. Adicao de ascorbil polifosfato, como fonte de vitamina C, em dietas para alevinos de pintado, *Pseudoplatystoma corruscans* (Agassiz, 1829). Maringa 23:855-861.

Gale WL, Fitzpatrick MS, Lucero M, Contreras-Sanchez WM, Schreck CB. 1999. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in androgens. *Aquaculture*, 178, 349-357.

Garcia de Leon FJ, Gonzalez-Garcia L, Herrera-Castillo JM, Winemiller KO, Banda-Valdes A. 2001. Ecology of the alligator gar, *Atractosteus spatula*, in the Vicente Guerrero Reservoir, Tamaulipas, Mexico. *The Southwestern Naturalist* 46, 151-157.

Geahlen RL, Koonchanok NM, McLaughlin JL. 1989. Inhibition of protein tyrosine kinase by flavonoids and related compounds. *J. Nat. Prod.*, 52, 982-986.

Gonzales GF, Cordova A, Gonzales C, Chung A, Vega K, Villena A. 2001a. *Lepidium meyenii* (maca) improved semen parameters in adult men. *Asian J. Androl.* 3, 301-303.

Gonzales GF, Ruiz A, Gonzales C, Villegas L, Cordova A. 2001b. Effect of *Lepidium meyenii* (maca) roots on spermatogenesis of male rats. *Asian J. Androl. 3*, 231-233.

Goudie CA, Redner BD, Simco BA, Davis KB. 1983. Feminization of channel catfish by oral administration of steroid sex hormones. *T. Am. Fish. Soc.*, 112, 670-672.

Goudie CA, Shelton WL, Parker NC. 1986. Tissue distribution and elimination of radiolabel led methyl testosterone fed to sexually undifferentiated blue tilapia. *Aquaculture*, 58, 215-226.

Green BW, Veverica KL, Fitzpatrick MS. 1997. Fry and fingerlings production. In: H Egna and C Boyd (Eds.), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, FL, pp. 215-243.

Guerrero RD, Shelton WL. 1974. An aceto-carmine squash method of sexing juvenile fishes. *Prog. Fish Cult.*, 36, 56.

Guigen Y, Baroiller JF, Ricordel MJ, Iseki K, McMeel OM, Martin SAM, Fostier A. 1999. Involvement of estrogens in the process of sex differentiation in two fish species: the rainbow trout (*Oncorhynchus mykiss*) and a tilapia (*Oreochromis niloticus*). *Mol. Reprod. Develop.*, 54, 154-162.

Hamre, K., Ness, T., Espe, M., Holm, J.C., Lie, O., 2001. A formulated diet for Atlantic halibut (*Hippoglossus hipoglossus* L.) larvae. Aquaculture Nutrition 7, 123-132.

Howell WM, Hunsinger RN, Blanchard PD. 1994. Paradoxical feminization of female western mosquito fish during exposure to spironolactone. *Progr. Fish Cult.*, 56, 51-55.

Johnson BL and Noltie DB. 1997. Demography, growth and reproductive allocation in stream-spawning longnose gar. *Transactions Am.Fish.Soc.* 126, 438-466.

Joshi SC, Ahotupa M, Koshan ML, Mäkelä S, Santii R. 1999. Inhibition of aromatase by flavonoids in cultured jeg-3 cells. Pages 39-374 in Kumpulainen JT and Salonen JT, editors. Natural antioxidants and anticarcinogens in nutrition, health and disease. R.S.C. UK.

Kossowski, C., 1996. Perspectives de l'elevage des poisons-charts (Siluroidei) en Amerique du Sud. Aquatic Living Resources 9, 189-195.

Lee KJ, Dabrowski K, Rinchard J, Gomez C, Vilchez C. 2001. The effects of maca meal on growth and sex differentiation of juvenile rainbow trout. Page 361 *in* Book of Abstracts, Aquaculture America 2001, Lake Buena Vista, Florida.

Lee K-J., Dabrowski, K. 2002a. Tissue gossypol and gossypolone enantiomers in rainbow trout fed low and high levels of dietary cottonseed meal. *J. Agric. Food Chem*. 50, 3056-3061.

Lee K-J., Dabrowski K. 2002b. High-performance liquid chromatographic determination of gossypol and gossypolone enantiomer in fish tissues using simultaneous electrochemical and ultraviolet detectors. *J. Chromatogr. B* , 779, 313-319.

Lee K-J, Dabrowski K, Rinchard J, Gomez C, Guz L., Vilchez C. 2004. Supplementation of maca (*Lepidium meyenii*) tuber meal in diets improves growth rate and survival of rainbow trout *Oncorhynchus mykiss* (Walbaum) alevins and juveniles. *Aquacult. Res*., 35, 215-223.

Lee K-J, Dabrowski K, Sandoval M, Miller MJS. 2005. Activity-guided fractionation of phytochemicals of maca meal, their antioxidant activities and effects on growth, feed utilization, and survival in rainbow trout alevins. *Aquaculture* 244, 293-301 .

Lee, K.J., Dabrowski, K., Rinchard, J., Gomez, C., Guz, L., Vilchez, C., 2004. Supplementation of maca (*Lepidium meyenii*) tuber meal in diets improves growth rate and survival of rainbow trout *Oncorhynchus mykiss* (Walbaum) alevins and juveniles. Aquaculture Research 35, 215-223.

Leonardo, A.F.G., 2003. Inducao a maturacao final, ovulacao e fertilizacao do cachara, *Pseudoplatystoma fasciatum*, em cativeiro. Master thesis, Universitidade Estadual Paulista, Centro de Aquicultura da UNESP, Campus de Jaboticabal, Sao Paulo, Brazil, 34p.

Leonardo, A.F.G., Romagosa, E., Borella, M.I., Batlouni, S.R., 2004. Induced spawning of hatchery-raised Brazilian catfish, cachara *Pseudoplatystoma fasciatum* (Linnaeus, 1766). Aquaculture 240, 451-461.

Lin F, Dabrowski K, Timmermans LPM. 1997. Early gonadal development and sexual differentiation in muskellunge (*Esox masquinongy*). *Can. J. Zool.*, 75, 1262-1269.

Lohiya NK, Mishra PK, Pathak N, Manivannan B, Jain, SC. 1999. Reversible azoo-spermia by oral administration of the benzene chromatographic fraction of the chloroform extract of the seeds of *Carica papaya* in rabbits. *Advan. Contraception*, 15, 141-161.

Love J.W. 2002. Sexual dimorphism in spotted gar *Lepisosteus oculatus* from Southeastern Louisiana. *Am. Midl. Nat.*, 147, 393-399.

Mäkelä S, Straus L, Saarien N, Salmi S, Streng T, Joshi S, Santi R. 1999. Dietary phytoestrogens - mechanism of action and possible role in the development of hormonally dependent diseases. Pages 349-355 *in* Kumpulainen JT and Salonen JT. Natural antioxidants and anticarcinogens in nutrition, health and disease. RS.C., UK.

Martino, R.C., Cyrino, J.E.P., Portz, L., Trugo, L.C., 2002. Effect of dietary lipid level on nutritional performance of the surubim, *Pseudoplatystoma coruscans*. Aquaculture 209, 209-218.

Mbahinzireki GB, Dabrowski K, Lee K-J, El-Saidy D, Wisner ER. 2001. Growth, feed utilization and body composition of tilapia (*Oreochromis* sp.) fed cottonseed meal-based diets in a recirculating system. *Aquacult. Nutr.*, 79,189-200.

Mele PG, Dada La, Paz C, Neuman I, Cymeryng CB, Mendez CF, Finkielsten CV, Maciel FC, Podesta EJ. 1997. Involvement of arachidonic acid and the lipoxygenase pathway in mediating luteinizing hormone-induced testosterone synthesis in rat Leydig cells. *Endocrine Research*, 23, 15-26.

Mendoza R, Aguilera C, Rodriguez G, Gonzalez M, Castro R. 2002. Morphophysiological studies on alligator gar (*Atractosteus spatula*) larval development as a basis for their culture and repopulation of their natural habitats. *Rev. Fish Biol. Fisher.*, 12, 133-142.

Miksicek RJ. 1995. Estrogenic flavonoids: structural requirement for biological activity. *Proc. Soc. Exp. Biol. Med*., 208, 44-50.

Mirza JA, Shelton WL. 1988. Induction of gynogenesis and sex reversal in silver carp. *Aquaculture,* 68, 1-14.

Moreau, M.A. and Coomes, O.T. 2006. Potential threat of the international aquarium fish trade to silver aoawana Osteoglossum bicirhosum in Peruvian Amazon. Oryx 40: 152-160.

Moreau R, Dabrowski K. 2000. Biosynthesis of ascorbic acid by extant actinopterygians. *J. Fish Biol*., 57, 733-745.

Moundipa FP, Kamtchouing P, Koueta N, Tantchou J, Foyang NPR, Mbiapo FT. 1999. Effects of aqueous extracts of *Hibiscus macranthus* and *Basella alba* in mature rat testis function. *J. Ethnopharm*., 65, 133-139.

Olszewska M, Wolbis M. 2002. Flavonoids from the leaves of *Prunus spinosa* L. *Polish J. Chem*., 76, 967-974.

Ottobre, J.S., Houmard, B.S., Ottobre, A.C., 1989. Luteal production of steroids and prostaglandins during stimulated early pregnancy in the primate: differential regulation of steroid production by chorionic gonadotropin. Biology of Reproduction 41, 393-400.

Papoulias DM, Noltie DB, Tillitt DE. 2000. Effects of methyl testosterone exposure on sexual differentiation in medaka, *Oryzias latipes*. *Mar. Environ. Res*., 50, 181-184.

Park KH, Rodriguez-Montes GA, Bonello P, Lee K-J, Dabrowski K. Determination of quercitin concentrations in fish tissues after feeding quercitin-containing diets. Submitted to *Aquacult. Intern.*

Pelissero C, Lenczowski MJ, Chinzi D, Davail-Cuisset B, Sumpter JP, Fostier A. 1996. Effects of flavonoids on aromatase activity, an *in vitro* study. *J. Steroid Biochem. Mol. Biol*., 57, 215-223.

Piferrer F, Donaldson EM. 1989. Gonadal differentiation in coho salmon, *Oncorhynchus kisutch*, after a single treatment with androgen or estrogen at different stages during ontogenesis. *Aquaculture,* 77, 251-262.

Quiros CE, Epperson A, Hu HJ, Holle M. 1996. Physiological studies and determination of chromosome number in Maca, *Lepidium meyenii* (Brassicaceae). *Econ. Bot*., 50, 216-223.

Rinchard J, Dabrowski K, Garcia-Abiado MAR, Ottobre J. 1999. Uptake and depletion of 17a-methyltestosterone during induction of masculinization in muskellunge, *Esox masquinongy*: effect on plasma steroids and sex reversal. *Steroids*, 64, 518-525.

Rinchard, J., Garcia-Abiado, M.A., Dabrowski, K., Ottobre, J., Schmidt, D., 2002a. Induction of gynogenesis, rearing and gonad development in muskellunge *Esox masquinongy*. Journal of Fish Biology 60, 427-441.

Rinchard, J., Dabrowski, K., Ottobre, J., 2002b. Changes of plasma steroid concentrations associated with spontaneous or induced ovulation in yellow perch *Perca flavescens*. Fish Physiology and Biochemistry 26, 239-248.

Rinchard J, Mbahinzireki G, Dabrowski K, Lee K-J, Garcia-Abiado M.A., Ottobre J. 2002c. Effects of dietary cottonseed meal protein level on growth, gonad development and plasma sex steroid hormones in tropical fish tilapia, Oreochromis sp. *Aquacul. Int*., 10, 11-28.

Rodriguez G, Contreras WM, Dabrowski K. 2005. Continued studies on the use of phystochemicals as possible sex differentiation affecting agents in Tilapia nilotica by dietary administration and immersion treatments. Aquaculture America 2005, Jan.17-20 2005 New Orleans Louisiana USA.

Santell RC, Chang YC, Nair MG, Helferich WG. 1997. Dietary genistein exerts estrogenic effects upon the uterus, mammary gland and the hypo thalami/pituitary axis in rats. *J. Nutr*., 127, 263-269.

Solar II, Donaldson EM, Hunter GA. 1984. Optimization of treatment regimes for controlled sex differentiation and sterilization in wild rainbow trout (*Salmo gairdneri* Richardson) by oral administration of 17a-methyltestosterone. *Aquaculture*, 42, 129-139.

Steel, R.G.D., Torrie, J.H., 1980. Principles and Procedures of Statistics. McGraw-Hill Book Company, New York.

Tzchori I, Degani G, Elisha R, Eliyahu R, Hurvitz A, Vaya J and Moav B. 2004. The influence of phytoestrogens and oeastrodiol on growth and sex determination in the European eel (Anguilla anguilla). *Aquacult. Res*., 35, 1213-1219.

van den Hurk R, Lambert JGD, Peute J. 1989. Steroidogenesis in the gonads of rainbow trout fry (*Salmo gairdneri*) before and after the onset of gonadal sex differentiation. *Reprod. Nutr. Dev.,* 22, 413-425.

Zar JH. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey.

Zheng BL, He K, Kim CH, Rogers L, Shao Y, Huang ZY, Lu Y, Yan SJ, Qien LC, Zheng QY. 2000. Effect of a lipidic extract from *Lepidium meyenii* on sexual behavior in mice and rats. *Urology*, 55, 598-602.

Aquaculture CRSP Support for IIFET 2006 Portsmouth

Applied Technology and Extension Methodologies (12 ATE15) / Activity / USA

Collaborating Institutions

Oregon State University
Richard S. Johnston, Ann L. Shriver

Objectives

The main objective of the requested support is to enhance the aquaculture-economics related content of the twelfth biennial conference of the International Institute of Fisheries Economics and Trade (IIFET) to be held in Portsmouth, UK, in July 2006. Sub-objectives include:

- Improving opportunities for peer interaction by developing country scientists involved in aquaculture economics related research and extension
- Enhancing the conference proceedings by including more aquaculture content, thereby improving the worldwide diffusion of aquaculture research results

Significance

IIFET is the world's only global organization of fisheries and aquaculture economists. In existence since 1982, the organization has held twelve biennial international conferences, gathering academic researchers and trainers, government resource managers, and industry practitioners in a single global forum. Individuals from over 65 countries, covering all of the world's major fishing and aquaculture regions, have presented research and exchanged ideas, information, and potential solutions to fisheries management, seafood trade, and aquaculture issues and problems. IIFET Conferences provide opportunities for participants from all over the world, and from varied professional orientations, to gather up to date information on how issues are being tackled in other countries, successful and unsuccessful strategies and methods, and varied perspectives. In addition conference participants develop critical peer networks which enable future research collaboration.

ACRSP support will enable the conference organizers to broaden the coverage of aquaculture related issues examined at IIFET 2006 Portsmouth. Themes suggested by ACRSP staff can be added to the list of topics, which will attract the submission of presentations from a variety of countries. Submitted papers can then be organized into sessions during which participants will have opportunities to interact both in larger groups, and one on one, creating a positive professional dynamic for future interactions.

In order to attract and reward excellent graduate students, IIFET and the conference organizers will establish and series of awards to total $900, for the three "Best Student Papers" in aquaculture topics related to low income food deficit countries. IIFET will develop rules and guidelines for the award competition, and solicit papers. The input of ARSP will be sought on selection criteria. Prizes will be awarded in a ceremony at the conference, with appropriate recognition of USAID and ACRSP support – if possible by an ACRSP representative.

In addition, partial travel support grants will be made to 35 developing country scientists to enable their participation in the IIFET 2006 Portsmouth conference. IIFET and the conference organizers will solicit and prioritize applications and interact with potential awardees, to determine what resources they have available to them and which we need to provide. Input on final selection will be sought from ACRSP advisors.

Benefits:

1. Improved coverage of aquaculture topics at conference
2. Increased participation of aquaculture-social science researchers from around the world
3. Strengthening of IIFET network capabilities in aquaculture /seafood marketing, enabling researchers to maintain and develop research relationships throughout the world
4. Improved recognition of the significance of the role of aquaculture in meeting the world demand for fish products
5. Improved coverage of aquaculture topics in conference proceedings, improving post-conference diffusion of aquaculture-related research
6. Improved interaction between ACRSP and IIFET social science networks
7. Acknowledgement of USAID/ACRSP support on Conference Proceedings CD, conference website, and other conference materials
8. Provision of conference registration to participant(s) from CRSP headquarters