Pond Dynamics/Aquaculture Collaborative Research Support Program

Seventeenth Annual Administrative Report

1 August 1998 to 31 July 1999

Acknowledgments
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This report addresses program accomplishments of the Pond Dynamics/Aquaculture Collaborative Research Support Program during the reporting period of 1 August 1998 to 31 July 1999. Program activities are funded in part by the United States Agency for International Development (USAID) under Grant No. LAG-G-00-96-90015-00.

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INTRODUCTION

The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) conducts research that contributes significantly to the removal of major constraints to aquacultural development, thereby promoting economic growth and enhancing food security. This report describes the activities and accomplishments of the PD/A CRSP during the period 1 August 1998 to 31 July 1999.

The PD/A CRSP is funded by the United States Agency for International Development (USAID), under authority of the International Development and Food Assistance Act of 1975 (PL 94-161), and by the universities and institutions that participate in the CRSP. This cohesive program of research is carried out in selected developing countries and the United States by teams of US and host country scientists. Now operating under its fourth USAID grant since 1982, the CRSP is guided by the concepts and direction set down in the *Continuation Plan 1996–2001*, which was awarded funding under USAID Grant No. LAG-G-00-96-90015-00. This grant authorizes program activities from 1 August 1996 to 31 July 2001. An overview of CRSP history and how the program has evolved since its inception is provided in Appendix 1.

The activities of this multi-national, multi-institutional, and multidisciplinary program are administered by Oregon State University (OSU), which functions as Management Entity (ME) and has technical, programmatic, and fiscal responsibility for the performance of grant provisions. ME activities at OSU are carried out through a Program Management Office (PMO), which is supported in the task of program administration by three advisory bodies: the Board of Directors (BOD), the Technical Committee (TC), and the External Evaluation Panel (EEP). PMO staff as well as advisory group membership during the reporting period appears in Appendix 2.

ANNUAL HIGHLIGHTS

The most significant factor affecting the operations of the Pond Dynamics/Aquaculture CRSP in the third year of operations under its current 1996–2001 grant was a USAID funding cut of $1.2 million as compared to the amount authorized in the grant for the same period. Despite the enormous funding setback, the CRSP carried out an impressive array of activities in the reporting period. The major decisions and accomplishments by the Program Management Office, Board of Directors, External Evaluation Panel, and Technical Committee are noted below.

- The PMO coordinated a lengthy and rigorous process for determining Ninth Work Plan allocations, an allocation process made more difficult than usual in the context of the FY98 budget cut. While the actual proposal review took place in the previous reporting period, a two-part proposal ranking exercise necessitated an additional administrative step to clarify the relative weights of scores. Once a decisionmaking framework was established, the portfolio of proposals receiving meritorious scores was further assessed and then narrowed to achieve balance among both geographic regions and CRSP research themes. Ninth Work Plan funding decisions were made in October 1998.

- The CRSPs former Honduras project, under the direction of researchers from the Department of Fisheries and Allied Aquacultures, Auburn University, declined an award for funding of Ninth Work Plan research and advised the ME of its intent in January 1999 to withdraw from the program. A combination of factors likely contributed to this decision, among them a USAID decision to discontinue funding for shrimp research and the program's fiscal and management direction away from fully supporting expatriate researchers' salaries. In April 1999, Auburn University dissolved its existing Memorandum of Understanding with the Secretaría de Agricultura y Ganadería in Honduras.

- The ME was apprised by Auburn University in September 1998 of a possible Honduras project subcontract shortfall. Over the course of several months and many negotiations with USAID, PD/A CRSP Director Hillary Egna was able to enlist the support of USAID to grant a one-time closedown award of $55,000 for the PD/A CRSP Honduras project.

- On 22 March 1999 the Management Entity issued a restricted Request for Proposals (RFP) for a lead institution for a new CRSP Honduras project with a deadline of 12 April 1999. Two proposals were received, and these were sent out for review to the BOD, EEP, TC, and a number of reviewers external to the program. Elements in each proposal received favorable reviews, but neither alone was evaluated as sufficiently substantive to be awarded as written. After discussion, the proponents agreed to redesign and merge their proposals. New subcontracts with the Department of Biological and Agricultural Engineering, University of Georgia, and with the Department of Agricultural Economics and Rural Sociology, Auburn University, were in progress by the end of the reporting period. The University of Georgia has lead responsibility for the Honduras project, with Auburn University as a collaborating US institution. The Honduran counterpart institution is the Escuela Agrícola Panamericana.

- The PD/A CRSPs Ninth Work Plan, describing research activities to be conducted from 1 August 1998 through 30 April 2001, was printed in early 1999. The CRSPs reduced FY98 budget necessitated major revisions to the

original Ninth Work Plan research portfolio to ensure adequate coverage of critical target areas, including the elimination of the Global Experiment and other studies and curtailment of several research support activities. In addition, the start dates of Ninth Work Plan investigations were staged over a nine-month period to allow for funding of as much of the original research portfolio as possible. The staged start dates of Ninth Work Plan research projects are listed in Appendix 4.

Projects having completed Eighth Work Plan research were first to receive funds for Ninth Work Plan investigations, in accordance with the ME policy that there be no overlap between the two work plans. Building into this policy some flexibility, the ME allowed a one-time exemption to this policy; by request to the ME, a principal investigator could carry forward one Eighth Work Plan study while receiving funds to commence Ninth Work Plan research.

The following projects were granted exemptions to carry forward one Eighth Work Plan study: Kenya project (Auburn University and Oregon State University); Adoption/Diffusion project (Auburn University); Reproduction Control project (Auburn University); and Thailand project (University of Michigan). By the close of this reporting period, the Thailand project had completed its outstanding Eighth Work Plan investigation.

- The PD/A CRSP has typically held a centralized annual meeting, providing a forum for meetings among a number of program components—program researchers and administrators, the TC, the BOD, and EEP—over the course of several days. No annual meeting took place in 1999 as a consequence of the FY98 funding cut. The decision to not hold an annual meeting was arrived at in consultation with the BOD, EEP, and TC. Despite the cancellation of the annual meeting, these advisory bodies were involved in program activities by mail vote.

- The BOD and EEP participated in several major program activities in the reporting period including providing input for Ninth Work Plan allocation decisions (September and October 1998) and reviewing proposals for the Honduras Lead Project award (April 1999).

- As a result of the cancellation of the annual meeting, the 1999 TC membership election was held by mail vote in lieu of in person. Newly elected to the TC were CRSP principal investigators John Bolte, Claude Boyd, Tom Popma, and Salvador Tello, and external at-large member Marc Verdegem; Joe Molnar was re-elected. A complete listing of Technical Committee and Subcommittee members appears in Appendix 2.

- Other TC activities in the reporting period included providing input for Ninth Work Plan allocation decisions; reviewing proposals for the Honduras Lead Project award; and developing a less administratively intense process for principal investigators to report work plan changes owing to the need for the PMO to cut back on administrative services as a result of the FY98 budget cut.

- As mentioned above, the process for documenting work plan changes was modified in the reporting period. Instead of a requirement to secure the prospective approval of the TC and PMO, principal investigators will now report changes to work plans in the regular process of annual reporting. Changes that significantly alter the objectives or scope of a research plan are still required to be brought forward for consideration before being implemented. While the process for reporting changes has been modified, the changes will continue to be tracked and documented in work plan addenda.

- The PMO produced the *Second Addendum to the Eighth Work Plan* in early 1999 to document changes necessitated in the course of research to an experimental design or schedule. Changes occurring since the compilation of the Second Addendum will appear in a forthcoming Addendum, which will also likely include any changes that have been necessitated to investigations funded under the Ninth Work Plan.

- The Scope-of-Work for the 1997 EEP report was approved by USAID and distributed to EEP members in January 1998. A revised Scope-of-Work was developed at the request of EEP members in September 1998, and the report submittal date was amended from 30 April 1998 to 1 December 1998. The EEP submitted its final report to the PMO in mid-December 1998. The report was distributed to program participants for comment, and this input was incorporated into the MEs response. The *Annual External Evaluation Panel Review Report of the PD/A CRSP for the Period January 1997–January 1998*, containing the EEPs report and the responses of the ME, was published in mid-January 1999 and thereafter distributed to USAID and program participants.

- The work of the PD/A CRSP was represented in an exhibit of 24 photographs entitled "Mutual Benefits for Developing Countries and the United States," at a display in the USAID Information Center at the Ronald Reagan Building in Washington, DC, from 21 September through 31 December 1998. The PMO worked closely with the CRSP Council to bring the exhibit together. The exhibit was designed to display the activities and accomplishments of the nine CRSPs in the developing world and the US. A virtual tour of the exhibit continues to be available on the Internet at <www.ianr.unl. edu/crsps/virttour.htm>.

- The opening of the CRSP photo exhibit coincided with the September meeting of BIFAD, the Board for International Food and Agricultural Development. Director Egna attended the exhibit opening as well as the BIFAD meeting.

- The Director participated in CRSP Council meetings (both by teleconference and in person) throughout the reporting period. In addition, the Director attended the 1998 International Center's Week in Washington, DC, in October.

- A special symposium entitled "CRSP: A Unique USAID Partnership with Higher Education" was a feature of the October 1998 Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. The meetings, with a theme of Protecting Land, Water, and Biological Resources, were held in Baltimore, Maryland. CRSP Director Dr. Hillary Egna co-authored a paper, "Introduction, Historical Development, and Overview of the CRSPs," which was presented at the symposium. Additionally, the PD/A CRSP presented a poster authored by Egna and John Baker entitled "The Pond Dynamics/Aquaculture CRSP: Contributions to International Aquaculture."

- As part of a joint CRSP Council activity, the PD/A CRSP participated in a case study project coordinated by the Association of International Agriculture and Rural Development (AIARD) to illustrate the win-win benefits of investments in international agriculture and rural development to both the United States and developing countries. The first phase of the project included a compendium of case studies distributed on the Internet and in hard copy to policy and decision makers, universities, nongovernmental organizations, and private sector companies.

- Director Egna and Assistant Director Cormac Craven attended a March 1999 USAID workshop in Newport, Oregon, at the invitation of USAIDs Africa Bureau and Management Systems International (MSI). "Reengineering Partnerships in USAIDs Environmental and Natural Resource Management Programs in Africa" was the title of the two-day workshop designed to promote a more "outcome/results" approach to environmental and natural resource management projects, rather than focusing on the function or process of a project.

- At the invitation of Food and Agriculture Organization of the United Nations, Director Egna attended the March 1999 "Joint FAO/NACA Expert Consultation for the Development of a Regional Collaborative Programme on Sustainable Aquaculture for Rural Development (SARDev)" in Thailand. Egna presented a paper with CRSP researcher Dr. C. Kwei Lin entitled "The Pond Dynamics/Aquaculture CRSP: Developing Technologies and Networks for Sustainable Aquaculture and Rural Development."

- In June 1999, proponent and PD/A CRSP Director Hillary Egna submitted a proposal entitled "Improving Nutritional Status of Children under Five through Enhanced Micronutrient Availability, Access and Utilization" to USAIDs Center for Economic Growth and Agricultural Development, Office of Agriculture and Food Security, Global Bureau. Collaboration among existing organizations with which the CRSP enjoys linkages and exploration of new potential partners is axiomatic to the competitive advantage of this potential buy-in from USAID, as is the ability to call upon the established PD/A CRSP host country institution network. A decision on the award was not anticipated until sometime into next year's CRSP reporting year.

- Two new memoranda of understanding between CRSP host country partners and US institutions were executed in the reporting period. Central Luzon State University, Philippines, and the University of Hawaii formalized their working relationship in September 1998. In June 1999, the MOU between Universidad Juárez Autónoma de Tabasco, Mexico, and Oregon State University was officially in place. In addition, a new MOU between the Escuela Agrícola Panamericana, Honduras, and the University of Georgia was in progress at the close of the reporting period. A complete listing of active memoranda of understanding appears on page 83.

RESEARCH AND RESEARCH SUPPORT AGENDA

Research conducted by the PD/A CRSP since 1982 has helped to remove some of the constraints facing aquaculture development. Still, aquaculture continues to be hampered in several important areas. In developing the *Continuation Plan 1996–2001*, the CRSP undertook an in-depth constraints analysis. That analysis led to the identification of a number of major constraints that limit the development of extensive to semi-intensive sustainable aquaculture systems. Chief among these were:

- Inefficient and inconsistent aquacultural productivity
- Negative environmental effects resulting from aquaculture operations
- A poor understanding of social and economic factors
- Insufficient human capacity development
- Poor or outdated information management
- Limited networking capacities

The *Continuation Plan 1996–2001* responds to the first three of these factors by setting a research agenda that addresses constraints to aquacultural productivity, environmental effects, and social and economic aspects of aquaculture. The second three constraints are addressed by a research support agenda committed to improving human capacity development, information management, and networking. To carry out that agenda, the program has a Research Support component comprising three projects:

- An Education Development project dedicated to strengthening human capacity in participating countries and regions;
- A project that manages the CRSP Central Database, the largest repository of standardized data related to aquaculture; and
- An Information Management project for reporting and disseminating project and program outputs via publications and a central website.

The PD/A CRSPs multidisciplinary team of researchers and advisors represents a wide range of US and international aquacultural experience. During the reporting period, participating US institutions included:

- Auburn University
- The Ohio State University
- Oregon State University
- Southern Illinois University at Carbondale
- University of Arizona
- University of Arkansas at Pine Bluff
- University of California, Davis

- University of Delaware
- University of Hawaii
- University of Georgia
- The University of Michigan
- University of Oklahoma
- University of Texas

Research activities were conducted at host country sites in Honduras, Peru, Kenya, Thailand, and the Philippines, at the participating US institutions, and with new collaborators in Mexico, Guatemala, and Panama. Memoranda of Understanding, representing formal ties between US and host country institutions, which were in place (or in progress) during the reporting period include those between:

- Auburn University and the Secretaría de Agricultura y Ganadería, Republic of Honduras (dissolved in April 1999)
- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico
- Oregon State University and the Department of Fisheries, Kenya
- University of Hawaii at Manoa and Freshwater Aquaculture Center, Central Luzon State University
- Southern Illinois University at Carbondale and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana
- The University of Michigan and the Asian Institute of Technology, Thailand
- University of Georgia and Escuela Agrícola Panamericana, Zamorano, Honduras (in progress as of 31 July 1999)

RESEARCH PROGRAM FRAMEWORK

The *Continuation Plan 1996–2001* program framework, and the foundation for the current portfolio of PD/A CRSP research projects, consists of two building blocks: research in sustainable production systems and research support activities.

The sustainable production systems research framework is organized into the areas of production optimization, environmental effects, and social and economic aspects. Each area is further subdivided into specific research themes, which are the thematic areas of research needed to remove constraints to the development of more sustainable aquaculture. The results framework for research areas as presented in the *Continuation Plan 1996–2001* is summarized in Table 1, and the results framework for research themes is provided in Tables 2 through 4. Research areas and their respective themes are listed here:

Research Area:	Production Optimization
Research Themes:	Pond Dynamics
	Feeds and Fertilizers
	Reproduction Control
	Aquaculture Systems Modeling
	New Aquaculture Systems/New Species
Research Area:	Environmental Effects
Research Themes:	Effluents and Pollution
	Appropriate Technology
	Responsible Science Policy
	Geographic Information Systems: Planning, Policy, and Global Data Analysis
Research Area:	Social and Economic Aspects
Research Themes:	Marketing and Economic Analysis
	Adoption/Diffusion
	Food Security
	Regional Analysis: Human-Environment Interactions
	Decision Support Systems
	Product Diversification

NINTH WORK PLAN

The Ninth Work Plan of the Pond Dynamics/Aquaculture CRSP was developed by the CRSP Technical Committee and describes activities to be conducted by the CRSP from 1 August 1998 through 30 April 2001. CRSP work plans have typically covered two-year periods. This holds true under the Ninth Work Plan for individual investigations, but while the overall time frame is greater than two years, no one investigation extends beyond a two-year period.

Increasing the time period of the overall work plan was necessitated by the CRSPs substantially reduced USAID budget allocation for the third year of the *Continuation Plan*—thus the start dates of Ninth Work Plan investigations were staged over a nine-month period to allow for funding of as much of the original research portfolio as possible.

Despite the staged funding approach, the budget cut also necessitated major revisions to the portfolio to ensure adequate coverage of the critical areas within the newly imposed financial constraints, such as the elimination of the Global Experiment (see below) and other studies and curtailment of several research support activities. Ninth Work Plan research is underway in Mexico, Honduras, Peru, Kenya, the Philippines, and Thailand, as well as in the US.

Earlier PD/A CRSP work plans—the first through the third—specified identical experiments (called Global Experiments) at all CRSP sites to provide a baseline for comparisons among sites. This approach was changed starting with the Fourth Work Plan when different but related experiments were also conducted at the various sites. The particular topics studied at each site were based on the research and information needs in each country, as identified by the Technical Committee.

The body of investigations funded under the Eighth and Ninth Work Plans reflects the broadening of research as was proposed in the *Continuation Plan 1996–2001* as well as increased integration among sites. In addition to prime site activities, CRSP research now underway includes a cross-cutting, thematic approach for investigations that may be conducted at one or more PD/A CRSP sites and whose results may have wider application than results from prime and companion site investigations. Status updates on Eighth Work Plan research that had not yet concluded by the end of the current reporting period are contained herein, as are updates on research funded under the Ninth Work Plan.

Researchers will find in the course of conducting their work that methods or schedules may need to be modified. The Program Management Office tracks such changes to assure continuing accountability for program awards. Reflecting methods and schedule changes to the funded research under the Eighth Work Plan, work plan addenda were printed in Spring 1998 and Spring 1999. Additional changes to Eighth Work Plan research as well as changes to Ninth Work Plan research will be collected and printed in a forthcoming work plan addendum document.

Table 1. Results Framework for Research Areas within the *Production Systems* PD/A CRSP Building Block.

PRODUCTION SYSTEMS				
PD/A CRSP RESEARCH AREA	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Production Optimization	* To increase the overall sustainability of aquacultural production systems through production optimization.	* Productivity and sustainability can be increased with better management of pond inputs, waste reduction, use of underutilized resources, and the conservation of non-renewable resources.	* More sustainable, efficient production systems appropriate for the biophysical environment.	* Improved scientific understanding of pond processes. * Improved pond management strategies. * Significant advances in reproduction technology. * Development of alternative aquacultural systems.
Environmental Effects	* To minimize the detrimental environmental impacts of aquaculture operations through improved pond management.	* Sustainable aquaculture is possible only in a healthy environment. Detrimental effects of aquaculture operations can be reduced or eliminated through changed management development.	* Reduced detrimental environmental impact of aquaculture operations.	* Development of methodologies to assess and reduce negative environmental impacts of aquaculture operations.
Social and Economic Aspects	* To increase our understanding of the social and economic implications of aquaculture development.	* Successful aquaculture development is contingent upon the social and economic constraints of each location.	* Improved viability of subsistence and commercial aquaculture farms at various sites.	* Positive net returns to capital investment. * Positive financial and nutritional impact on participating household communities.

Table 2. Results Framework for Research Themes within the *Production Optimization* PD/A CRSP Research Area.

PRODUCTION OPTIMIZATION				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Pond Dynamics	* To further our understanding of the influence of pond processes on pond productivity.	* Knowledge of pond processes and organisms is necessary to improve productivity and fine-tune existing pond management guidelines as well as to reduce production losses and waste as aquaculture systems become more intensified.	* Improved predictability of pond processes and pond productivity.	* Illumination of the role of heterotrophy on pond production. * Development of pond bottom management techniques through a better understanding of pond soil-water interactions.
Feeds and Fertilizers	* To optimize use of pond inputs.	* Optimal fish growth can be achieved if the culture species' nutritional needs are addressed.	* Improved capabilities for prescribing optimal feed/fertilizer inputs to meet economic and environmental criteria.	* Reduce inputs of fertilizers and/or feeds to produce one unit of fish.
Reproduction Control	* To develop short- and long-term solutions to reproduction technology problems.	* Guaranteed seed supply and reliable broodstock is essential for the undertaking and maintenance of fish farming. Gender manipulations add management options which increase economic viability in intensified systems.	* Improved efficiency, efficacy, and safety of steroid use. * Successful production of sufficient amounts of YY-males. * Successful use of piscivorous fish to control excess tilapia offspring.	* Development of procedures that guarantee the safety of animals and farmers during steroid use. * Demonstration of the functional nature of YY-males for producing all male tilapia offspring. * Demonstration of the effects of piscivorous fish on tilapia production.
Aquaculture Systems Modeling	* To analyze and synthesize research results into models which better describe system processes.	* Models demonstrate the state of our current understanding of systems and system processes and provide direction for further inquiries.	* Improved representation of systems processes.	* Simulations which adequately describe biophysical processes in ponds.
New Aquaculture Systems/New Species	* To develop alternative aquaculture systems through the use of new or underutilized resources or through resource partitioning. * To develop culture systems for local and native species.	* Production can be tailored to local conditions through diversification of aquaculture systems.	* Development of production procedures for new species, combinations of species and/or the establishment of new aquaculture systems.	* Foundation for the use of other species and/or new species combinations in pond aquaculture.

Table 3. Results Framework for Research Themes within the *Environmental Effects* PD/A CRSP Research Area.

ENVIRONMENTAL EFFECTS				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Effluents	* To improve effluent water quality and water use efficiency.	* Reduction of excess nutrient loads will lessen environmental impact.	* Reduced nutrient loading.	* Demonstration of the effectiveness of CRSP guidelines to reduce effluent load.
Appropriate Technology	* To develop socially acceptable and environmentally friendly aquaculture technologies.	* Modification of current practices, tools, and facilities will lessen environmental impact.	* Reduced resource use in socially acceptable ways.	* Development of innovative approaches which result in a reduction of pond inputs, energy and/or excessively intensive management practices.
Responsible Science Policy	* To develop policies and guidelines that will govern the CRSPs work with exotic species, pharmaceuticals, and biotechnology.	* Communication and cooperation between potential host countries and the CRSP will be facilitated by a codified set of guidelines.	* Improved interaction with host country researchers and government officials in the area of exotics/drugs.	* Faster processing of necessary paperwork by host country officials.
GIS: Planning, Policy, Global Data Analysis	* To analyze and synthesize existing information at local, national, and regional scales.	* Integrating tools are required to assess potential and impact of aquaculture operations at scales above individual ponds.	* Analysis tools to determine environmental effects of proposed aquaculture locations.	* Assembly of datasets containing relevant summaries of CRSP research and data.

Table 4. Results Framework for Research Themes within the *Social and Economic Aspects* PD/A CRSP Research Area.

SOCIAL AND ECONOMIC ASPECTS				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Marketing and Economic Analysis	* To develop marketing strategies for aquacultural products based on analysis of markets.	* Financial success is dependent upon meeting market demands.	* Improved pricing of aquaculture products. * Improved sales of products. * Reduced risk of adopting CRSP pond management technologies.	* Provision of information which (when applied) will allow the targeted aquaculture industry to access new markets and increase the volume of sold goods.
Adoption/Diffusion	* To identify barriers to the acceptance of new aquaculture technologies.	* Aquaculture technology will be adopted if the social, economic, and technological requirements of the local community are addressed. In order to create a successful aquaculture development, these requirements must be known by decision-makers.	* Successfully identified barriers to adoption of CRSP practices.	* Provision of guidance to extension workers to further increase acceptance of CRSP technologies in host countries.
Food Security	* To improve understanding of food security issues and their relationship to aquacultural practices.	* Extensive fish farming can successfully provide a source of necessary animal protein for the rural poor.	* Assessment of food security needs of the rural poor, and the impact of aquaculture on dietary intake of animal protein.	* Provision of information on nutritional status and needs of rural poor. * Assessment of technology transfer impact on rural poor.
Regional Analysis: Human-Environment Interactions	* To develop an information base of the effects of socio-economic conditions on the development of a local, national or regional aquaculture industry.	* Aquacultural development is often seriously constrained by the regulatory, social, and economic environment. These large-scale constraints must be known in order to implement a successful aquaculture development strategy.	* Improved understanding of the socioeconomic conditions that constrain aquaculture development.	* Development of recommendations that enable host countries to establish a successful aquaculture development strategy.
Decision Support Systems	* To refine computer applications to assist planners and managers in the development of economically efficient production technologies.	* Profitability can be improved through computer exploration of the effects of different management strategies on pond production potential and economic performance.	* Increased use of DSS by target clientele.	* Delivery of completed DSS to CRSP researchers, in-country personnel, development agencies, US producers, and extension agents. * Positive feedback from DSS users.
Product Diversification	* To develop a range of aquaculture products.	* Consumption of aquaculture products will increase if consumers are given a variety of product options.	* Availability of new aquaculture products in local markets.	* Development of processes and guidelines for the production of new aquacultural products.

RESEARCH SUPPORT

Preparation of the *Continuation Plan 1996–2001* entailed a review of current aquaculture literature and discussions with many aquaculturists to determine research needs and constraints to aquaculture development. In addition to limited knowledge of various aspects of production systems, lack of access to training and to information were found to restrict aquaculture development. In response to these needs, the program created research support as a separate building block of its proposed research activities. Research support activities build capacity through education, technology transfer, information management, and networking.

Central Database, Education Development, and Information Management and Networking are the three branches of the CRSPs research support activities. Annual activity reports for these three projects make up this chapter.

CENTRAL DATABASE MANAGEMENT

MOU No. RD009G

Staff

Oregon State University, Corvallis, Oregon

John Bolte	US Co-Principal Investigator, Project Leader
Doug Ernst	Database Manager (Research Assistant, US)

Networking and Educational Outreach

The PD/A CRSP website continues to expand its network of electronic resources through the work of CRSP researcher and Database Manager Doug Ernst with links to CAMEL Database, the Agrisurf web index, and the National Fishing Industry Education Center of TAFE located in NSW, Australia. The CAMEL database, a collection of databases created at Oregon State University, can be accessed by internal and external data and literature search and referencing systems. Agrisurf web index, an invaluable resource for students, researchers, and aquaculturists, contains over 12,000 separate agriculture-related websites in its directory that link users to products and information in aquaculture and agriculture. The National Fishing Industry Education Centre of TAFE provides training, aquaculture industry news and information, and learning resources to members of the aquaculture community.

Ernst visited two high schools in Oregon to answer questions about aquaculture, supply literature about fish culture, and provide tilapia fry for production.

Publication

Ernst, D., 1999. Fish performance engineering, In: R. Stickney (Editor), Encyclopedia of Aquaculture. John Wiley and Sons (submitted).

Work Plan Activities

The following report describes Central Database activities carried out during the first year of the Ninth Work Plan.

REPORT: PD/A CRSP CENTRAL DATABASE MANAGEMENT AND DEVELOPMENT

Ninth Work Plan, Database Management 2 (9DM2)

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BACKGROUND

The PD/A CRSP Central Database is a centralized storage and retrieval system for aquaculture research data (Hopkins et al., 1987; Batterson et al., 1991; Bolte et al., 1998; Ernst et al., 1997; Ernst and Bolte, 1999). The Database currently contains datasets from CRSP-sponsored research, but it is open to other aquaculture research with compatible objectives and compliance with standardized methodology. The Database is available cost-free and is of interest to researchers, educators and students, outreach and extension agents, and producers in pond-based aquaculture. Datasets may be searched and retrieved based on specified location (research site), calendar year, fish species, fish culture method, and desired type of data. An interface to the data and related information in the Database is provided at the Database website, located at <biosys.bre.orst.edu/crspDB/>. For intensive users of the Database, the contents are also available on electronic media.

The Database currently contains over 100 aquaculture production studies and represents the world's largest inventory of standardized aquaculture data. The majority of studies currently in the Database are for production of Nile tilapia (*Oreochromis niloticus*) in subtropical and tropical solar algae ponds receiving inputs of plant materials, inorganic/organic fertilizers, and/or prepared feeds. Studies of other pond fishes and penaeid shrimp, under monoculture and polyculture management, are also available. Countries with research and research-support projects that have contributed to the Database include Egypt, Honduras, Indonesia, Kenya, Panama, Peru, Philippines, Rwanda, Thailand, and the USA.

The Database was started by the CRSP in 1985. Rationales for its ongoing development include:

1) To provide a mechanism for analysis of variance and multivariate analyses among geographically dispersed aquaculture research sites, in addition to analyses within single ponds and among ponds at a single location; and
2) To support development of predictive models for aquaculture pond processes and software for aquaculture design and management. More simply, the Database can be applied directly to aquaculture design and management analyses.

For this purpose, the Database provides comprehensive methods and results of applied studies for specific fish culture sites (regions), culture methods, and fish species. These datasets can serve as empirical benchmarks for evaluation of fish production at a given facility and provide a basis for the evaluation of alternative design and management methods.

OBJECTIVES

Objectives of work to be completed under the Ninth Work Plan address needs of both data suppliers and users. For data suppliers, objectives are to support and enhance the ongoing entry of new datasets into the Database, including current research projects and past-due data submissions from CRSP research projects prior to the Eighth Work Plan (that is, before 1 August 1996). This effort includes continued improvements in the technical support provided to data suppliers and in the mechanisms used to administer data submissions from CRSP research projects. For data users, objectives are to improve Database query procedures, provide linkages for extracted datasets to related information resources, and provide statistical processing and data reduction for extracted datasets.

Objectives of this report are to describe accomplishments to date and ongoing work for each of the tasks to be completed under the Ninth Work Plan. Technical methods and Internet and software tools used in this work are described in Ernst et al. (1997). The reporting period is 1 August 1998 to 31 July 1999.

TASKS AND ACCOMPLISHMENTS

Data Submission

As of 31 July 1999, the Database contained datasets from 101 research studies performed under CRSP work plans through the Eighth Work Plan (Table 1). Data submissions to the PD/A CRSP Central Database can be broken into two major periods. From 1983 until the beginning of the Eighth Work Plan in 1996,

Table 1. Total experiments reported in the PD/A CRSP Central Database as of 31 July 1999, organized by research site and Work Plan. Numbers shown indicate number of studies submitted to date. Additional studies for past and current Work Plans are due for many sites. If experiments were not conducted or datasets are not due to the Database, cells are marked with an "X."

Site Code	Site Name	Work Plan									Total
		1	2	3	4	5	6	7	Int	8	
A	Aguadulce, Panama	2	2	2	X	X	X	X	X	X	6
B	Gualaca, Panama	2	X	2	X	X	X	X	X	X	4
C	Ayutthaya, Thailand	1	2	2	3	4	5	1	1	5	24
D	Nong Sua, Thailand	1	X	X	X	X	X	X	X	X	1
E	Bogor, Indonesia	2	1	2	X	X	X	X	X	X	5
F	Comayagua, Honduras	2	2	2	2	4	2	0	X	0	14
G	Iloilo, Philippines	2	2	2	X	X	X	X	X	X	6
H	Rwasave, Rwanda	2	X	2	4	3	0	0	X	X	11
I	Asian Inst. Tech., Thailand	X	X	X	3	3	3	3	0	5	17
J	Choluteca, Honduras	X	X	X	0	X	0	0	1	0	1
K	Abbassa, Egypt	X	X	X	X	X	X	1	X	X	1
L	Univ. of Oklahoma, USA	X	X	X	X	X	X	X	X	0	0
N	Auburn University, USA	X	X	X	X	X	X	X	X	1	1
O	Oregon State Univ., USA	X	X	X	X	X	X	X	X	2	2
P	FAC, Philippines	X	X	X	X	X	2	3	0	0	5
Q	Univ. Arkansas, PB, USA	X	X	X	X	X	X	X	X	X	0
R	UNAP, Peru	X	X	X	X	X	X	X	X	1	1
S	Sagana, Kenya	X	X	X	X	X	X	X	X	1	1
U	Huay Luang, Thailand	X	X	X	X	X	0	1	0	0	1
	Total	14	9	14	12	14	12	9	2	15	101

CRSP researchers were not contractually required to submit data to the PD/A CRSP Central Database. Efforts to collect past-due data submissions are ongoing and ultimately depend on the goodwill of CRSP researchers. Significant progress has been made regarding submission of past-due datasets but roughly 25% remain outstanding.

Beginning with the Eighth Work Plan, researchers are contractually required to submit data. In addition, improved data submission protocols are now in place to address systematic problems in past procedures. These upgraded procedures are more flexible with respect to data formatting and more comprehensive through the use of data identifiers and provision of supporting information (see the *Database Submission Manual* available at the Database website). Data submissions from CRSP projects under the Eighth Work Plan have been proceeding according to project schedules.

Work Plan and Experiment Summary Tables
Summary tables for each work plan, listing CRSP research projects and experiment specifications, are critical to data submission procedures; to communication among CRSP researchers, the Database Manager, and the Program Management Office (PMO); and to the value of the Database to users. Absence of these tables in the past has limited the utility of the Database to users outside of the CRSP.

Work plan summary tables are used by the Database Manager to track data submission requirements and to provide a single, current accounting of project specifications for all interested parties. Work plan summary tables are used by Database users to access related information of extracted datasets or simply to provide a tabular overview of past and current CRSP research projects. For data entry and editing access to these tables within the CRSP, an interface is provided at the Database website, consisting of a number of linked and interactive data entry and review forms.

Work plan summary tables list and describe CRSP projects performed under each work plan. Project specifications include:

1) Project identification code (actively linked to experiment treatment specifications);
2) Research location (actively linked to site descriptions);
3) Start and end dates of study period;
4) Project leader name and contact information (actively linked email addresses);
5) Project titles, thematic classification, and abbreviated descriptions;
6) Related CRSP and other publications (actively linked for the Eighth Work Plans and onward); and
7) Data availability in the Database.

Summary tables have been partially completed for the First through the Fourth Work Plans; currently 49 projects are listed with project specifications consisting of references to CRSP Data Reports. Summary tables are fully completed for the Fifth through the Ninth Work Plans, with 198 projects listed with complete project specifications.

Experiment treatment summary tables list and describe the treatment protocols used for a given research project. This information essentially consists of the fish culture methods employed and includes:

1) Fish (or shrimp) stocking densities under monoculture or polyculture management;
2) Initial fish sizes;
3) Frequencies and rates of applied fertilizers and/or prepared feeds; and
4) Additional treatment specifications such as water exchange and aeration.

This information is required by Database query procedures that use fish culture methods as search criteria and for the interpretation of extracted datasets with respect to the materials and methods used in the study. For the Eighth Work Plan and onward, experiment treatment specifications are submitted in conjunction with project datasets (see *Data Submission Manual*). Prior to the Eighth Work Plan, materials and methods information was not provided. To the extent possible, experiment treatment specifications for past projects have been developed by reviewing project reports and by compiling management data in the Database. Results, questions, and incomplete information identified by this work were reviewed in a prior Database report (Ernst and Bolte, 1999). To verify and augment this information, CRSP researchers access study-specific forms available at the Database website for adding, editing, and reviewing the experiment treatment specifications used in individual studies.

Using the work plan and experiment treatment forms together, past-due data submissions can be added to the Database. To support this objective, forms were developed in collaboration with the CRSP Technical Progress Subcommittee (TPS). At the 1997 CRSP Annual Meeting, the TPS was assigned the responsibility of developing work plan summary tables for the First through Interim Work Plans and, in collaboration with the Database Manager, determining which datasets prior to the Eighth Work Plan were past due and contacting responsible researchers. To date, the TPS has added project specifications for the Fifth, Sixth, Seventh, and Interim Work Plans to the work plan summary tables.

Supported Data Types and Analytical Methods
The specific types of data supported by the Database originally included physical, chemical, and biological variables of pond-based fish production. These include: 1) weather; 2) pond soil analyses; 3) pond applications; 4) water quantity and management; 5) water quality and primary productivity; and 6) fish productivity. Additional data types now supported by the Database, include: 1) fish reproduction; 2) socioeconomic; 3) economic; and 4) additional weather and pond soil variables. Original and new data types are defined in the *Database Submission Manual*.

Standardization of datasets for fish reproduction studies is still under development, pending a determination of the common themes that would be most useful to Database users. For socioeconomic studies, a standardized questionnaire, developed by Joe Molnar (Auburn University), is available for assessing the adoption of specific aquaculture technologies by fish producers. For economic studies,

standardized templates and data types are available for partial enterprise budgets and related analyses. Partial budget analyses support comparative economic analyses of experimental treatments in comparison to a base production scenario (control treatment) and may include on-farm production trials as well as research experiments. Budget templates were developed in collaboration with Carole Engle (University of Arkansas at Pine Bluff). In conjunction with this work, the *Database Submission Manual* continues to be updated with new data types and associated formats.

Closely related to the comprehensive listing of data types in the *Database Submission Manual* are the analytical methods used to generate these data. For physical, chemical, and biological variables, methods are described in the PD/A CRSP *Handbook of Analytical Methods* (Piedrahita et al., 1991). In addition to an in-house printed version, the handbook is available at the Database website for use by research personnel and Database users, for which copyrighted sections of the printed version have been replaced with references. This public domain version is useful to data users as contextual information for research projects (materials and methods) and to aquaculture research projects outside of the CRSP that are required to submit data developed under standardized methodology. The Database provides permanent and electronically accessible storage for this important document. The CRSP Materials and Methods Subcommittee has been charged with revisions to the handbook, which can be easily added to the handbook in its electronic form.

Database Search Procedures

Two improvements to Database search and extraction procedures have been accomplished. Database search criteria (query constraints) used to define data searches originally consisted of fish production site, dates (organized by work plan), fish species, and desired data types. Search criteria now also include fish production methods, described earlier under the experiment treatment summary tables. Use of fish production methods as search criteria requires the availability of complete experiment treatment specifications. Treatment specifications for studies funded under the Eighth and Ninth Work Plans are complete and available for use at this time.

A second improvement concerns the list of data types shown to the Database user, from which desired data types are selected. Originally, this list included all data types in the Database and resulted in queries that returned no data when the selected data type was not available for the given query. This problem reflected a greater-than-anticipated variability in data types collected across all CRSP projects. To alleviate this problem, the Database was inventoried, data types available for each study were compiled, and the list of data types shown to the user for the currently selected study dates and research site is limited to available data types.

Contextual Linkage for Extracted Datasets

Considerable progress has been made in the ability to direct the user to related, context-specific, Internet-accessible information for a given extracted dataset. These linkages utilize both automated (active links) and manual (references) website navigation. These linkages take advantage of project information and literature maintained at the PMO website as well as new components of the Database developed for this purpose. Availability of related resources enhances the ability of the Database user to interpret and apply datasets. Related information includes site and facility descriptions, analytical methods and data type descriptions, experiment treatment specifications, related publications (electronic and printed), and author citations and contact information.

Site and facility descriptions are linked directly by the site name used in a query. Analytical methods and data definitions are available in the CRSP *Handbook of Analytical Methods* and *Database Submission Manual*. Discussed earlier, experiment treatment specifications prior to the Eighth Work Plan are incomplete but available in their current states. For studies funded under the Eighth and Ninth Work Plans, complete treatment specifications are available. Linkages to related publications and author information are completed for the Fifth through Ninth Work Plans. Prior to the Fifth Work Plan, this information is generally lacking except for references to CRSP *Data Reports*. To support linkage to project literature, a CRSP publications database has been developed and is available at the Database website. Additions to the publications database are ongoing, and there are currently 469 publications listed. The publications database contains titles, authors, abstracts, keywords, descriptions, and links to full-text electronic documents maintained at the PMO website. The publications database can be searched based on keywords, subjects, and authors.

Statistical Data Summaries and Data Reduction

Three major Ninth Work Plan tasks are still in progress to provide Database users with dataset statistics and reduction tools. Currently, extracted datasets contain raw, time-series data for every sample or measurement taken of the selected data type, for every replicate (three to four per treatment) in the experiment treatment(s) selected in the data query. These datasets can be viewed in tabular and graphical formats or downloaded in delimited format for use in spreadsheets. This type of data is of most use to people working in aquaculture research and model development. Users such as educators, students, extension agents, and producers, and collaboration with related aquaculture databases are best supported by statistically distilled presentations of these data and by design and management tools calibrated with these data.

To address this need, three tasks are in progress to develop:

1) automated mechanisms to generate experiment-treatment summary statistics (range, mean, and variance statistics and support for analysis of variance);
2) automated regression procedures to determine equation parameters for fish growth models; and
3) automated mechanisms to summarize treatment specifications and generated statistics and parameters to tables that combine multiple treatments from multiple experiments.

Generated data also include variables calculated by combining time and sample data, for example, fish growth and feeding rates, feed conversion efficiency, and biomass density and productivity. As with raw data, generated data will be available in tabular and graphical formats at the Database website or can downloaded.

Progress to date for these tasks includes:

1) improved mechanisms to group replicates (ponds) into their original experimental treatments;
2) development of models for fish growth based on fish size, water temperature, and availability of prepared (exogenous) and natural (endogenous) foods; and
3) development of models for estimating natural foods based on primary productivity, whole pond respiration rates, and "critical standing crop" and "carrying capacity" fish biomass densities.

Database Promotion

Promotion of the Database to potential users is ongoing. Critical issues are awareness of the Database availability, content, and applications. To date, the Database has been promoted through aquaculture conferences, publications, and linkages to related websites and databases. Direct promotion to specific user groups remains to be accomplished, following completion of the statistical data summary and reduction tools discussed earlier and a supporting *Database Users Manual*. Data submission from outside the CRSP has shown no success to date, but the potential for this type of collaboration will increase as the analytical capacity available at the Database website is further developed and made known.

Indicators used to assess the impact of the Database project and accomplishment of its stated objectives include numbers of linkages completed with other organizations and requests for use of the Database. Since its inception in January 1997, the Database website has received 2,940 visitors, 1,540 of these in the last year. While it is not known how these visitors utilized the site, questions directed to the Database Manager come primarily from prospective or active fish culturists with questions about pond management or the suitability of tilapia culture to their specific conditions. Negative comments regarding resources available at the Database website have not been received, but it is assumed that the majority of users are interested in summary fish production data and linked literature resources rather than large sets of raw data. The only known intensive users of the Database come from within the CRSP.

Collaboration with related databases has been established for some time. Collaborators include the International Center for Living Aquatic Resources Management (ICLARM), Network of Aquaculture Centres in Asia-Pacific (NACA), and Consortium of International Earth Science Information Networks (CIESIN). Data content and format requirements have been established for these potential indexing links and access points to the Database, but completion of the intended scope of these collaborations will follow completion of the statistical data summary and reduction tools discussed earlier. Simple site-to-site web linkage with major fishery, aquaculture, and agriculture professional societies, research groups, universities, and information providers continue to be developed. These links are not listed here and are available in the periodic Database impact reports.

LITERATURE CITED

Batterson, T., H. Berkman, K. Hopkins, R. Piedrahita, and T. Popma, 1991. Final Report on Database Management. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 51 pp.

Bolte, J.P., D.H. Ernst, and D. Lowes, 1998. Central Database management. Fifteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 36–45.

Ernst, D.H. and J.P. Bolte, 1999. PD/A CRSP Central Database management and development. Sixteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 9–14.

Ernst, D.H., J.P. Bolte, and D. Lowes, 1997. PD/A CRSP Central Database: An information resource for pond-based aquaculture. In: K. Fitzsimmons (Editor), Tilapia Aquaculture, Proceedings from the Fourth International Symposium on Tilapia in Aquaculture (ISTA), November 1997. NRAES-106, Vol. 2. Northeast Regional Agricultural Engineering Service, Ithaca, New York, pp. 683–700.

Hopkins, K.D., J.E. Lannan, and J.R. Bowman, 1987. A Database Management System for Research in Pond Dynamics. CRSP Research Reports 87-1. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 4 pp.

Piedrahita, R.H., C. Boyd, and J. Szyper, 1991. Handbook of Analytical Methods. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 150 pp.

EDUCATION DEVELOPMENT

MOU No. RD009E

Staff Information

Oregon State University, Corvallis, Oregon

Marion McNamara	Education Development Coordinator (US)
Gabriela Montaño	Student Worker (Mexico)

Background

The Education Development Component (EDC) was established in response to the need to improve human capacity development, one of the constraints to aquaculture to be addressed by the CRSP during this grant. The goal of the EDC is to complement the research activities of all CRSP projects by strengthening human capacity in participating countries and regions.

Networking and Educational Outreach

Education Development Coordinator Marion McNamara provided organizational assistance for the Fifth Central American Symposium on Aquaculture (18–20 August 1999). The EDC received submissions from and corresponded with authors of invited and contributed papers and responded to requests for information regarding the Symposium's Call for Papers. Additionally, the EDC compiled the papers to be presented at the Symposium and designed, edited, and laid out the Symposium proceedings.

The Philippines Education Advisory Panel recommended in a previous reporting period that the CRSP provide support in the form of small stipends to graduate students. In this period, the Panel specifically recommended support of a doctoral student at the University of the Visayas.

McNamara assisted three public school teachers in securing the sponsorship of the Oregon Department of Education to attend regional aquaculture workshops.

Publication

Green, B.W, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), 1999. V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (in press).

McNamara, M. and J. Molnar, 1999. Human capital impacts of the Pond Dynamics/Aquaculture CRSP. International Center for Aquaculture Communiqué, International Center for Aquaculture and Aquatic Environments, Auburn University (in press).

Work Plan Activities

Twelve EDC activities were funded under the Eighth Work Plan. With the exception of Human Capacity Development 1B (8HCD1B) "Create a CRSP Fellowship Program to Provide Appropriate Support for Graduate-Level Students," these activities were completed. Activity 8HCD1B was commenced in this reporting period by the EDC but will be continued via a subcontract issued by the ME to Auburn University.

The following Eighth Work Plan studies continued into the current reporting period:

- Create a CRSP Fellowship Program to Provide Appropriate Support for Graduate-Level Students at each CRSP Host Country Site/8HCD1B. The report submitted for this activity was a progress report. (Future reports on this activity will be submitted by the Auburn University Principal Investigator who will be serving as the student's major professor.)
- Coordinate Evaluation of CRSP-Sponsored Short Courses and Workshops/8HCD1D. While activities for this work plan were completed in the previous reporting period, the final report for this activity follows.
- Maintain and Improve the Database of CRSP Education and Training Alumni/8HCD1F. The final report for this activity follows.
- Establish a Library of Information on CRSP Institutions/8HCD1I. The final report for this activity follows.
- Seek External Support for Additional Activities to Follow-on ISTA IV/8HCD1J. While activities for this work plan were completed in the previous reporting period, the final report for this activity follows.
- Work with Institutions in CRSP Host Countries to Seek Additional Scholarship Funding from Government Agencies, Foundations, and the Private Sector to Support Masters and Doctoral Students/8HCD1K. The final report for this activity follows.
- Seek External Support for a Station Manager Workshop to Be Held in the US/8HCD1L. While activities for this work plan were completed in the previous reporting period, the final report for this activity follows.

The EDC was offered but declined funding for proposals submitted for consideration under the Ninth Work Plan Request for Proposals. The Philippines component of EDC activities to be carried out under the Ninth Work Plan, among them the support for a doctoral student at the University of the Visayas, has been taken up by the lead Philippines Project.

REPORT: ACTIVITIES OF THE EDUCATION DEVELOPMENT COMPONENT UNDER THE EIGHTH WORK PLAN

Marion McNamara
Office of International Research and Development
Corvallis, Oregon, USA

All of the following reports are printed as submitted. Referenced attachments are not included here because of space constraints but are available upon request to the Program Management Office.

CREATE A CRSP FELLOWSHIP PROGRAM TO PROVIDE APPROPRIATE SUPPORT FOR GRADUATE-LEVEL STUDENTS AT EACH CRSP HOST COUNTRY SITE

Eighth Work Plan, Human Capacity Development 1B (8HCD1B)
Progress Report

Following the recommendations of the Honduras Education Advisory Panel, the EDC worked with the US PI in Honduras during the summer of 1998 to publicize the availability of the two-year scholarship to support a student who planned to work in the Honduras aquaculture industry for a masters degree in aquaculture. Over 50 application packages were distributed. The EDC worked with Dr. John Grover, Auburn University's Academic Coordinator for the Department of Fisheries and Allied Aquacultures, to establish selection criteria which were stringent enough to ensure academic success. These included a bachelors degree in aquaculture or related sciences, strong letters of recommendation from teachers and or employers, experience with aquaculture, commitment to making a contribution to the development of aquaculture in Honduras, and satisfactory scores on the TOEFL and GRE. Four applications were received. The EDC organized a scholarship committee to evaluate qualified applications. The committee selected Oscar Zelaya, and the EDC processed his application to Auburn and arranged for his travel and support. Zelaya began his Masters program in March 1999, and began work on his thesis in May 1999. He will examine the relationship between pond soil and water quality, evaluating the efficiency of recirculating systems and the impact of high density stocking rates on water and soils. His projected completion date is March 2001.

COORDINATE EVALUATION OF CRSP-SPONSORED SHORT COURSES AND WORKSHOPS

Eighth Work Plan, Human Capacity Development 1D (8HCD1D)
Final Report

The EDC conducted evaluations for three CRSP-sponsored workshops, including two in Honduras and one in the United States. Copies of those evaluations are attached. *

MAINTAIN AND IMPROVE THE DATABASE OF CRSP EDUCATION AND TRAINING ALUMNI

Eighth Work Plan, Human Capacity Development 1F (8HCD1F)
Final Report

The EDC maintains records of formal and informal training efforts conducted by CRSP researchers. These records are updated yearly with the data supplied by Principal Investigators in their Annual Reports. Data through January 1999 is included in the attached spreadsheet, which will be updated as reports are received from Principal Investigators.*

ESTABLISH A LIBRARY OF INFORMATION ON CRSP INSTITUTIONS

Eighth Work Plan, Human Capacity Development 1I (8HCD1I)
Final Report

The EDC established a library of information on CRSP institutions, including graduate and undergraduate bulletins, and information specific to aquaculture programs and centers. In addition, links to CRSP institutions are found on the PD/A CRSP web page.

SEEK EXTERNAL SUPPORT FOR ADDITIONAL ACTIVITIES TO FOLLOW-ON ISTA IV

Eighth Work Plan, Human Capacity Development 1J (8HCD1J)
Final Report

The EDC planned and advertised a post-ISTA IV workshop on utilizing information resources for aquaculture (see flier*), but did not attract the minimum number of paid registrants needed to make the course. Fliers were sent to the CRSP mailing list, to all past ISTA participants, to all APEC Marine Resources Working Group participants, and included in all mailings for ISTA IV publicity and registration (see partial mailing lists*).

* Referenced attachments are not included in this publication because of space constraints but are available upon request to the Program Management Office.

WORK WITH INSTITUTIONS IN CRSP HOST COUNTRIES TO SEEK ADDITIONAL SCHOLARSHIP FUNDING FROM GOVERNMENT AGENCIES, FOUNDATIONS, AND THE PRIVATE SECTOR TO SUPPORT MASTERS AND DOCTORAL STUDENTS

Eighth Work Plan, Human Capacity Development 1K (8HCD1K) Final Report

The following institutions were contacted seeking additional support for Masters and Doctoral Students, although none of them were able to offer assistance to CRSP graduate students:

Institute for Science, Stockholm, Sweden
APEC Marine Resources Working Group
Carnegie Corporation of New York
The Ford Foundation
Global 2000
W.R. Kellogg Foundation
Tinker Foundation
National Science Foundation
The Rockefeller Foundation
The Spencer Foundation

SEEK EXTERNAL SUPPORT FOR A STATION MANAGER WORKSHOP TO BE HELD IN THE US

Eighth Work Plan, Human Capacity Development 1L (HCD1L) Final Report

Partial support for the Station Managers Workshop was received from the Honduras, Philippines, and Kenya CRSP projects, which provided round trip transportation from their respective countries for the participants. Funding external to the CRSP was sought but not obtained.

INFORMATION MANAGEMENT AND NETWORKING

MOU No. RD009D

Staff

Oregon State University, Corvallis, Oregon

Danielle Clair*	Information Manager
Ingvar Elle*	Systems Administrator and Webmaster
Kris McElwee	Graduate Research Assistant (through September 1998); Assistant Information Manager (from October 1998)
Deborah Burke*	Graduate Research Assistant
Heidi Furtado*	Undergraduate Student Worker (from October 1998)
Josh Moentenich*	Undergraduate Student Worker (February through May 1999)
Matt Niles*	Graduate Research Assistant

* Employed at less than full-time.

Presentation

Egna, H.S., C.K. Lin, and D.Z. Clair. The Pond Dynamics/Aquaculture CRSP: Developing technologies and networks for sustainable aquaculture and rural development. Presented to the Join FAO/NACA Expert Consultation on Sustainable Aquaculture for Rural Development at Chiang Rai, Thailand, March 1999.

Conferences

Oregon Academy of Science 57th Annual Meeting at Salem, Oregon, February 1999. (Burke, Egna, McElwee)
Copyright Law Workshop at Eugene, Oregon, April 1999. (Clair)
Professional Management Institute Series at Corvallis, Oregon, April 1999. (Clair)
Essentials of Design for the Editor at Chicago, Illinois, April 1999. (McElwee)
Graduate Student Association Conference at Corvallis, Oregon, April 1999. (Burke, McElwee)
Northwest Anthropology Meeting at Newport, Oregon, April 1999. (Burke)

Work Plan Activities

The following report describes Information Management and Networking Component activities in the first year of the Ninth Work Plan.

REPORT: ANNUAL ACTIVITIES OF THE INFORMATION MANAGEMENT AND NETWORKING COMPONENT

Ninth Work Plan, Information Management and Networking 2 (9IMNC2)

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BACKGROUND

The mission of the Information Management and Networking Component (IMNC) is to increase awareness and visibility of the PD/A CRSP by publishing and providing accessible technical and programmatic information, to monitor and report CRSP impacts, and to foster networking among persons involved in aquaculture.

Of the CRSPs research support components, IMNC works in closest concert with the Program Management Office (PMO) in disseminating technical and programmatic information in accordance with grant reporting requirements and in collecting and analyzing program impact information. Component objectives are to:

- Disseminate technical and programmatic information generated by the CRSP by providing appropriate materials and avenues;
- Identify target audiences for publications;
- Track outputs of CRSP investigations; and
- Promote networking of CRSP participants with aquaculturists around the world.

In the reporting period IMNC activities have encompassed publication production and distribution, Internet activities, impact monitoring, and program promotion and networking.

CRSP PUBLICATIONS

Data and Resource Management

An ongoing IMNC activity is managing the program's mailing database, which increases by about 10% per year. The database currently numbers 1,065 entries from 96 countries. IMNC staff also maintain a detailed inventory of PD/A CRSP publications and track publication circulation. In addition, IMNC staff work together with the PD/A CRSP Central Database Manager to facilitate the data submission

request process. Because study completion dates form the Database Manager's basis for requesting data submissions of CRSP researchers, reference to an up-to-date information source that reflects the most recent status of any study is essential. IMNC staff thus maintain a web page accessible by the Database Manager that identifies the funded studies under a given work plan and reflects study completion dates and any changes reported by CRSP researchers.

Production

IMNC has produced and distributed a variety of publications and informational materials during the reporting period, listed below.

Sixteenth Annual Administrative Report
Clair, D., D. Burke, K. McElwee, M. Niles, and H. Egna (Editors), 1999. PD/A CRSP, Oregon State University, Corvallis, Oregon, 100 pp.

Sixteenth Annual Technical Report
McElwee, K., D. Burke, M. Niles, and H. Egna (Editors), 1999. PD/A CRSP, Oregon State University, Corvallis, Oregon, 190 pp.

PD/A CRSP Site Descriptions
McElwee, K. (Editor), 1999. PD/A CRSP, Oregon State University, Corvallis, Oregon, 84 pp.

"CRSP-Developed Technologies Provide Domestic Rewards and Returns"
Printed October 1998 and reprinted April 1999, 8-panel brochure.

Annual External Evaluation Panel Review Report
Printed January 1999, 35 pp.

Ninth Work Plan
Printed April 1999, 92 pp.

Second Addendum to the Eighth Work Plan
Printed Spring 1999, 18 pp.

"PD/A CRSP Databases and Software: Promoting Research and Dialogue within the World Aquaculture Community"
Printed May 1999, 8-panel brochure.

Aquanews, quarterly newsletter (distributed by hard copy and available on the CRSP website): Vol. 13, No. 4 and Vol. 14, Nos. 1, 2, and 3.

EdOp Net, monthly newsletter of aquaculture-related education and employment opportunities (distributed by hard copy and electronic mail and available on the CRSP website): Vol. 3, Nos. 8, 9, 10, 11, and 12; Vol. 4, Nos. 1, 2, 3, 4, 5, 6, and 7.

CRSP Research Reports, an in-house publication series which includes *Notices of Publication*:

98-125 Acute and sublethal growth effects of un-ionized ammonia to Nile tilapia *Oreochromis niloticus* (10/98)
98-126 A water budget model for pond aquaculture (10/98)
98-127 A strategic reassessment of fish farming potential in Africa (10/98)
98-128 A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds (10/98)
99-129 Aquaculture extension in Rwanda (4/99)
99-130 Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*) (4/99)
99-131 The effects of fertilization and water management on growth and production of Nile tilapia in deep ponds during the dry season (4/99)
99-132 Relationship between Secchi disk visibility and chlorophyll *a* in aquaculture ponds (4/99)

CRSP Participant Directory, published August 1998 and February 1999.

Following the 1997 publication of *Dynamics of Pond Aquaculture* (Eds. Hillary S. Egna and Claude Boyd), the CRSP commissioned Dr. Christopher Knud-Hansen, former CRSP researcher, to write a pond fertilization booklet entitled *Pond Fertilization: Ecological Approach and Practical Application*. The 137-page booklet is written primarily for educated farmers, extension workers, and aquaculture students and scientists. The overriding objective of the guide is to help fish farmers worldwide optimize their resources for efficient fertilization—obtaining higher yields at reduced costs. The manuscript was significantly revised following review by four reviewers internal and external to the CRSP, and was published in September 1998.

Besides the IMNC-produced publications listed above, a 10-year bibliography of publications, presentation, and theses authored by CRSP participants, including those published in the current period, appears in Appendix 7 of this report.

WORLD WIDE WEB

PD/A Website Developments

IMNC is responsible for the development and maintenance of the PD/A CRSP website <www.orst.edu/dept/crsp/homepage.html>, which was brought online in 1995. The

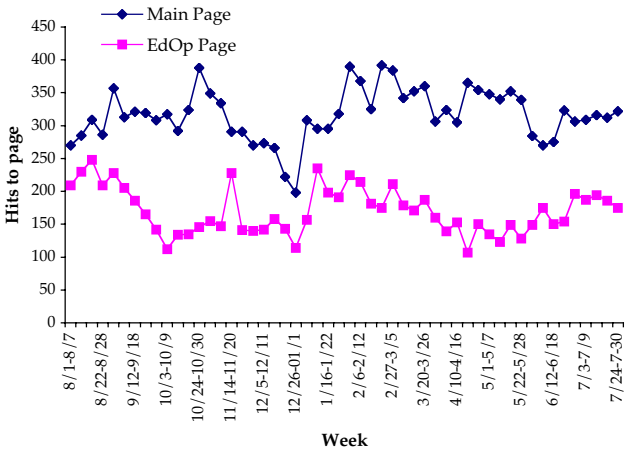

Figure 1. Weekly hits to the PDA/CRSP website's home page and EdOp Net page. The EdOp Net section contains searchable and timely announcements of educational and employment opportunities in aquaculture and related fields.

IMNC tracks usage of the website. The site averaged over 300 external hits each week , with the EdOp Net page, rebuilt by IMNC since its initiation by the EDC, the most visited, averaging 170 hits per week (Figure 1). The Publications page was also popular, with an average of 125 hits per week (Figure 2). Other pages feature programmatic information, links to aquaculture-related websites, and links to the PD/A CRSP Database and other data tools. Web-related activities in the current reporting period have included:

- Additions to the publications section;
- The development of a new section directed toward PD/A CRSP principal investigators;
- Major improvements to the PD/A CRSP Publications Database; and
- Changing delivery of educational and employment opportunities from static to dynamic markup via a Filemaker Pro–based database application.
- Use of the PD/A CRSP ftp site for disseminating the Honduras Request for Proposals and related forms and documents.

Publications and their Formats

The Publications page of the PD/A CRSP website is an important source of programmatic and research material. Documents are placed on the site in one of two formats: PDF and HTML. Documents containing many complex graphics and a detailed layout are generally placed on the site in PDF format. These documents can be read with Adobe Acrobat. Documents added in this format to the Publications page in the last year include:

- *Pond Fertilization: Ecological Approach and Practical Applications*
- *Lessons Learned in On-Farm Trials: The PD/A CRSP Experience*
- *Aquanews*–PD/A CRSP quarterly newsletter (4 issues)
- *Sixteenth Annual Technical Report*
- *Sixteenth Annual Administrative Report*
- Full versions of *PD/A CRSP Research Reports* 87-1, 88-8, 92-45, 93-54, 96-94, 98-124a, and 98-124b

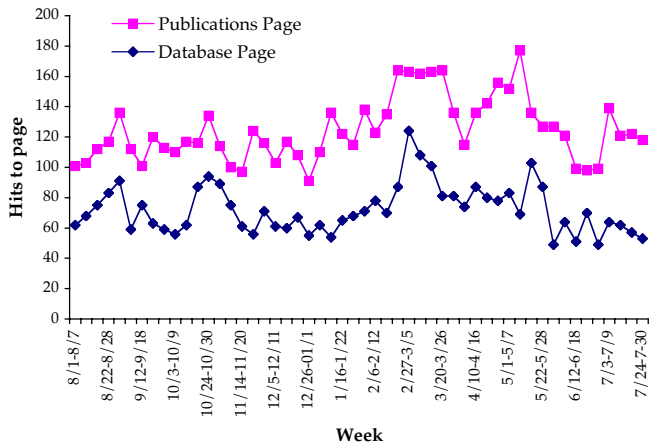

Figure 2. Weekly hits to the Publications and Data Tools pages of the PD/A CRSP website. The Publications section contains descriptions of, links to, and ordering information for most PD/A CRSP publications. The Data Tools page contains descriptions of and links to the Central Database and POND© decision support software.

Documents that contain few graphics and can be divided into relatively short sections are placed on the web in HTML format. Publications added in the last year in this format include:

- *PD/A CRSP Notices of Publication* (including French and Spanish versions where available)
- Monthly editions of *EdOp Net* (see more on *EdOp Net* below)
- Complete list of PD/A CRSP Publications

All tables of contents are placed on the web in HTML format to allow rapid browsing of publication contents.

PD/A CRSP Key Program Information Section

In order to provide critical program information and to facilitate the reporting process for PD/A CRSP participants, a new section titled PD/A CRSP Key Program Information was developed. This section, which is password-protected, provides information of specific relevance to CRSP participants. Material available only from this section includes the External Evaluation Panel Scope of Work (1997-1998) and the External Evaluation Panel Report (1997-1998). Various forms, including the Impact Report Form, Travel Form, and Emergency Locator Form are also available here.

Central Database Additions and Improvements

The PD/A CRSP Central Publications Database is a joint effort between PD/A CRSP Central Database and IMNC staff. In the past year an estimated 250 references were added to the database to bring the total number of references to 469. Publications for which references were added this year include the *Sixteenth Annual Technical Report*, the *Eighth Work Plan*, and *PD/A CRSP Notices of Publication*, including the comprehensive set of English abstracts as well as the available French and Spanish versions.

A Boolean search was added to the database enabling users to search using any combination of keyword, publication type, author, language (English, Spanish, French), year, site, and investigation code.

Entry of publication references into the database is accomplished through a web-based interface. This interface has recently been greatly enhanced by the addition of an SQL-based update page.

Employment and Educational Opportunities Section

The PD/A CRSP EdOp Net section is a popular source of aquaculture-related employment and education opportunities made available from the PD/A CRSP website and in hard-copy format. Due to a growth in employment opportunities, statically updating position announcements in HTML became impractical. In response to this, IMNC dedicated resources to improving the site. EdOp Net's new content delivery is significantly more efficient and user-friendly through the use of a searchable relational database and its web-enabling plug-in. This has allowed opportunities in the database to be marked up into html "on the fly," which has resulted in considerable time savings. More recently, the database was moved to a much faster server, which has resulted in more rapid content delivery. This database also serves as the source for the information that is compiled into the monthly hard-copy newsletter format for individuals without access to online resources.

IMPACT MONITORING

The CRSP uses impact indicators to monitor the effects of its research on stakeholders, beneficiaries, extension services, the research community, and the field of aquaculture. In the previous reporting period, the CRSP commissioned a review of the existing project impact indicators to determine whether they adequately reflected and recorded project results. The reviewer (Dr. Candace Buzzard, now with USAID/Botswana) worked individually with CRSP principal investigators to refine the indicators associated with each subcontract. IMNC is responsible for annually soliciting and collecting researchers' quantifications of their impacts.

In addition to these formal impact indicators, IMNC staff collect project-specific impact information designed to capture CRSP participants' activities that were sponsored by the CRSP or came about as a result of CRSP work. These forms are requested on a quarterly basis and allow the IMNC to monitor, track, and report progress in the areas of outreach, public service, and professional development. The types of information collected include:

- Research progress
- Institution building (contacts with host country scientists, government officials, extension agents, farmer organizations, farmers, non-governmental organizations)
- New host country involvement
- Physical support for host country institutions (e.g., pond renovation)
- Linkage development (technical or professional communications with USAID missions, host country institutions, non-governmental organizations, and regional institutions)
- Conferences attended
- Students advised
- Lectures, seminars, presentations, and workshops given
- Outreach activities (community or school extension activities) undertaken
- Electronic linkages made
- Publications, including technical papers and book chapters, authored
- Theses published
- Awards or commissions received
- Informational material developed

Though formerly tracked by the CRSPs Education Development Component, IMNC this year collected information related to student activities supported by CRSP researchers. Support typically includes providing graduate research assistantships, hiring undergraduate student workers, providing research materials, and advising student workers' research papers. During this reporting period, five formal programs (two Masters and three Ph.D. degrees) were completed by CRSP-sponsored students. The following theses were completed this year with assistance from CRSP researchers:

Burke, D.A., 1999. An analysis of social relationships at a development site in Kenya. M.A. thesis, Oregon State University, Corvallis, Oregon.

Gross, A., 1999. Nitrogen cycling in aquaculture ponds. Ph.D. dissertation, Auburn University, Alabama.

Jamu, D., 1998. Modeling organic matter and nitrogen dynamics in integrated aquaculture/agriculture systems: effects of cycling pathways on nitrogen retention and system productivity. Ph.D. dissertation, University of California, Davis, California.

Sonnenholzner, S., 1999. Chemical and physical properties of shrimp pond sediment in Ecuador and some management strategies for pond preparation. Ph.D. dissertation, Auburn University, Alabama.

Tain, F.H., 1999. Impacts of aquaculture extension on small-scale *Oreochromis niloticus* production in northeastern Thailand. M.S. thesis, The University of Michigan, Ann Arbor, Michigan.

PROGRAM PROMOTION AND NETWORKING

IMNC sought to increase the visibility of the PD/A CRSP at Oregon State University through participation in two campus-wide events—University Day and Earth Information Day—and sponsorship of a third—the Graduate Student Conference. The CRSP hosted a booth for University Day and Earth Day, and in total the booths received approximately 200 visitors during these events. IMNC staff answered questions about the program and distributed informational materials such as program brochures, annual reports, *EdOp Net* (the program's educational opportunities network newsletter), and *Aquanews*, the PD/A CRSP quarterly newsletter. In addition to the distribution of informational materials, IMNC increased program visibility through the creation of a jovial atmosphere at the Earth Day booth with a fish placard for visitors to be photographed behind. To encourage people to acquaint themselves with the PD/A CRSP Website their photographs were placed on the web for viewing. Additionally, at each of the events tilapia recipes were available. The CRSP was also a co-sponsor of the session entitled "It Takes a Village to Raise a Fish: Multidisciplinary Perspectives of Natural Resources" at the Graduate Student Conference, held in April 1999 at Oregon State University.

IMNC also established new connections both domestically and internationally and provided information worldwide via CRSPMail, an electronic mail address for website visitors. During this reporting period, CRSPMail received 15 queries from individuals representing El Salvador, Belize, Brazil, Thailand, Cambodia, Sri Lanka, India, the Philippines, Japan, Austria, and the US. Questions addressed a variety of topics related to aquaculture such as the availability of inexpensive, high-quality feeds in the Philippines, the construction of an ozone-producing system for shrimp ponds, and the effects of tilapia as an exotic species. In a number of circumstances the PD/A CRSP Website and *EdOp Net* proved to be valuable resources for individuals contacting the program.

PD/A CRSP researchers were also responsive to CRSPMail inquiries and offered assistance and resources. For example, Project Leader for Philippines research Chris Brown at the University of Hawaii was able to offer assistance to an individual in finding extension agents and contacts in the Philippines related to the start-up of milkfish and shrimp farms. In another instance CRSPMail received a request for information regarding a research project that involved collaboration between the CRSP and the Food and Agriculture Organi-

zation of the United Nations to assess the aquaculture potential in South America using GIS. IMNC directed the individual with this request to contact CRSP researcher Shree Nath at the University of Georgia, who was a co-collaborator on the project. Nath was able to link this individual with researchers from both FAO and the University of Stirling. Though the CRSP does not conduct research on biological filtration, IMNC was able to direct an inquiry related to this topic to CRSP researcher Kevin Fitzsimmons (University of Arizona), who has done a great deal of work in biological filtration for recirculating aquaculture systems, for treatment of aquaculture effluents, and for treatment of other wastewaters, thus highlighting the dynamic nature and flexibility of the PD/A CRSP.

To increase communication within the PD/A CRSP community, an electronic mailing list, PDA-CRSP-L, was established to replace AQUACUL. The mailing list, which includes approximately 65 members, allows any subscriber to distribute a message quickly and at no cost to the entire group. Typical postings include administrative information of general interest, availability of new publications, requests for training materials, announcements of opportunities in the field of aquaculture, and relevant travel advisories.

In addition to these activities, IMNC worked closely with the PMO in creating materials for the following events:

- An exhibit of 24 photographs highlighting the accomplishments of the nine CRSPs entitled "Mutual Benefits for Developing Countries and the United States," in the USAID Information Center at the Ronald Reagan Building in Washington, D.C., from 21 September through 31 December 1998.
- A special symposium entitled "CRSP: A Unique USAID Partnership with Higher Education," which was part of the October 1998 Annual Meetings of the American Society of Agronomy, Crop Science Society of American, and Soil Science Society of America, held in Baltimore, Maryland.
- A case study project coordinated by the Association of International Agriculture and Rural Development (AIARD) to illustrate the win-win benefits of investments in international agriculture and rural development to both the United States and developing countries.

Research Summary

Research conducted under the Eighth and Ninth Work Plans includes nine of the fifteen themes outlined in the *Continuation Plan 1996–2001* (see also Tables 1 through 4 on pp. 6–9 of the present report). In the reporting period (1 August 1998 through 31 July 1999), CRSP scientists conducted research in the following areas: pond dynamics, feeds and fertilizers, reproduction control, aquaculture systems modeling, new aquaculture systems/new species, effluents and pollution, marketing and economic analysis, adoption/diffusion, and decision support systems.

A summary of each study report received during the reporting period is presented below. Reports are identified by research area, research theme and code, project leader, and report title. In addition, information about the status (i.e., final vs. progress) of each report is also provided. For example, a final report was owed if the completion date for a study fell within the reporting period; similarly, if a study was not scheduled to be completed until after the close of the reporting period, a progress report was owed on 31 July. Please see Appendix 5 for a tabular overview of reports received, themes addressed, and study completion dates (where these differ from completion dates listed in the *Eighth* or *Ninth Work Plan*, it is owing to schedule changes requested and approved in the reporting period).

Research Area: Production Optimization
Research Theme: Pond Dynamics Research
8PDR1/Pond soil characteristics and dynamics of soil organic matter and nutrients/Boyd [Final report]

The final results from the Eighth Work Plan study appear in the progress report for 9PDR2.

Research Area: Production Optimization
Research Theme: Pond Dynamics Research
9PDR2/Pond soil characteristics and dynamics of soil organic matter and nutrients/Boyd [Progress report]

Historically, little work has been conducted on pond bottom soils. As production levels have increased, the importance of pond bottom soils has been recognized. This study is a continuation of Eighth Work Plan studies to characterize the pond soils at all CRSP sites. One goal of the research is to bring pond soils into the existing system of Soil Taxonomy. In support of a set of horizons developed by CRSP researchers, the layers found in the soil cores collected at freshwater PD/A CRSP sites in Iquitos, Peru, and Sae Kaeo, Thailand, show the typical layering seen in other CRSP sites and in the US, although layers in the Peru cores were weakly developed. The soils in both locations were highly weathered. Soil incubations were found to provide little useful information on pond nutrient dynamics and will no longer be conducted. An additional study examined soil respiration in soils from freshwater catfish ponds in Auburn, Alabama, and brackishwater shrimp ponds in Ecuador. Results suggest that studies to correlate pond water quality with soil organic matter content should sample the upper 1 to 2 cm of soil.

Research Area: Production Optimization
Research Theme: Pond Dynamics Research
8KR1/New site development and characterization/Bowman [Final report]

In late March of 1997, the CRSP initiated research at Sagana Fish Farm, Kenya. (Development of the Kenya site was initiated in 1994 and continued through the Interim Work Plan, culminating with a formalized Memorandum of Understanding in March 1997.) Site enhancement activities included renovating ponds, supplying laboratories, and installing a weather monitoring system. Beginning in December 1997, weather data were collected on solar radiation, photosynthetically active radiation, precipitation, relative humidity, wind speed, and air temperature. The first year's data suggest that Sagana belongs to a Köppen Aw climate type (tropical wet and dry). Pond soil analyses indicate that the black cotton soils at Sagana are clay-rich, will require liming to prevent carbon-limitation, and have a high phosphorus adsorption capacity. Pond source water chemistry was also described.

Research Area: Production Optimization
Research Theme: Pond Dynamics Research
8TR1/Effect of mud turbidity on fertilization, and an analysis of techniques to mitigate turbidity problems in wet season/Diana [Final report]

Turbidity of pond water is a problem in areas where bottom soils and dikes contain heavy clays or where clays are introduced by run-off or source water. Turbidity can adversely affect water quality and fish growth by inhibiting light penetration, increasing acidity, and binding with mineral nutrients and with phytoplankton cells. A number of pond management techniques can mitigate turbidity and thus allow normal phytoplankton growth in response to fertilizer inputs. This study continues prior research that evaluated turbidity mitigation techniques in the dry season. This experiment was conducted in the wet season in ponds stocked with Nile tilapia at the Asian Institute of Technology, Thailand. The five treatments were: 1) no cover (control); 2) pond dikes covered with black plastic to prevent turbidity from run-off; 3) pond bottoms covered with green manure to alter soil texture; 4) pond bottoms covered with fine plastic mesh to prevent disturbance by fish; and 5) pond dikes covered with straw. Compared to the warm-season experiment, the plastic-covered treatment was more effective at decreasing turbidity, likely because it decreased turbidity from run-off. The weed-covered treatment resulted in high fish mortality in the dry season; better timing of fish stocking prevented mortality in the wet-season experiment. Fish growth was significantly higher in the straw- and weed-covered treatments than in the other treatments. The decay

of both straw and weeds, although it depressed DO concentrations, released nutrients for plankton growth. In addition, the straw decreased turbidity from run-off, thus making it the best mitigating technique in the wet season.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8HR1/Intensification of tilapia production: Effects of feeding at different stocking rates on pond water quality/Green [Final report]

A study was designed to examine the effects of three stocking rates on tilapia yield, profitability, and pond nutrient budgets. Fish mortality due to an interrupted water supply delayed the study. Fingerlings raised in a second attempt escaped in the floods following tropical storm Mitch. As a result of damages from the flood, the study was not completed.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8KR3/Relative contribution of supplemental feed and inorganic fertilizers in semi-intensive tilapia production/Bowman [Final report]

One of the constraints to the development of aquaculture in Kenya has been the scarcity of nutritionally complete feeds. The application of chemical fertilizers may address this constraint by enhancing food production and indirectly providing protein to complement energy-rich rice bran. To characterize the productive capacity of ponds and identify lowest-cost combinations of rice bran and inorganic fertilizer, researchers in Kenya initiated a 20-week experiment to test four feed and fertilization regimes applied to ponds stocked with *Oreochromis niloticus* and *Clarias gariepinus*: 1) urea and diammonium phosphate (DAP) to provide 16 kg N ha^{-1} wk^{-1} and 4 kg P ha^{-1} wk^{-1}; 2) urea and DAP applied to give 8 kg N ha^{-1} wk^{-1} and 2 kg P ha^{-1} wk^{-1}, plus rice bran fed at 60 kg ha^{-1} d^{-1}; 3) rice bran fed at 120 kg ha^{-1} d^{-1}; and 4) rice bran as in treatment 3 and fertilizer as in treatment 2. As reported in last year's progress report, the net fish yields averaged 1,127, 1,582, 1,607, and 2,098 kg ha^{-1} for treatments 1 through 4, respectively. Treatment 1 was the most cost-effective treatment, although costs for treatments 2 through 4 were comparable. The costs of treatments 1 and 2 will be of most interest to farmers; however, treatment 1 fish may not reach marketable size due to the absence of fertilizer. The relative profitability of different fertilization schemes depended heavily on the cost of rice bran.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8KR3A/Nutritional contribution of natural and supplemental foods for Nile tilapia: Stable carbon isotope analysis/Lochmann [Final report]

The optimization of nutrient utilization can result in lower feed costs, higher production, and reduced effluent loads. In this study, carbon isotope analysis was used to determine the contribution of different natural and supplemental food sources to the nutrition of Nile tilapia, analyzing inputs and fish (*Oreochromis niloticus* and *Clarias gariepinus*) from the companion study 8KR3. Fish were preconditioned by feeding them corn, which has a less negative isotope ratio than bran. The most distinctive trend in the isotope data was the more positive values for plankton, *Clarias*, and *Oreochromis* in treatment 1 (no rice bran) versus treatments 2 through 4 (rice bran) for midpoint and final samples. Plankton had more positive values in treatment 1 versus the other treatments in the initial samples as well, possibly due to a pretreatment effect. Significantly higher chlorophyll *a* concentrations were observed in treatment 1 than in the other treatments. Given that the isotope ratios of plankton and rice bran were generally more negative than those of the fish, it was difficult to distinguish their relative nutritional contributions. Future studies might benefit by dividing plankton into different categories before isotope analysis, because utilization of zooplankton and phytoplankton varied between treatments. Isotope analysis might also clarify the trophic relationship between *Clarias* and *Oreochromis* in different treatments, given that gut content data do not.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8FFR1K/Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/Bowman [Progress report]

Prior PD/A CRSP research has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers. While increased fertilization generally increases primary productivity (and thus tilapia yield) in aquaculture ponds, experiments to find optimal levels of inorganic fertilization rates are lacking. Researchers at all PD/A CRSP sites undertook the Eighth Work Plan Global Experiment to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimal primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rate; and 3) develop a full-cost enterprise budget for the most profitable nitrogen fertilization rate identified. Researchers at Sagana Fish Farm in Kenya undertook two experiments, one in the cool season and one in the warm season. In both experiments, ponds were stocked with *Oreochromis niloticus* at an initial density of 1 t ha^{-1} and with *Clarias gariepinus*. Treatments for this experiment consisted of nitrogen (urea and diammonium phosphate) applied at 0, 10, 20, and 30 kg ha^{-1} wk^{-1} and phosphorus applied at 8 kg ha^{-1} wk^{-1}. In both experiments, a highly significant quadratic correlation existed between nitrogen input rate and gross fish yield, with better correlation in the cool-season experiment. Fish production was much lower in the warm-season experiment, with gross yield (at a nitrogen fertilization rate of 20 kg ha^{-1} wk^{-1}) of 1,901 kg ha^{-1} versus 3,229 kg ha^{-1} in the cool season. The highest marginal return occurred at 20 kg N ha^{-1} wk^{-1} in both experiments. These results are similar to those reported from the Honduras site. Another finding indicated that production of a given pond over both experiments was related to cumulative nitrogen input; that is, a carry-over effect of fertilization was suggested. The final report for this study will carry results of the full-cost enterprise budget of the most profitable treatment.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8PHR1/Development of low-cost supplemental feeds for tilapia in pond and cage culture/Fitzsimmons [No report submitted; last year's report satisfies final report requirement]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8FFR1Ph/Global Experiment: Optimization of nitrogen fertilization rates in freshwater tilapia production ponds during cool season/Brown [Study not begun; work plan schedule change filed]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
8FFR1T/Global Experiment: Optimization of nitrogen fertilization rates in freshwater tilapia production ponds during cool season/Diana [Final report]

Prior PD/A CRSP research has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers. While increased fertilization generally increases primary productivity (and thus tilapia yield) in aquaculture ponds, experiments to find optimal levels of inorganic fertilization rates are lacking. Researchers at all PD/A CRSP sites undertook the Eighth Work Plan Global Experiment to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimal primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rate; and 3) develop a full-cost enterprise budget for the most profitable nitrogen fertilization rate identified. In last year's progress report for the same study, the results from a warm-season experiment addressing these three objectives were reported, as well as the results of an additional study that examined the relationship between initial fish size and pond carrying capacity. The final report for this investigation summarizes results from the cool-season experiment conducted at the Asian Institute of Technology, Thailand. Ponds were stocked with sex-reversed male *Oreochromis niloticus* at an initial density of 1 t ha^{-1}. Treatments for this experiment consisted of nitrogen (urea) applied at 0, 10, 20, and 30 kg ha^{-1} wk^{-1} and phosphorus (TSP) applied at 8 kg ha^{-1} wk^{-1}. Gross fish yield increased with increasing nitrogen fertilization rate, to a maximum (at 30 kg N ha^{-1} wk^{-1}) of 1,938 kg ha^{-1}. This was lower than that reported in the warm-season experiment, 2,409 kg ha^{-1}. Fish growth ceased around day 70, but the ponds were not harvested until day 91. The partial budget analysis showed that the 30 kg N ha^{-1} wk^{-1} treatment was most profitable. A full-cost enterprise budget analysis indicated that a net profit of US$2.13 could be produced from a 200-m^2 pond, compared to US$11.90 in the warm-season experiment. If fish had been harvested before growth ceased, profits could have been much higher. The results of this study also suggest that farmers can optimize resource utilization and maximize profits by starting tilapia in densely stocked ponds and moving them to less densely stocked ponds when fish growth ceases.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
9FFR4/Timing of the onset of supplemental feeding of tilapia in ponds/Brown [Progress report]

Based on socioeconomic studies carried out by CRSP researchers, tilapia production has intensified and farmers in Central Luzon, Philippines, are receptive to adoption of new technology. In an attempt to provide guidance to farmers who seek to increase production in a cost-effective manner, a study was initiated to test the effects on tilapia production of low-level feeding or feeding during only a part of the production cycle. This study builds on CRSP research conducted in Thailand, which demonstrated that initiating feeding of Nile tilapia after 80 days in pond resulted in the same yield as initiating at 38 days. In this study, seven farmers compared production in two ponds in which supplemental feeding commenced at 45 and 75 days post-stocking. The study was still underway at the time the report was written, but preliminary results showed that in four out of seven farms, growth was better in ponds that received supplemental feeding 45 days post-stocking. Water quality appeared uncorrelated to time of initiation of feeding.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8RCR1A/Methods for strain variations in sex ratio inheritance/Phelps [No report submitted; pending work plan change approval, last year's report will satisfy final report requirement]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8RCR1B/Methods for androgenesis techniques applicable to tilapia/Shelton [Final report]

Chromosome manipulation techniques to yield YY male tilapia have been the focus of this investigation. Previous progress reports outlined techniques of photoperiod and temperature manipulation to manage spawning, determined tau curves describing temperature dependence of mitotic interval, and established optimal UV doses to inactivate the DNA of unfertilized Nile tilapia eggs. The past year's work builds on prior research, applying the protocols developed earlier to manage spawning and to inactivate the DNA of eggs. The phenotypic marker used was the recessive blond color of males used for fertilization. Ova from normal-colored Nile tilapia of a Ghana stock were UV-treated, fertilized with milt from blond males, and subjected to cold shock (11°C) for 60 min at 59, 69, or 79 min post-activation. The development of non-pigmented androgenotes through hatching and swim-up was tracked. The highest hatch rate (22% of control) occurred in the 69-min post-activation treatment, which was just prior to the first mitotic cytokinesis. Out of 157 androgenotes that hatched, only 57 survived to swim-up. Juvenile mortality rates remained high, and only five of these androgenotes had survived to July. Progeny testing, assuming sufficient survival, and the optimization of shock time and type will constitute the focus of future investigations.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8RCR1C/Methods for contribution from the male and female genome to sex inheritance/Phelps [No report submitted; please see Editor's Note, p. 37.]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8RCR1D/Methods for development of YY lines of male and female *O. niloticus*/Phelps [No report submitted; please see Editor's Note, p. 37.]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8RCR3B/Detection of MT in pond water after treatment with MT food/Phelps [Final report]

Administering food impregnated with 17α-methyltestosterone (MT) can be used to produce male-biased populations of tilapia, resulting in faster growth and reduced reproduction. However, the steroid may be lost into the environment from uneaten or unmetabolized food. Non-target organisms may then be at risk of exposure. This study complements a laboratory study completed by other CRSP researchers last year. Nile tilapia fry were stocked in adjacent cages and fed for 28 days a diet containing 60 mg MT kg^{-1} or a non-treated feed. Effectiveness of MT to produce all males within both groups of tilapia was determined. Water and soil samples were collected prior to, during, and after the treatment period and analyzed for MT residues. The treated fish were effectively masculinized (91% male), while the sex ratio of fish raised in a cage 50 cm away was unaffected (48% male). In the laboratory study conducted at Oregon State University, MT was detected in water and soil samples during treatment, in water for one week after treatment, and in soils for four weeks after treatment. In this field experiment, very little evidence of MT escapement into the water column was measured. Radioimmunoassay results from soil samples indicate cross-reaction with other materials in addition to MT; the apparent initial MT content of soil in these ponds with no prior application of MT was 875 pg g^{-1}. The aggressive feeding behavior of tilapia, combined with rapid breakdown in conditions of high light intensity and temperature plus metabolism by fungi and bacteria of excreted, unmetabolized steroids, is proposed as an explanation for the lack of apparent contamination of pond water and soils with MT.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
8KR2/Strain variations in sex ratio inheritance/Bowman [Final report]

Populations of Nile tilapia give the expected mean sex ratios of 50:50, but the ratio can vary considerably when individual pair spawns are considered. This study was planned in collaboration with reproduction control researchers (see Phelps report "Methods for strain variations in sex ratio inheritance," 8RCR1A) to determine the sex ratio inheritance of the strain of Nile tilapia (*Oreochromis niloticus vulcani*) cultured at Sagana Fish Farm. Spawning success and survival were too low in the first year of the study to obtain the number of fingerlings required to complete the study. During the second year, it was determined that the strain of tilapia at Sagana may not be pure and that it may be contaminated with *O. spirulis*. At this point, the researchers decided not to perform additional pair spawns.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
9RCR5A/Effect of treatment timing and dose on masculinization with trenbolone acetate/Fitzpatrick [Final report]

Tilapia tend to reproduce prolifically in ponds, which results in a harvest of many small fish instead of fewer, more marketable fish. Stocking single-sex populations addresses this problem, and because males grow faster than females, male-biased populations are preferred. The use of masculinizing hormones has been the topic of CRSP reproduction control research. Earlier studies on the hormones 17α-methyldihydrotestosterone (MDHT) and 17α-methyltestosterone (MT) reported variable success with masculinizing tilapia. Treatment timing and dose with the synthetic androgen trenbolone acetate (TA) are tested in this study. A series of three experiments varying the timing of exposure revealed that Nile tilapia were significantly masculinized when immersed in 500 mg TA l^{-1} for three hours at 13 or 14 days post-fertilization. These results differ from those found in an earlier study, suggesting that the window of sensitivity to masculinizing hormones is short and may vary between broods. Two experiments that varied the dose were hampered by small brood sizes and high mortality, but suggest that minor increases in dosage (e.g., 500 to 1,000 mg TA l^{-1}) do not significantly increase masculinization. A final experiment, with a fractional factorial design, was also hindered by small sample size. However, the fractional factorial design offers promise as a means to rapidly and efficiently determine optimal timing, dose, exposure time, and fish density.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
9RCR5B/Masculinization of tilapia by immersion in trenbolone acetate: Growth performance of trenbolone acetate–immersed tilapia/Fitzpatrick [Study not begun; work plan schedule change filed]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: AQUACULTURE SYSTEMS MODELING RESEARCH
8ASMR1A/Aquaculture pond modeling for the analysis of environmental impacts and integration with agriculture: Model evaluation and application to the ecological analysis of integrated aquaculture/agriculture systems/Piedrahita [Final report; report title different than study title in *Eighth Work Plan*]

CRSP researchers designed a model to analyze the environmental impacts of aquaculture and the ecological functioning of integrated aquaculture/agriculture systems. The first two years of research under this investigation involved the development of a model to analyze and predict organic matter and nitrogen flows in aquaculture ponds and the evaluation of this model using sensitivity analysis and model verification methods. The verified model was then

used to prioritize future research areas in integrated agriculture/aquaculture. The final report for this investigation gives additional information about the model validation and application. The results suggest a number of field experiments that would be valuable: to examine effects of pond water removal (timed with agricultural cycles, not pond cycles) on pond water quality and fish yield; to assess the effects of varying stocked fish size and stocking density; and to determine the effects of varied prestocking practices to improve food availability at time of stocking. A 120-day simulation using dry-season data from CRSP research in Honduras modeled the effects of different organic matter and nitrogen cycling pathways on tilapia and corn production. It was found that merely increasing the number of nitrogen cycling pathways did not increase nitrogen retention and productivity and that applying pond sediment to crops that have also received inorganic fertilizer did not increase productivity.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: AQUACULTURE SYSTEMS MODELING RESEARCH

8ASMR1B/Aquaculture pond modeling for the analysis of environmental impacts and integration with agriculture: Modeling of temperature, dissolved oxygen, and fish growth rate in stratified ponds using stochastic input variables/Piedrahita [Final report; report title different than study title in *Eighth Work Plan*]

The development of data tools to be used in planning and managing fish ponds is one goal of PD/A CRSP research. Many models are deterministic; that is, the same results will be generated each time a given set of input data is run through the model. Stochastic modeling, as in this investigation, generates varying inputs and results in a probability distribution of possible outcomes. The earlier progress reports for this study described refinements to and validation of a model designed to predict water temperature, dissolved oxygen, and fish growth under the effects of random weather variables. The final report for this investigation describes the model and each of its components. The weather generation module was developed using daily clearness indices measured at three PD/A CRSP sites. Generated weather variables were in satisfactory agreement with data from CRSP sites. However, the quality of fish-growth and water-quality simulations varied between sites and treatments. Variability between replicate ponds, particularly in Thailand, was not well predicted by the simulations; identifying the cause of that variability is recommended as a goal of future research efforts. In spite of its limitations, the model can be used to generate stochastic weather values at sites with limited weather data and to identify possible probability distributions for water quality and fish growth.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: NEW AQUACULTURE SYSTEMS/NEW SPECIES RESEARCH

9NS2/Culture of mixed-sex Nile tilapia with predatory snakehead/Diana [Abstract]

Overpopulation of tilapia ponds due to uncontrolled reproduction can result in stunting due to food shortage. Overpopulation can be controlled by stocking single-sex populations, culture in cages, culture with predators, intermittent harvesting, and induction of sterility. Little research has been conducted to date on the stocking of predatory fish. A study begun in May 1999 will compare growth and production of Nile tilapia in ponds stocked with monoculture of sex-reversed tilapia, monoculture of mixed-sex tilapia, or polyculture of mixed-sex tilapia and predatory snakehead at ratios of 10:1, 20:1, 40:1, and 80:1.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH

8HR2-1/Estuarine water quality monitoring and estuarine carrying capacity/Green [Final report]

A long-term water quality monitoring project in estuaries in shrimp-producing regions of Honduras was initiated in 1993 by the PD/A CRSP. The project's goal was to add to the estuarine water quality database, providing a scientific basis for estuarine management and sustainable development of shrimp culture. In the current project, samples were collected from 20 sites on 12 estuaries. Samples were analyzed for total settleable solids, nitrate-nitrogen, ammonia-nitrogen, filterable reactive phosphorus, chlorophyll *a*, total alkalinity, salinity, BOD_2, and reactive silicate. Salinity, total nitrogen, and chlorophyll *a* concentrations increased in comparison to 1996-1997 levels, as a result of the 1997-1998 El Niño in Honduras.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH

8HR2-2/Evaluation of shrimp farming impacts in Golfo de Fonseca region, Honduras/Ward [Final report; report title different than study title in the *Eighth Work Plan*]

This study is the continuation of a data collection and modeling study underway for the past several years in two of the channel estuaries draining into the Gulf of Fonseca, Honduras. In this study, the capacity of these two estuaries to assimilate dissolved oxygen (DO) was examined. Using data collected mainly in 1995, biochemical oxygen demand (BOD) loadings from shrimp farms were estimated, and a transport model for salinity and DO in the estuaries was applied to the data to predict mean concentrations of salinity and DO in the estuaries. The model was found to satisfactorily predict DO concentrations, and future loadings based on full shrimp farm development along the two estuaries were then input to determine the resulting DO under these conditions. It was found that 1995 BOD levels already press the carrying capacity in both systems, and at full development DO levels will be worsened.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH

8HR4/Water exchange to rectify low dissolved oxygen/Green [Final report]

This experiment builds on a previous experiment, "Influence of daily water exchange volume on water quality and shrimp production" (HR3), which indicated that daily or emergency water exchange did not significantly affect shrimp production, but that water quality was better in

ponds that received daily water exchange. This experiment examines the effects of time of initiation of water exchange on early morning dissolved oxygen, water quality, and shrimp production. Water was exchanged in experimental ponds at a rate of 10% per day, six days per week, beginning at four, seven, or ten weeks after stocking. While treatment effects began to appear, the torrential rains of tropical storm Mitch on 30–31 October 1998 resulted in the flooding of experimental ponds and the loss of data. It is impossible, therefore, to draw any conclusions regarding the effects of treatment.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER1/Use of pond effluents for irrigation in an integrated crop/aquaculture system/Wood [Progress report]

Research has shown pond effluents to be valuable in flood irrigation of crops, but there has been little research conducted to address the use of pond water in more efficient irrigation systems of high-value vegetable crops. In this study, an experiment was conducted at Sagana, Kenya, to determine the suitability of polyculture (tilapia (*Tilapia aureus*) and African catfish (*Clarias gariepinus*)) fish-pond effluent for drip irrigation of French bean (*Phaseolus vulgaris* cv. Samantha). A variety of treatments was used, testing various combinations of irrigation and fertilizer treatments. A decline in yield with increasing amounts of pond effluent was observed, possibly owing to particulates that clog drip line emitters. The results of this study indicate that pre-treatment filtration or alternative irrigation methods are required before application of nutrient-enriched pond water will be advantageous.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER2A/Fate of methyltestosterone in the pond environment: Detection of MT in soil after treatment with MT food/Fitzpatrick [Final report]

Treating tilapia with 17α-methyltestosterone (MT) to produce all-male populations has become a common practice in aquaculture, and concerns have been raised about production of steroid wastes and metabolites that are potential environmental contaminants. This study examined the persistence of MT in soil after treatment of tilapia with MT. Fry were treated with MT for four weeks beginning at the initiation of feeding in 60-l tanks that contained 5 kg of soil, gravel, or no soil. Water and soil samples were taken before treatment and at weekly intervals beginning on the last day of treatment. In tanks with soil or gravel, MT concentrations in water decreased to background levels by 35 days after the beginning of treatment (one week after the end of treatment). In the tanks with no soil, MT concentrations remained above background levels through 49 days. In tanks with soil, MT was detectable in the soil after 84 days (eight weeks after ending treatment). In tanks with gravel or no soil, MT was detected in a fine sediment that formed after the end of treatment. The results of this experiment demonstrate the persistence of MT in soil for up to eight weeks after ending treatment, raising the possibility of unintended MT exposure.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER2B/Fate of methyltestosterone in the pond environment: Detection of MT in pond soil from a CRSP site/Fitzpatrick [Abstract]

This study, currently underway at the Universidad Juárez Autónoma de Tabasco, Mexico, will examine persistence of 17α-methyltestosterone (MT) in the environment after its use for tilapia masculinization at one or more PD/A CRSP sites. Fry have been treated with MT for four weeks beginning at the initiation of feeding, and water and soil samples were taken from the pond before treatment and one day after treatment. Samples will also be taken four weeks after the end of treatment, and concentrations of MT will be determined by radioimmunoassay. A similar sampling design may also be used at Sagana Fish Farm, Kenya, with subsequent analysis of samples at Oregon State University.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER3/Integrated recycle systems for catfish and tilapia culture/Diana [Study not begun; work plan schedule change filed]

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS
8MEAR1/Nonparametric estimation of returns to investment in Honduras shrimp research/Engle [Final report]

This study sought to estimate the economic returns to the investment in shrimp research by the PD/A CRSP in Honduras using a nonparametric approach. A survey was used to collect data on yield, input application, and prices for shrimp farms in Honduras for their first year of operation and for the year 1997. Results showed increases in productivity between 1995 and 1997, indicating technical progress due to research. The internal rate of return to public and private investment in research was 45%, but the internal rate of return to public-sector investment in research was more than 6,352%, indicating an effective leveraging of public funds and private-sector capital to generate technological progress.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS
8MEAR2/Risk analysis of shrimp farming in Honduras/Engle [Final report]

While Honduras has established itself as the leading producer of farm-raised shrimp in the Central American region and shrimp farming represents the third staple of the national economy of Honduras, few economic analyses have been conducted to date. In this study, production data were collected from 21 farms for the year 1997. These data include technical aspects of farms such as stocking densities, feeding rates, and feed conversion ratios, as well as financial performance data such as production costs and farm revenue. A risk analysis was conducted from these data using three scenarios defined according to farm size and a fourth to

aggregate farms with uncommonly high yields. Results indicate that risk is more associated with low yields than with high production costs and that, regardless of size, farms should target a minimum acceptable yield; production of less than 450 kg ha^{-1} was associated with a large potential for loss.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS
9MEAR3/Development of Central American markets for tilapia produced in the region/Engle [Progress report]

This study will seek to identify and characterize existing market channels for fish and seafood in Honduras through the use of a survey instrument, which has been developed and is currently under review. Using the survey instrument, profiles will be developed of the types of markets that sell tilapia in Honduras, and the factors related to increased tilapia sales and the likelihood of other markets adding tilapia will be determined. Contacts have been made to identify a graduate student and enumerators to assist with the project, and the surveys will be conducted from September through December 1999.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS
9MEAR4/Economic and social returns to technology and investment in Thailand/Engle [Progress report]

A survey will be conducted in this study to measure rates of adoption of CRSP-developed technologies in northeastern Thailand. The rates of adoption will be used in a quantitative model to measure the internal rate of return to the investment in aquaculture research in Thailand. This study follows Eighth Work Plan research measuring the returns to research investment for CRSP-sponsored shrimp research in Honduras.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
8ADR1-1/Fish culture in the Peruvian Amazon: Producer perceptions and practices in three river systems/Molnar [Final report; report title different than study title in the *Eighth Work Plan*]

In this study, research was conducted to discover the nature of small-scale, community-based aquaculture employed in the Peruvian Amazon. Rural communities were visited, and fish farmers, community residents, and public and private agency officials were interviewed to determine the various strategies and approaches to aquaculture employed in this region. A high degree of variability was observed in the species used and the level of management applied. Variations were also found in the quality of pond construction and culture conditions. The data show few barriers to aquaculture in this region, and local fish farmers appear to be in an advantageous situation for fish culture. Fish farmers were also found to be receptive to technical assistance. The results further indicate that additional research is needed to identify and communicate production practices that will reduce risk and enhance aquaculture benefits.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
8ADR1-2/Sources of technical assistance for fish farmers in the Peruvian Amazon/Molnar [Progress report; report title different than study title in the *Eighth Work Plan*]

In this study, survey data were collected from a sample of 146 fish farmers near Iquitos, Peru, in selected communities served by NGOs, in an effort to determine relative desire for and exposure to extension efforts in the region. The survey results address varying perceptions of need for technical assistance based on gender and the type of operating arrangements for aquaculture. Results indicate that about 38% of the women surveyed had no contact with extension efforts, compared to 9% of the men. All the women and 95% of them men participating in the survey indicated that they desired extension contact in the future. The results of this study suggest that NGOs can be productive and enduring mechanisms for supporting family-based fish culture in rural areas of the Peruvian Amazon.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
8ADR2/Impacts of integrated fish culture on resource-limited farms in Guatemala and Panama: An ex-post evaluation/Lovshin [Final report]

This study evaluated the current status of tilapia pond projects initiated in the 1980s by the governments of Guatemala and Panama with financial support from the US Agency for International Development, in an attempt to determine the technological, economic, and social factors that influenced the success or failure of integrated fish culture projects there. In both Guatemala and Panama, aquaculture did not have the intended impact on household nutrition and income for a variety of technical, domestic, economic, social, and broad political reasons. In both countries, although aquaculture projects did not meet intended goals related to fish culture, many project participants found ways to profit from the existence of ponds by using ponds for irrigation, animal watering, or rice paddies. In Guatemala, 28 of 46 individual household ponds were still used at some level of proficiency. In Panama, 15 of 21 cooperatively managed ponds were still used at some level of proficiency.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
8KR5/Regional outreach in Africa/Bowman [Final report]

In order to disseminate information obtained from PD/A CRSP research, learn about fish culture practices and research priorities and activities in Kenya and neighboring African countries, and encourage the establishment of regional linkages between research and extension, CRSP researchers attended meetings of the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC) Inter-African Committee and Symposium on Oceanography, Sea and Inland Fisheries; the East African Environmental Network (EAEN); and the Fisheries Society of Africa. Representatives from seven African nations and numerous international organizations attended the OAU/STRC Inter-African Committee meeting where CRSP

researchers set up a display to publicize the program. At the EAEN Conference, CRSP researchers presented an invited paper entitled "An overview of aquaculture practices in East Africa: Potential environmental impacts and prospects for sustainable livelihoods," which was published in a proceedings volume. CRSP researchers gave nine presentations (oral and poster), which spanned topics such as the feeding and fertilization of semi-intensive tilapia monoculture and polyculture systems, the status of fisheries in Kenya and specifically of Lake Baringo, fish smoking, fish diversity in Lake Tanganyika, and parasitic fauna of tilapia species in Lake Naivasha and the Oloidien Bay.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
9ADR3/Aquaculture training for Kenyan fisheries officers and university students/Bowman [Progress report]

To increase the pond management skills of fisheries personnel currently involved in aquaculture extension and enhance the research and extension capabilities of university students likely to be employed in the aquaculture sector, PD/A CRSP researchers in Kenya developed training sessions relevant for university students, fisheries officers, fish farmers, and extension agents. Five graduate-level university students conducted their thesis research and four undergraduate students did their six-week "attachment" (or internship) at Sagana Fish Farm under the supervision of CRSP researchers. Fisheries officers at Sagana Fish Farm have taken on their own research projects (e.g., *Clarias* fingerling production techniques, feed electivity indices for *Clarias* and tilapia in fertilized ponds, and construction and testing of fish graders) under the guidance of CRSP researchers at Sagana Fish Farm, while other staff members have been selected for professional training in work with computers and applied biology. Additionally, a farmer education day was designed that addressed topics such as regulation of water flow, predator and weed control, feeds and fertilizers, stocking rates and carrying capacity, integration of farm practices with fish ponds, fish harvest techniques, and fish drying and smoking. Seven fisheries officer/farmer training sessions were also conducted throughout the Central Province of Kenya.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR4/Establishment of companion sites in the Africa region/Bowman [Progress report]

To verify program research results obtained at the CRSP prime site in Kenya and expand the breadth of CRSP research, researchers in Kenya are seeking to identify and establish one or more companion sites in the East Africa region and design and implement investigations at the newly identified companion site. Recently the Project Leader (and former PD/A CRSP researcher) of the International Center for Living Aquatic Resources Management (ICLARM) in Malawi visited Sagana Fish Farm and explored the possibility of a three-way collaboration between the PD/A CRSP, Bunda College in Malawi, and ICLARM. Representatives of Bunda College are currently reviewing a proposal for a student from Bunda College to conduct research at the National Aquaculture Center in Malawi, which is managed by ICLARM. This creates an excellent opportunity for regionalization, because Malawi is the seat of the Fisheries Office for the Southern African Development Community (SADC) and Bunda College is the fisheries and aquaculture training site for SADC countries.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR5/Regional outreach in Africa/Bowman [Progress report]

In order to promote the dissemination of information emanating from PD/A CRSP research results, learn about fish culture practices and research priorities and activities in Kenya and neighboring African countries, and encourage the establishment of regional linkages between research and extension, CRSP researchers attended the following meetings: Shallow Water Bodies in the Tropics, held in Naivasha, 12–16 April 1999; the Fisheries Society of Africa Executive Officer's Meeting, held in Nairobi, 22 April 1999; and East African Environmental Network Conference, held in Nairobi, 28–29 May 1999. At the Shallow Water Bodies in the Tropics Conference four presentations were made by graduate students conducting CRSP research. An abstract on pond effluent use for crop irrigation was submitted to the Seventeenth Conference and Silver Jubilee of the Soil Science Society of East Africa, to be held in Kampala, Uganda, in September 1999. CRSP researchers also plan to attend and present research results at a conference on the Lake Victoria Basin in November 1999.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: DECISION SUPPORT SYSTEMS
9DSSR3/Enhancing the POND© decision support system for economics, education, and extension/Bolte [Progress report]

This report discusses the latest design, functional modules, and application areas of POND©, a software decision support tool for analyzing and projecting cultural and economic aspects of warmwater aquaculture production systems. Current efforts focused on completing POND© Version 4.0, which has expanded enterprise budget capabilities compared to previous versions. The results of this study will enable continued improvement of analytical tools for managing warmwater aquaculture facilities and enhance understanding of the economic implications of various facility configurations and management options.

RESEARCH PROJECTS

POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

Staff

Auburn University, Auburn, Alabama

Claude E. Boyd	US Co-Principal Investigator, Project Leader
C. Wesley Wood	US Co-Principal Investigator
Laurence Massaut	Postdoctoral Fellow (Belgium) (through February 1999)
Brenda Wood	Technician
Dominique Gautier	Graduate Student (France) (from March 1999)
Martha Rowen	Graduate Student (not CRSP funded)
Jinwon Seo	Graduate Student (Korea) (not CRSP funded)
Stanislaus Sonnenholzner	Graduate Student (Ecuador) (through June 1999; partially CRSP funded)
Yelcin Tepe	Graduate Student (Turkey) (from September 1998; not CRSP funded)
Taworn Thunjai	Graduate Student (Thailand) (partially CRSP funded)
Oscar Zelaya	Graduate Student (Honduras) (from March 1999; fully funded)

Background

The interactions among nutrients, primary and heterotrophic productivity, and fish yield are known as pond dynamics. Current PD/A CRSP research in pond dynamics focuses on the influence of pond bottom soils on water quality and productivity. The two primary goals of pond dynamics research are characterizing the soils at each of the PD/A CRSP research sites (Honduras, Peru, Kenya, the Philippines, and Thailand) and examining the changes in organic matter and nutrient concentrations and availability over time. The results will be used to develop a pond soil classification system similar to that used in terrestrial soils. The information on changes in nutrient availability over time and site soil characteristics will be especially relevant to pond fertilization studies and practices.

Work Plan Research

The following Eighth Work Plan study continued into the current reporting period:

- Pond soil characteristics and dynamics of soil organic matter and nutrients/8PDR1. The report submitted for this study was a final report; the final results from this study appear in the progress report for 9PDR2.

This subcontract was awarded funding to conduct the following Ninth Work Plan study:

- Pond soil characteristics and dynamics of soil organic matter and nutrients/9PDR2. The report submitted for this study was a progress report.

Networking

Researchers Claude Boyd and Wes Wood traveled to PD/A CRSP host country institutions (Instituto de Investigaciones de la Amazonia Peruana and Universidad Nacional de la Amazonia Peruana) in Iquitos, Peru, to take soil samples. In addition to meetings with host country Principal Investigators Salvador Tello, Fernando Alcántara, and Enrique Rios Isern in Peru, Boyd and Wood attended a meeting of the Shrimp Farmers Association of Peru in Tumbes. Wood informed farmers about the research efforts of the program and the potential application of CRSP findings to pond management. Additionally in June 1999, Boyd met with farm owners and managers from the Asociación Nacional de Acuicultores de Honduras (ANDAH) to discuss the continuation of efforts to conduct pond soil analyses.

Boyd maintains contact with two scientists, Laurence Massaut and Amit Gross, who recently finished their Ph.D.s at Auburn University and who worked on PD/A CRSP soils research. Massaut currently works with the Belgian government and is stationed at Escuela Superior Politécnica del Litoral/Centro Nacional de Acuicultura y Investigaciones Marinas (ESPOL/CENAIM) in Ecuador, and Gross is working for an environmental laboratory in Tasmania that does soil, water, and food testing and consultancy in these areas for individuals, industry, and local authorities.

In Thailand Boyd met with several scientists at the Thailand Department of Fisheries to discuss environmental issues related to aquaculture and assist with the preparation of a Code of Conduct for aquaculture in Thailand. Boyd also attended a meeting attended by government officials and NGO representatives on environmental issues at the Network of Aquaculture Centres in Asia Pacific (NACA) in Bangkok. Boyd also met with Dr. Mali Boonyaratpalin in Thailand to discuss possible cooperation on pond soils research and to assist in the design of an experiment on the use of sodium nitrate as a pond soil oxidant.

Boyd has used information from his CRSP research in preparing codes of best management practices for the Global Aquaculture Alliance, a USAID project in Honduras, and a World Bank project in Thailand. Boyd has also developed a number of contacts through his work with the Global Aquaculture Alliance. He conducted soil analyses for shrimp farms in Madagascar and Indonesia and visited farms in Madagascar, Panama, and Honduras to provide water quality advice.

Student Involvement

Research under this subcontract involves numerous students. Among these, some are unfunded, some are partially funded, and one, Oscar Zelaya, is fully funded by the CRSP. This Honduran student was selected to receive CRSP funding for graduate studies under 8HCD1B, an Eighth Work Plan activity originally overseen by the CRSPs Education Development Component (see pp. 16–17). Responsibility for overseeing this activity has since been transferred to Claude Boyd, Zelaya's major professor. Zelaya's thesis research is described in work plan study 9ER4, "Effects of water recirculation on bottom soils and water quality in aquaculture ponds," which will appear in the Addendum to the Ninth Work Plan.

Educational Outreach

Boyd has used examples from CRSP data in his lectures for the graduate course Water Science, which he teaches at Auburn University.

Publications

Boyd, C.E. and A. Gross, 1998. Use of probiotics for improving soil and water quality in aquaculture ponds. In:

T.W. Flegel (Editor), Advances in Shrimp Biotechnology. BIOTEC, Bangkok, Thailand, pp. 101–106.

Boyd, C.E. and L. Massaut, 1999. Risks associated with the use of chemicals in pond aquaculture. Aquacult. Eng., 20:113–132.

Boyd, C.E. and C.S. Tucker, 1998. Pond Aquaculture Water Quality Management. Kluwer Academic Publishers, Boston, Massachusetts, 700 pp.

Gross, A., 1999. Nitrogen cycling in aquaculture ponds. Ph.D. dissertation, Auburn University, Alabama, 142 pp.

Sonnenholzner, S., 1999. Chemical and physical properties of shrimp pond sediment in Ecuador and some management strategies for pond preparation. Ph.D. dissertation, Auburn University, Alabama.

Sonnenholzner, S. and C.E. Boyd, 1999. Aerobic organic matter decomposition in aquaculture pond soils as measured by respiration chambers. J. World Aquacult. Soc. (in press).

Sonnenholzner, S. and C.E. Boyd, 1999. Chemical and physical properties of shrimp pond bottom sediments in Ecuador. J. World Aquacult. Soc. (in press).

Sonnenholzner, S. and C.E. Boyd, 1999. Decomposition of organic matter as measured by soil respiration in shrimp ponds treated with chemical and biological amendments. World Aquacult. (submitted).

Presentations

Boyd discussed CRSP findings in the following presentations:

Boyd, C.E. Pond soil and water quality management. Presented to the International Aquaculture Conference at São Paulo, Brazil, 26–27 August 1998.

Boyd, C.E. Soil and water quality management in shrimp farming. Presented to Aquaculture Brazil '98 at Recife, Brazil, 1998.

Boyd, C.E. Aquaculture environmental management. Presented to the Fifth Asian Aquaculture Conference at Chiang Mai, Thailand, 10–14 November 1998.

Boyd, C.E. Use of probiotics in aquaculture. Presented to the Fifth Asian Aquaculture Conference at Chiang Mai, Thailand, 10–14 November 1998.

Boyd, C.E. Soil and water quality management in aquaculture. Presented to the Venezuelan Aquaculture Conference at Porto Real, Venezuela, 1998.

Boyd, C.E. Mechanical aeration in pond aquaculture. Presented to the Annual Meeting of American Society of Mechanical Engineers at Washington, D.C., 1998.

Boyd, C.E. Environmental and sustainability issues in US aquaculture. Plenary address, Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Boyd, C.E. Environmental issues in aquaculture. Plenary address, Texas Aquaculture Association Annual Meeting at El Campo, Texas, 1999.

Boyd, C.E. Pond fertilization. Presented to the Regional Aquaculture Meeting at Culiacán, Mexico, 1999.

Boyd, C.E. Control of suspended solids in effluents from coastal aquaculture ponds. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E. The Global Aquaculture Alliance Codes of Practice. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E., 1999. Promoting environmentally responsible aquaculture to meet world food needs. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E. Measurement of pH in pond bottom soils. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E. Environmental management in aquaculture. Presented to the Aquaculture Meeting, Pacific Economic Cooperation Council at Lima, Peru, 9 June 1999.

Conferences

International Aquaculture Conference at São Paulo, Brazil, 26–27 August 1998. (Boyd)

Aquaculture Brazil '98 at Recife, Brazil. (Boyd)

Fifth Asian Aquaculture Conference at Chiang Mai, Thailand, 10–14 November 1998. (Boyd)

Aquaculture America '99 at Tampa, Florida, 27–30 January 1999. (Boyd)

Texas Aquaculture Association Annual Meeting at El Campo, Texas, 1999. (Boyd)

Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999. (Boyd)

Workshops

Boyd, C.E. Pond soil and water quality management workshops. Conducted in Tumbes, Peru, 18–19 August 1998.

Boyd, C.E. Pond dynamics workshop. Conducted for commercial aquaculturists, Melbourne, Australia, 3 May 1999.

Boyd, C.E. Water quality in aquaculture workshop. Conducted for commercial aquaculturists, Adelaide, Australia, 4 May 1999.

Boyd, C.E. Aquaculture and the environment workshop. Conducted for Western Australia Fisheries Department,

Perth, Australia, 6 May 1999.

Boyd, C.E. Dissolved oxygen management in ponds workshop. Conducted for the Asociación Nacional de Acuicultores de Honduras, Cholutеca, Honduras, 16 June 1999.

Award

Boyd received the Creative Research Award from Auburn University, Alabama, in February 1999. The award was presented by the Vice Provost of Auburn University's Research Office.

POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL ORGANIC MATTER AND NUTRIENTS

Ninth Work Plan, Pond Dynamics Research 2 (9PDR2)
Progress Report

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

C. Wesley Wood
Department of Agronomy and Soils
Auburn University, Alabama, USA

Taworn Thunjai and Stanislaus Sonnenholzner
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

Analyses of soil cores from the bottoms of three freshwater fish ponds in Thailand and three in Peru revealed the typical layering in bulk density, total carbon, total nitrogen, and other selected physical and chemical variables observed in ponds at other CRSP sites and at Auburn University. Thus, we are now confident that the system of dividing soil profiles into S horizon (surface mixed sediment), M horizon (unmixed bulk sediment), T horizon (transition layer), and P horizon (original pond bottom soil) is based on a general feature of pond soil profiles. The soils from Iquitos, Peru, were very highly weathered and low in concentrations of macronutrient cations and micronutrients. There was very weak development of horizons in ponds at Iquitos. Organic matter decomposition in pond soils at Iquitos appears to be nitrogen limited. Ponds at Sae Kaeo, Thailand, had more highly developed horizons than those at Iquitos, Peru. The pond soils at Sae Kaeo also were highly weathered, but higher in cations and micronutrients than the Iquitos pond soils. Respiration per unit carbon (mg CO_2 g^{-1} C) was significantly different ($P < 0.01$) among layers in ponds from Auburn, Alabama, and Ecuador, and the highest respiration rate was obtained in the uppermost 1.0-cm layer. Higher respiration rate is attributed to a higher ratio of labile to refractive organic matter in the upper layers.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

Staff

University of Oklahoma, Norman, Oklahoma

William Shelton	US Principal Investigator, Project Leader
Robert Raymond	Research Assistant (from May 1999)
Linda Bird	Graduate Research Assistant (January through May 1999)

Background

Limited knowledge of the reproductive physiology and breeding of culture species was identified as one of the key constraints to aquaculture in the *Continuation Plan 1996–2001*. Specifically, effective and practical control of reproduction is the major constraint in tilapia culture. Inter- and intraspecific breeding programs can result in populations with highly skewed sex ratios but often give inconsistent results. Interspecific crosses have not proven to be practical due to difficulties in maintaining the parent species integrity.

Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in Nile tilapia, *Oreochromis niloticus*. The androgenetic approach to developing YY males simplifies the identification of YY males as all males produced should be of the YY genotype. Research under the Eighth and Ninth Work Plans was scheduled to develop appropriate techniques for the androgenetic production of YY male tilapia.

Work Plan Research

The following Eighth Work Plan study continued into the current reporting period:

- Methods for androgenesis techniques applicable to tilapia/8RCR1B. The report submitted for this study was a final report.

Note: The studies grouped under the research theme 8RCR1, "Monosex tilapia production through androgenesis," are collaborative projects between Auburn University (under Subcontract No. RD010A-09) and the University of Oklahoma.

Networking

A representative from a company in the Ivory Coast contacted CRSP researcher William Shelton regarding the development of food production capabilities as a recovery program for the country. Shelton referred the representative to CRSP researchers in Kenya in addition to aquaculture researchers at the International Center for Living Aquatic Resources Management in Malawi, a potential companion site collaborator with the CRSP.

Presentation

Shelton, W. and R. Phelps. Sex manipulation in *Oreochromis niloticus*. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Conference

Aquaculture America '99 at Tampa, Florida, 27–30 January 1999. (Shelton)

METHODS FOR ANDROGENESIS TECHNIQUES APPLICABLE TO TILAPIA

Eighth Work Plan, Reproductive Control Research 1B (8RCR1B) Final Report

William L. Shelton
University of Oklahoma
Norman, Oklahoma, USA

ABSTRACT

Control of reproduction is vital to aquaculture and includes artificial propagation as well as management of unwanted recruitment. Developments in manipulation of the reproductive system provide options to enhance production. Nile tilapia, *Oreochromis niloticus,* spawning was managed by photoperiod and temperature manipulation. A controlled light cycle of 20L:4D and water temperature of 26 ± 2°C directed spawning to a predictable time frame. A developmental rate (τ_0) relationship was described and applied to chromosome manipulation. Blond Nile tilapia are homozygous recessive for a color mutation that was used as a phenotypic marker in the development of protocol for androgenetic induction. Androgenotes were produced by neutralizing the female genome of normal color Nile tilapia (600 J m^{-2} UV dose), activating the egg with sperm from blond males, and diploidizing with cold shock (11 ± 0.5°C for 60 min) applied at various times after incubation at 28 ± 0.2°C. Shock applied at 69 min post-activation produced greater numbers of androgenotes than shocks applied at 59 or 79 min post-activation. Optimization for shock type and associated parameters will be required for production of practical numbers of androgenotes for YY-male breeding programs.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

Staff

Auburn University, Auburn, Alabama

Ronald P. Phelps	US Principal Investigator, Project Leader
R. Lee Warrington	Graduate Research Assistant

Background

Limited knowledge of the reproductive physiology and breeding of culture species was identified as one of the key constraints to aquaculture in the *Continuation Plan 1996–2001*. Specifically, effective and practical control of reproduction is the major constraint in tilapia culture. Inter- and intraspecific breeding programs can result in populations with highly skewed sex ratios but often give inconsistent results. Interspecific crosses have not proven to be practical due to difficulties in maintaining the parent species integrity. Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in Nile tilapia, *Oreochromis niloticus*. The androgenetic approach to developing YY males simplifies the identification of YY males as all males produced should be of the YY genotype.

Broodstock and seed supply was also identified as a major constraint in the *Continuation Plan 1996–2001*, resulting in reproduction control becoming one of the CRSP research priorities. Much of the CRSP research effort has focused on tilapia, for which management of unwanted reproduction is an essential part of most culture systems. The objectives identified in the Eighth Work Plan include a series of studies which address this issue by determining whether there is an autosomal influence on the sex ratio of Nile tilapia and developing a pure YY line of male Nile tilapia. An additional study addresses the health and environmental impacts of a commonly used masculinization technique by detecting androgen from treated feed in pond water.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Methods for contribution from the male and female genome to sex inheritance/8RCR1C. No report was submitted for this study.
- Methods for development of YY lines of male and female *O. niloticus*/8RCR1D. No report was submitted for this study.
- Detection of MT in pond water after treatment with MT food/RCR3B. The report submitted for this study was a final report.

Note: The studies grouped under the research theme 8RCR1, "Monosex tilapia production through androgenesis," are collaborative projects between the University of Oklahoma (under Subcontract No. RD010A-02) and Auburn University. The studies under the research theme 8RCR3, "Detection of masculinizing agents in the pond environment," involve collaboration between Oregon State University (under MOU No. RD009C) and Auburn University.

METHODS FOR CONTRIBUTION FROM THE MALE AND FEMALE GENOME TO SEX INHERITANCE

Eighth Work Plan, Reproduction Control Research 1C (8RCR1C)
No Report Submitted

Editor's Note:
No report was submitted. The following information was submitted by the Principal Investigator in quarterly impact reports:
"The control portion of this study has been completed. Thirty spawns were obtained from individuals where the sex ratios of the progeny were known. The sex ratios from the 1998 season spawns are now being determined.

"The Auburn portion of the study (RCR1C) Methods for the Contribution from the Male and Female Genome to Sex Inheritance was to include the evaluation of sex ratios from androgenic males and females. Fish of this type have not been available for evaluation."

METHODS FOR DEVELOPMENT OF YY LINES OF MALE AND FEMALE *O. NILOTICUS*

Eighth Work Plan, Reproduction Control Research 1D (8RCR1D)
No Report Submitted

Editor's Note:
No report was submitted. The following, submitted by the Principal Investigator, explains the lack of progress on this work plan:
"Several factors have affected the schedule to the Auburn phase of this work plan. No strain of *O. niloticus* evaluated in Work Plan 8 (RCR1A) Methods for Strain Variations in Sex Ratio Inheritance gave an acceptable conformity to a 50:50 sex ratio for use in this study. Individual fish evaluated as part of (RCR1C) Methods for the Contribution from the Male and Female Genome to Sex Inheritance offer promise for the development of the lines needed for this work plan. The development of lines based on selection of individual fish is part of the activities in Work Plan 9. Results to date suggest that it will be necessary to develop such lines based on individual selection before YY technology will be successful.

"This work plan is also dependent on the successful development of androgenic techniques that can be applied to a true breeding strain."

DETECTION OF MT IN POND WATER AFTER TREATMENT WITH MT FOOD

Eighth Work Plan, Reproduction Control Research 3B (8RCR3B)
Final Report

R.P. Phelps
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

M.S. Fitzpatrick and W.M. Contreras-Sánchez
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

R.L. Warrington and J.T. Arndt
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

The objective of the study was to determine if methyltestosterone (MT) can be detected in the treatment environment and, if so, for how long after treatment. *Oreochromis niloticus* fry with a mean initial length of 9.5 mm were stocked into adjacent cages in an earthen pond at Auburn University, Alabama, at 2,000 fry cage^{-1} and fed for 28 days a feed containing 60 mg MT kg^{-1} or a non-treated feed. At the end of the controlled feeding period both sets of fish were harvested, and growth and survival were determined. Fish were returned to their respective hapas and fed a non-hormone treated feed for additional growth until a mean total length of approximately 5 cm was reached. A sample of 100 fish from each hapa was preserved in 10% formalin and the sex was determined. Water and soil samples from the treatment pond were taken prior to, during, and after the hormone administration period. Water samples (collected approximately 10 cm below the surface) were taken weekly from within the cage receiving hormone-treated feed and the cage receiving non-treated feed. At the same time intervals water samples were taken at 2, 5, and 10 m from the cage receiving hormone-treated feed. Soil samples were taken of the upper 5 cm of soil at the same locations at which water samples were taken; samples were collected from under the cages and from the pond bottom at the distances specified above. Soil and water samples were analyzed at Oregon State University. There was no evidence that MT altered the sex ratio of non-target tilapia held in the same pond and confined near fish receiving MT. The treated population was 91% male, 5% female and 4% intersex. Fish held in an adjacent cage approximately 50 cm away and fed a non-hormone-treated diet had a sex ratio of 48% males and 52% females. Mean MT concentration in the water sampled within MT-treated or non-treated cages did not differ ($P = 0.14$). Pretreatment MT concentration in the water column was 8.0 ± 5.7 pg g^{-1}, and values within the treatment cage were similar except for one sample during the treatment period. The radioimmunoassay when used with soil cross-reacted with other materials in addition to MT. Pretreatment soil samples from the pond, which had no previous history of MT administration, had a concentration of 875 ± 147 pg g^{-1}. The highest concentration of MT indicated (1,417 pg g^{-1}) was from a soil sample beneath the cage receiving the non-treated feed.

REPRODUCTION CONTROL RESEARCH

MOU No. RD009C

Staff

Oregon State University, Corvallis, Oregon

Martin S. Fitzpatrick	US Co-Principal Investigator, Project Leader
Carl B. Schreck	US Co-Principal Investigator
Wilfrido M. Contreras-Sánchez	Graduate Research Assistant (Mexico)
Rob L. Chitwood	Research Hatchery Manager (not paid with CRSP funds)
Grant W. Feist	Research Assistant (not paid with CRSP funds)
Andrea Altomare	Undergraduate Student (September 1998 through June 1999)
Ed Buchner	Undergraduate Student (from September 1998)
James Cassidy	Undergraduate Student (September 1998 through June 1999)
Ian Chane	Undergraduate Student/Intern (through January 1999)
Beth Davis	Undergraduate Student (September 1998 through December 1998)
Kelly Hanley	Undergraduate Student (September 1998 through June 1999)
Terra Heilman	Undergraduate Student (September 1998 through June 1999)
Paula Iida	Undergraduate Student (September 1998 through April 1999)
Nancy Savage	Undergraduate Student (from September 1998)
Damien Wycoff	Undergraduate Student (October 1998 through June 1999)

Universidad Juárez Autónoma de Tabasco (UJAT), Villahermosa, Mexico

Gabriel Márquez-Couturier	Host Country Principal Investigator
Ulises Hernandez Vidal	Technician
Alejandro MacDonald Vera	Technician
Luis Arturo Dorantes Lopez	Undergraduate Student (from January 1999)
Alejandro Gomez Jiminez	Undergraduate Student
Thelma R. Gonzalez Marquez	Undergraduate Student
Guadelupe Morales Lara	Undergraduate Student
Sofia Caroline Santiago Ruiz	Undergraduate Student (from January 1999)
Alvaro Zacarias Sánchez	Undergraduate Student

Background

Broodstock and seed supply was identified as a major constraint in the *Continuation Plan 1996–2001*, resulting in reproduction control becoming one of the CRSP research priorities. Much of the CRSP research effort has focused on tilapia, for which management of unwanted reproduction is an essential part of most culture systems. Earlier studies examined the effectiveness of masculinization treatment by feeding with and immersion in two synthetic androgens. Reproduction Control Research under the Ninth Work Plan concentrates on developing techniques for masculinization through immersion to provide safe and cost-effective alternatives to treating fry with food that contains MT.

Work Plan Research

This MOU was awarded funding to conduct the following Ninth Work Plan Reproduction Control studies (see Effluents and Pollution Research (p. 44) for information on other funded studies under this MOU):

- Masculinization of tilapia by immersion in trenbolone acetate: Effect of treatment timing and dose on masculinization with trenbolone acetate/9RCR5A. The report submitted for this study was a final report.
- Masculinization of tilapia by immersion in trenbolone acetate: Growth performance of trenbolone acetate–immersed tilapia/9RCR5B. This study has not yet begun; a work plan schedule change has been filed.

Note: Research under this MOU was revised from that described in the *Ninth Work Plan*. Methods and schedule modifications to 9RCR5B will appear in the *Addendum to the Ninth Work Plan*. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information.

Networking

CRSP researchers at OSU continued to foster their relationship with the Universidad Juárez Autónoma de Tabasco (UJAT) and develop new institutional linkages in Mexico with the Universidad Autónoma Metropolitana (UAM) and Instituto Politécnico Nacional. CRSP researchers Martin Fitzpatrick, Wilfrido Contreras-Sánchez, and Gabriel Márquez-Couturier formalized the collaborative relationship that has been established for several years between OSU and UJAT in June 1999 with a Memorandum of Understanding (MOU). The MOU is accompanied by a second agreement, a "Specific Joint Authority," that outlines the research to be undertaken in Reproduction Control and Effluents by scientists in OSUs Department of Fisheries and Wildlife and UJATs School of Biological Sciences.

Fitzpatrick and Contreras at OSU maintained close communication with Márquez to coordinate research efforts; Márquez's students are conducting tilapia masculinization experiments. From late November 1998 to early January 1999, Contreras, an OSU graduate research assistant and faculty member at UJAT, was on site at UJAT to collaborate with Márquez on the setup of an experiment to determine the effect of trenbolone acetate on masculinization of tilapia, mirroring CRSP research design at OSU. OSU and UJAT researchers continue to be in frequent contact via email

regarding the progress of masculinization studies. In addition to frequent communication with Márquez, Contreras has been in contact with a professor conducting her Ph.D. research at UJAT concerning methods for assaying steroid hormones.

In February, Contreras met with professors from UAM and Instituto Politécnico Nacional in Mexico City regarding the potential for using alternative steroids for masculinization of tilapia. Professors of both educational institutions indicated an interest in collaborating on research on the fate of steroids in sediments and remain in email contact with OSU.

Fitzpatrick traveled in February to the Sixth Symposium on Reproductive Physiology of Fish in Bergen, Norway, where he presented a paper on alternate steroid treatments and their environmental effects (see presentations section below). Scientific colleagues from Israel, Sweden, Great Britain, Canada, USA, and Portugal were present at the symposium and asked for further information about CRSP reproduction control research at OSU. Requests for information focused on CRSP-developed protocols for measuring MT in soil and water samples. Fitzpatrick sent a description of methods to colleagues in Great Britain and will be sending vendor information to other interested scientists.

CRSP researchers at OSU have received requests for information about their reproduction control research from both scientists and farmers. Fitzpatrick met with a professor from Hofstra University in Hempstead, New York, who was involved in a tilapia venture in the Ivory Coast and has a variety of tilapia species under culture at Hofstra. The professor is interested in trying the immersion protocol for masculinization on various tilapia species cultured at Hofstra University. Contreras responded to a request for information on the masculinization of tilapia from a farmer in Tabasco, providing him with copies of relevant CRSP-authored materials and several other references.

The presence of CRSP researchers and CRSP-sponsored facilities at OSU has been a valuable resource to public schools in Oregon. Fitzpatrick received a report from a student of Arcadia Elementary School in Toledo, Oregon, who had visited the PD/A CRSP recirculating system at OSU to come up with a design for his system at Arcadia. The student reported that his class was selling tilapia in the local market.

Educational Outreach

Contreras conducted a training session on safe handling of steroids and use of immersion for the purposes of masculinizing tilapia for five undergraduate students working on their Bachelor's thesis projects. In addition, Contreras facilitated a workshop on decisionmaking and statistical analysis to 15 students at UJAT.

Fitzpatrick uses examples from CRSP-sponsored research in the graduate level course in Fish Physiology he teaches at OSU.

Publications

Contreras-Sánchez, W.M., M.S. Fitzpatrick, G. Márquez-Couturier, and C.B. Schreck, 1999. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in synthetic androgens: Timing and efficacy. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck, 1999. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. In: Proceedings of the Sixth International Symposium on Reproductive Physiology of Fish, 4–9 July 1999, Bergen, Norway (submitted).

Fitzpatrick, M.S., W.M. Contreras-Sánchez, R.H. Milston, and C.B. Schreck, 1999. Fate of the masculinizing agent methyltestosterone in the pond environment. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

Gale, W.L., M.S. Fitzpatrick, M. Lucero, W.M. Contreras-Sánchez, and C.B. Schreck, 1999. Masculinization of Nile tilapia by immersion in methyldihydrotestosterone. Aquaculture (in press).

Presentation

Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. Presented to the Sixth International Symposium on Reproductive Physiology of Fish at Bergen, Norway, 4–9 July 1999.

Conference

Sixth International Symposium on Reproductive Physiology of Fish at Bergen, Norway, 4–9 July 1999. (Fitzpatrick)

EFFECT OF TREATMENT TIMING AND DOSE ON MASCULINIZATION WITH TRENBOLONE ACETATE

Ninth Work Plan, Reproduction Control Research 5A (9RCR5A)
Final Report

Martin S. Fitzpatrick and Wilfrido M. Contreras-Sánchez
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Carl B. Schreck
Oregon Cooperative Fishery Research Unit
Biological Resources Division—U.S. Geological Survey
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

ABSTRACT

Preliminary studies in our laboratory showed that the synthetic androgen trenbolone acetate (TA) is a good candidate for masculinizing Nile tilapia fry using short immersions. In this study, we investigated the effects of treatment timing and treatment dose on the masculinizing potential of TA. Our results suggest that maximum masculinization can be achieved by short-term immersion on 13 and 14 days post-fertilization. Immersion prior to and after these days resulted in less or no masculinization. We tested the effects of dosage by using the traditional single factor experiment as well as a novel approach: the fractional factorial experiment. In one experiment, immersion in all doses (500, 750, and 1,000 µg l^{-1}) of TA resulted in significant masculinization with no differences observed between doses. In a subsequent experiment with fry from a different brood, none of the doses resulted in significant masculinization. The fractional factorial experiment was designed to simultaneously examine the effects of treatment dose, treatment duration, and density of fish. Significant masculinization occurred in some treatments; however, no clear pattern of interaction emerged among these factors. Nevertheless, this experimental approach holds great promise for gaining rapid screening results which will be useful in designing follow-up experiments.

AQUACULTURE SYSTEMS MODELING RESEARCH

Subcontract No. RD010A-03

Staff

University of California, Davis, California

Raul H. Piedrahita	US Principal Investigator, Project Leader
Daniel Jamu	Research Assistant (Malawi) (through September 1998)
Zhimin Lu	Research Assistant (People's Republic of China) (through June 1999)
Aaron Lee	Undergraduate Student Worker

Background

Current CRSP aquaculture systems modeling studies address constraints to aquaculture productivity and the environmental effects of aquaculture. The work builds on previous experience and achievements under the PD/A CRSP. Models of aquaculture ponds developed to date have been deterministic and have evolved from the original models in which water quality was assumed to be uniform throughout a pond to models of stratified ponds. One of the models currently under development uses stochastic weather inputs to generate probability distributions for pond water quality and fish yields. The second model is used to analyze the flow of nutrients, particularly nitrogen, in an integrated aquaculture/agriculture system. The two distinct efforts will result in models that are useful for:

1) the study of pond management practices and the evaluation of possible production targets;
2) the analysis of environmental impacts from aquaculture; and
3) the study of nutrient and resource cycling in integrated agriculture/aquaculture systems.

Models were tested with data from various PD/A CRSP sites. The stochastic model makes extensive use of the weather data included in the PD/A CRSP Central Database. In addition, water quality and fish yield results from various PD/A CRSP treatments and sites are used to calibrate and validate the models. The models also can be useful as components of decision support systems being developed by the PD/A CRSP. Ultimately, aquaculture system models provide improved understanding of the dynamics of aquaculture ponds and make it possible to design more reliable and efficient production practices.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Aquaculture systems modeling for the analysis of environmental impacts and integration with agriculture: Relationship between carbon input and sediment quality in aquaculture ponds/8ASMR1A. The report submitted for this study was a final report. The title of the submitted report ("Aquaculture pond modeling for the analysis of environmental impacts and integration with agriculture: Model evaluation and application to the ecological analysis of integrated aquaculture/agriculture systems") differs from the study title.
- Aquaculture systems modeling for the analysis of environmental impacts and integration with agriculture: Stochastic modeling of temperature, dissolved oxygen and fish growth rate in aquaculture ponds/8ASMR1B. The report submitted for this study was a final report. The title of the submitted report ("Aquaculture pond modeling for the analysis of environmental impact and integration with agriculture: Modeling of temperature, dissolved oxygen, and fish growth rate in stratified ponds using stochastic input variables") differs from the study title.

This project was offered but declined funding for proposals submitted for consideration under the Ninth Work Plan Request for Proposals.

Networking

Piedrahita has developed international connections in the Philippines, Belgium, and Portugal. The Honorable Angelito M. Sarmiento, Representative of the fourth district to the Philippines House of Representatives, met with Piedrahita during his visit to the University of California, Davis. Piedrahita described the PD/A CRSP and its involvement in the Philippines and provided Sarmiento with PD/A CRSP brochures and names and contact information of current and previous Philippine CRSP collaborators. Additionally, the pertinence of Piedrahita's aquaculture systems modeling research has resulted in requests for information from individuals as far away as Belgium and Portugal.

Educational Outreach

Piedrahita teaches Aquacultural Engineering courses at the University of California, Davis; he uses CRSP data in his lectures related to water quality. Additionally, he guest lectured for an Animal Biology course where he described the PD/A CRSP and the role of the Aquaculture Systems Modeling research theme in the program.

Publications

Jamu, D., Z. Lu, and R. Piedrahita, 1999. Relationship between Secchi disk visibility and chlorophyll *a* in aquaculture ponds. Aquaculture, 170:205–214.

Lu, Z., R. Piedrahita, and C. dos Santos Neto, 1999. Generation of daily and hourly solar radiation values for modeling water quality in aquaculture ponds. Trans. ASAE, 41:1853–1859.

Presentation

Lu, Z. and R.H. Piedrahita. The probability distributions of temperature and dissolved oxygen in stratified fish ponds under stochastic input weather variables. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Conference

Aquaculture America '99 at Tampa, Florida, 27–30 January 1999. (Lu)

AQUACULTURE POND MODELING FOR THE ANALYSIS OF ENVIRONMENTAL IMPACTS AND INTEGRATION WITH AGRICULTURE: MODEL EVALUATION AND APPLICATION TO THE ECOLOGICAL ANALYSIS OF INTEGRATED AQUACULTURE/AGRICULTURE SYSTEMS

Eighth Work Plan, Aquaculture Systems
Modeling Research 1A (8ASMR1A)
Final Report

Daniel Jamu and Raul H. Piedrahita
Biological and Agricultural Engineering Department
University of California
Davis, California, USA

ABSTRACT

A model developed to analyze the environmental impacts of aquaculture and the productivity and ecological function of integrated aquaculture/agriculture systems was evaluated using sensitivity analysis and model validation methods. The validated model was used to identify priority areas for future research in integrated aquaculture/agriculture systems and to study the flow of nitrogen in these systems. Sensitivity analysis results showed that the model was most sensitive to maximum photosynthetic rate, aerobic sediment depth, oxygen threshold for aerobic conditions, water infiltration rate, and organic matter sedimentation rate. Model validation was established by the successful replication of observed patterns for individual fish weight, dissolved oxygen, total ammonia nitrogen, sediment organic matter, sediment nitrogen, chlorophyll *a* biomass, and corn grain yield. Application of a qualitative evaluation of research priorities that combined sensitivity analysis and parameter availability identified stocking practices, sediment processes, and water management as priority areas for future research in integrated aquaculture/agriculture systems. Based on the simulation results, the model appears to be appropriate for analyzing the management of organic matter and nitrogen in integrated aquaculture/agriculture systems. The model is also useful for identifying research areas that may be important in the scientific understanding of integrated aquaculture/agriculture systems.

AQUACULTURE POND MODELING FOR THE ANALYSIS OF ENVIRONMENTAL IMPACT AND INTEGRATION WITH AGRICULTURE: MODELING OF TEMPERATURE, DISSOLVED OXYGEN, AND FISH GROWTH RATE IN STRATIFIED PONDS USING STOCHASTIC INPUT VARIABLES

Eighth Work Plan, Aquaculture System
Modeling Research 1B (8ASMR1B)
Final Report

Zhimin Lu and Raul H. Piedrahita
Biological Agricultural Engineering Department
University of California
Davis, California, USA

ABSTRACT

A model has been developed for the prediction of water temperature, dissolved oxygen (DO), and fish growth using stochastically generated input weather variables. The model has been calibrated and validated using data from pond sites in Thailand, Honduras, and Rwanda. The model includes modules for the generation of weather parameter values, and for the calculation of water quality and fish growth. The weather parameters generated include hourly solar radiation, air temperature, wind speed, and wind direction. The water quality variables modeled include water temperature, DO, total ammonia nitrogen, and phytoplankton (in terms of chlorophyll *a*). For modeling purposes, the water column is divided into three layers, each of which is considered to be fully mixed. Temperature and DO are calculated separately for each of the three layers resulting in simulations of stratified ponds. Given the stochastic nature of the weather input variables, the model must be run a number of times for a given set of pond management conditions. Typically, the model is run 20 times for each data set. The probability distributions for water quality and fish yield can be calculated from the simulation results, providing the basis for the estimation of probability distributions that can be of use to pond managers, planners, researchers, and teachers.

EFFLUENTS AND POLLUTION RESEARCH

MOU No. RD009C

Note: Additional project information on Staff, Networking, Educational Outreach, Publications, Presentations, and Conferences appears in the Reproduction Control Research section, pp. 39–40.

Principal Investigators

Oregon State University, Corvallis, Oregon

Martin S. Fitzpatrick — US Co-Principal Investigator, Project Leader
Carl B. Schreck — US Co-Principal Investigator

Background

Feeding 17α-methyltestosterone to developing tilapia fry is an effective means of producing monosex populations; nevertheless, alternative methods require investigation because of concerns raised about production of steroid wastes and metabolites that are potential environmental contaminants. Eighth Work Plan research in Reproduction Control revealed that feeding tilapia fry with MT food resulted in considerable "leakage" of MT into the water and soil of model ponds. Ninth Work Plan Effluents and Pollution studies examine the effects of MT-treated food on pond soil and water in model ponds and in ponds at CRSP sites in Mexico and Kenya.

Work Plan Research

This MOU was awarded funding to conduct the following Ninth Work Plan Effluents and Pollution studies (see Reproduction Control Research (p. 39) for information on other funded studies under this MOU):

- Fate of methyltestosterone in the pond environment: Detection of MT in soil after treatment with MT food/ 9ER2A. The report submitted for this study was a final report.
- Fate of methyltestosterone in the pond environment: Detection of MT in pond soil from a CRSP site/9ER2B. An abstract was submitted for this study.

Note: Research under this MOU was revised from that described in the *Ninth Work Plan*. Methods and schedule modifications to 9ER2B will appear in the *Addendum to the Ninth Work Plan*. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information.

FATE OF METHYLTESTOSTERONE IN THE POND ENVIRONMENT: DETECTION OF MT IN SOIL AFTER TREATMENT WITH MT FOOD

Ninth Work Plan, Effluents and Pollution Research 2A (9ER2A) Final Report

Martin S. Fitzpatrick and Wilfrido M. Contreras-Sánchez
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Carl B. Schreck
Oregon Cooperative Fishery Research Unit
Biological Resources Division—U.S. Geological Survey
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

ABSTRACT

This study examined the persistence of 17α-methyltestosterone (MT) in the environment after its use for masculinizing Nile tilapia. Fry were treated with a masculinizing dose of MT (60 mg kg^{-1}) for four weeks beginning at the initiation of feeding in model ponds which consisted of 60-l tanks that contained either 5 kg of soil, gravel, or no soil. Water and soil samples were taken before the onset of treatment and weekly beginning on the last day of treatment (water samples were also taken weekly during the four-week treatment period). Concentrations of MT were determined by radioimmunoassay, which revealed that the levels of MT in the water peaked at approximately 3.6 ng ml^{-1} at 28 days after the onset of feeding. Concentration of MT in water decreased to background level by 35 days after the onset of feeding (one week after the end of treatment with MT-impregnated food) in the tanks with soil or gravel, but remained above background through 49 days in the tanks without soil. The levels in the soil were approximately 6.1 ng g^{-1} at 28 days after the onset of feeding with MT-impregnated food and remained detectable in the soil at between 2.8 and 2.9 ng g^{-1} after 84 days (eight weeks after ending treatment with MT-impregnated food). In tanks with gravel or no soil, MT was detected at higher levels in a fine sediment that formed after the end of dietary treatment. These results demonstrate that MT persists in soil for up to eight weeks after cessation of MT treatment, which raises the possibility that unintended exposure to MT may occur.

FATE OF METHYLTESTOSTERONE IN THE POND ENVIRONMENT: DETECTION OF MT IN POND SOIL FROM A CRSP SITE

Ninth Work Plan, Effluents and Pollution Research 2B (9ER2B)
Abstract

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Corvallis, Oregon, USA

Gabriel Márquez-Couturier
División Académica de Ciencias Biologicas
Universidad Juárez Autónoma de Tabasco
Villahermosa, Tabasco, Mexico

Karen Veverica
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

Carl B. Schreck
Oregon Cooperative Fishery Research Unit
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Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

ABSTRACT

The following study will examine if 17α-methyltestosterone (MT) persists in the environment after its use for masculinizing Nile tilapia at one or more PD/A CRSP sites. Experiments are currently underway at the Universidad Juárez Autónoma de Tabasco, Mexico. Fry have been treated with a masculinizing dose of MT (60 mg kg^{-1}) for four weeks beginning at the initiation of feeding. Water and soil samples were taken from the pond before the onset of treatment and one day after the end of treatment; samples will also be taken at four weeks after the end of treatment. Concentrations of MT will be determined by radioimmunoassay. If possible, a similar sampling design will be applied to the Sagana Station, Kenya, with subsequent analysis of samples at Oregon State University.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

Staff

University of Arkansas at Pine Bluff, Arkansas

Carole Engle	US Co-Principal Investigator, Project Leader
Siddhartha Dasgupta	US Co-Principal Investigator (through December 1998)
Diego Valderrama	Graduate Research Assistant (Colombia)

Asian Institute of Technology, Pathum Thani, Thailand

Harvey Demaine	Host Country Principal Investigator (from January 1999)

Background

The *Continuation Plan 1996–2001* envisioned a broader involvement of social scientists in the PD/A CRSP. The intended impact of CRSP research is greater economic and social returns to farmers who adopt CRSP-developed technologies. Quantifying those returns is one goal of Eighth and Ninth Work Plan research. Reaching a better understanding of risk and farmers' perception of risk is valuable in developing and encouraging the adoption of technologies. As production increases as a result of CRSP research, markets must be developed to keep pace with increasing supply. The development of domestic markets for tilapia in Honduras is the focus of another Ninth Work Plan investigation.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Economic and social returns to technology and investment/8MEAR1. The report submitted for this study was a final report. The title of the submitted report ("Nonparametric estimation of returns to investment in Honduras shrimp research") differs from the study title.
- Risk analysis of pond management strategies/8MEAR2. The report submitted for this study was a final report. The title of the submitted report ("Risk analysis of shrimp farming in Honduras") differs from the study title.

This subcontract was awarded funding to conduct the following Ninth Work Plan studies:

- Development of Central American markets for tilapia produced in the region/9MEAR3. The report submitted for this study was a progress report.
- Economic and social returns to technology and investment in Thailand/9MEAR4. The report submitted for this study was a progress report.

Networking

CRSP researcher Carole Engle has been working with two educational institutions in Honduras—the Escuela Agrícola Panamericana, also known as Zamorano, and the Instituto Tecnológico de Honduras—and the Asociación Nacional de Acuicultores de Honduras (ANDAH) to identify graduate students to participate in Ninth Work Plan research.

Educational Outreach

Engle presented a lecture on the economics of shrimp farming, which was based on her CRSP research in Honduras, in the course Aquaculture Economics and Management offered at the University of Arkansas.

Publications

Dasgupta, S. and C.R. Engle, 1999. Nonparametric estimation of the returns to the investment in shrimp research in Honduras. Aquacult. Econ. Manage. (submitted).

Dasgupta, S. and C.R. Engle, 1999. Non-parametric estimation of the returns to investment in Honduras shrimp research. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

Green, B.W. and C.R. Engle, 1999. Commercial tilapia aquaculture in Honduras. In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana (in press).

Valderrama, D. and C.R. Engle, 1999. Risk analysis of shrimp farming in Honduras. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

NONPARAMETRIC ESTIMATION OF RETURNS TO INVESTMENT IN HONDURAS SHRIMP RESEARCH

Eighth Work Plan, Marketing and Economic Analysis Research 1 (8MEAR1)
Final Report

Siddhartha Dasgupta and Carole Engle
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

ABSTRACT

Economic returns to the investment in shrimp research in Honduras between 1993 and 1997 by PD/A CRSP researchers were estimated using a nonparametric approach. A survey of shrimp growers in Honduras provided data on yield, input application, and prices for their first year of production and for the year 1997. Research investment data

included funding from both public and private sectors. Results showed that total factor productivity indices increased from 1995 to 1997, indicating technical progress due to research. When both private and public investment were considered, the internal rate of return to the investment in research was 45%. However, the internal rate of return to public-sector investment alone was above 6,352%. This indicated that the public funds invested in shrimp research in Honduras have been leveraged effectively with private-sector capital to generate technological progress.

RISK ANALYSIS OF SHRIMP FARMING IN HONDURAS

Eighth Work Plan, Marketing and Economic Analysis Research 2 (8MEAR2)
Final Report

Diego Valderrama and Carole R. Engle
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

ABSTRACT

Honduras has established itself as the leading producer of pond-raised shrimp in Central America. Although this activity already represents the third staple of the national economy, relatively few economic analyses have been conducted to date. For this study, data on production of farm-raised shrimp were collected from 21 farms. Data are from the year 1997. Information was collected on technical aspects of shrimp culture (stocking densities, feeding rates, FCRs) as well as on financial performance of the farms (production costs, farm revenue) during the considered period. A risk analysis was carried out from the resulting data. Three scenarios were defined according to farm size and a fourth was created to aggregate farms with uncommonly high yields. Scenarios were defined in order to identify possible differences in management strategies. Simulations for this study were run with commercially available risk analysis software. Results indicated that farms of the last scenario have developed a major potential for profit, far greater than that of those farms adopting more conservative approaches. Risk is more associated with low yields than with high production costs. Regardless of size, farms should target a minimum acceptable yield. Annual production of less than 450 kg ha^{-1} is connected with a large potential for loss.

DEVELOPMENT OF CENTRAL AMERICAN MARKETS FOR TILAPIA PRODUCED IN THE REGION

Ninth Work Plan, Marketing and Economic Analysis Research 3 (9MEAR3)
Progress Report

Carole R. Engle
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

ABSTRACT

Marketing studies will be conducted in Honduras in Year 1 of this project to identify and characterize existing market channels for fish and seafood in Honduras. Profiles will be developed of the types of markets that currently sell tilapia in Honduras, and the factors related to increased tilapia sales will be determined. The factors that affect the likelihood of other markets adding tilapia products also will be determined. The survey instrument for the supermarket survey has been developed and is currently under review. The pretest of the survey instruments will be conducted in August 1999. Contacts have been made with Escuela Agrícola Panamericana (Zamorano) and the Universidad Tecnológica de Honduras to identify a potential graduate student and enumerators to assist with the project. Interviews with candidates will be conducted in August 1999, and the surveys will be conducted from September through December 1999.

ECONOMIC AND SOCIAL RETURNS TO TECHNOLOGY AND INVESTMENT IN THAILAND

Ninth Work Plan, Marketing and Economic Analysis Research 4 (9MEAR4)
Progress Report

Carole R. Engle
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

ABSTRACT

A survey will be conducted in northeastern Thailand to measure rates of adoption of CRSP-developed technologies. The rates of adoption will be used in a quantitative model to measure the internal rate of return to investment in aquaculture research in Thailand. This project follows work of the Eighth Work Plan that measured these returns to research for CRSP shrimp research in Honduras. Funding for this project was available as of July 1999.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-18

Staff

Auburn University, Alabama

Upton Hatch	US Co-Principal Investigator, Project Leader
Jose Falck	Postdoctoral Research Associate

Background

Research under this subcontract will determine profitability and risk indicators for various aquaculture systems developed by the CRSP in Honduras, which will be used to make a rapid determination of whether a particular tilapia production strategy is likely to be profitable, easy to implement, and associated with acceptable levels of risk. In doing so, this study addresses several socioeconomic constraints to the development of more sustainable aquacultural systems identified in the *Continuation Plan 1996–2001*, specifically, inadequate attention to economic analysis of production; poor understanding of investment, markets, and risk reduction; lack of attention to efficient resource utilization; and barriers to assimilation of technological innovations through extension and training.

Work Plan Research

Ninth Work Plan research under this subcontract has not yet begun; activities will be reported on in next year's annual report.

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-10

Staff

Auburn University, Alabama

Joseph J. Molnar	US Principal Investigator, Project Leader
Malkia Lockhart	Graduate Research Assistant (Bahamas)
Steve Mikloucich	Graduate Research Aide

Instituto de Investigaciones de la Amazonia Peruana (IIAP), Iquitos, Peru

Salvador Tello	Host Country Co-Principal Investigator, Host Country Project Leader
Fernando Alcántara	Host Country Co-Principal Investigator
Carlos Chavez	Graduate Student Survey Interviewer
Luciano Rodriguez	Graduate Student Survey Interviewer

Sagana Fish Farm, Sagana, Kenya

Bethuel Omolo	Senior Fisheries Officer and Head of Station
Judith Amadiva	Social Development Officer

Background

Adoption/Diffusion Research investigates the barriers to assimilation of technological innovations through extension and training. Advances in basic understanding of the pond environment and cultural practices must eventually be translated and diffused to hatcheries, fish farmers, and other agencies and organizations involved in aquaculture development. Documenting the central mechanisms of transaction between fish farmers and the knowledge system in aquaculture is a fundamental objective of this work. Current activities build on earlier Adoption/Diffusion Research, with a survey instrument that was used at the Honduras, Thailand, Philippines, and Kenya research sites being employed at the site in Peru. Baseline data will be collected on the technology needs and production niches of *Colossoma* farmers in the Peruvian Amazon.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Socioeconomic dimensions of aquaculture development: Baseline conditions, human capital impacts, and technology diffusion processes: Study 1/8ADR1-1. The report submitted for this study was a final report. The title of the submitted report ("Fish culture in the Peruvian Amazon: Producer perceptions and practices in three river systems" differs from the study title.
- Socioeconomic dimensions of aquaculture development: Baseline conditions, human capital impacts, and technology diffusion processes: Study 2/8ADR1-2. The report submitted for this study was a progress report. The title of the submitted report ("Sources of technical assistance for fish farmers in the Peruvian Amazon") differs from the study title.

Networking

CRSP researchers Joseph Molnar, Fernando Alcántara, and Salvador Tello made a series of field visits to tilapia farms and aquaculture facilities in the Department of San Martin. Through these field visits, Alcántara, Tello, and Molnar gathered information about the history of tilapia culture in Peru, the current state of tilapia production in the Department of San Martin, and farmers' perceptions of the ecological impacts of tilapia. As a result of this fieldwork, CRSP researchers have fostered relationships with CARE/Peru who provided interviewers for the study; Caritas, a Catholic relief organization; and a nongovernmental organization, Terra Nuova, which works in aquaculture in Iquitos and on the Iquitos–Nauta Road with subsistence producers and in the Tiger Basin with riverine communities.

In addition to field research, Molnar met extensively with representatives of NGOs located in Peru, host country scientists, and fish farmers.

Educational Outreach

A student who is studying communal effects on the fishery in Iquitos assisted Molnar with survey work in the Iquitos region.

Publications

McNamara, M. and J. Molnar, 1999. Human capital impacts of the Pond Dynamics/Aquaculture CRSP. International Center for Aquaculture Communiqué, International Center for Aquaculture and Aquatic Environments, Auburn University (in press).

Molnar, J., 1999. Sound policies for food security: The role of culture and social organization. Rev. Agricult. Econ. (in press).

FISH CULTURE IN THE PERUVIAN AMAZON: PRODUCER PERCEPTIONS AND PRACTICES IN THREE RIVER SYSTEMS

Eighth Work Plan, Adoption/Diffusion Research 1-1 (8ADR1-1)
Final Report

Joseph J. Molnar
Department of Agricultural Economics and Rural Sociology
International Center for Aquaculture and Aquatic Environments
Auburn University, Alabama, USA

Fernando Alcántara Bocanegra and Salvador Tello
Instituto de Investigaciones de la Amazonia Peruana (IIAP)
Iquitos, Peru

ABSTRACT

The Instituto de Investigaciones de la Amazonia Peruana (IIAP) is the leading governmental organization working in aquaculture and fisheries research in the Peruvian Amazon region. In addition, IIAP produces fingerlings, offers training courses, and works with nongovernmental organizations (NGOs) endeavoring to promote fish culture. This report summarizes fieldwork and survey results from rural communities in the Iquitos area of the Amazon served by NGOs assisted by IIAP. The researchers visited rural communities and interviewed fish farmers, community residents, and public and private agency officials to discover the strategies and approaches to small-scale, community-based aquaculture employed in the Peruvian Amazon. Subsequently, data were collected from a sample of 146 practicing fish farmers in the Napo, Tamishiyacu, and Tahuayo river systems areas north and south of Iquitos, as well as in the Iquitos-Nauta Road area directly south of the city. Fish farmers were identified in selected communities provided technical assistance in aquaculture by CARE/Peru and several other nongovernmental organizations. Results portray the species cultured, marketing strategies employed, and the perceived impact of fish culture on families and farming systems. The data show that fish farmers are in an advantageous situation for fish culture. They encounter few barriers to building ponds, obtaining fingerlings, feeding their fish, or marketing the product. Fruits and other forest-based fish foods are widely available to support extensive production systems. A number of NGOs are providing regular farm visits and advice on fish culture. The natural cycle of the Amazonian river systems ensures a market period of relatively high prices for farm-reared fish. Additional attention is needed on identifying and communicating production practices that will reduce risk and enhance the benefits of aquaculture.

SOURCES OF TECHNICAL ASSISTANCE FOR FISH FARMERS IN THE PERUVIAN AMAZON

Eighth Work Plan, Adoption/Diffusion Research 1-2 (8ADR1-2)
Progress Report

Joseph J. Molnar
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International Center for Aquaculture and Aquatic Environments
Auburn University, Alabama, USA

Fernando Alcántara Bocanegra and Salvador Tello
Instituto de Investigaciones de la Amazonia Peruana (IIAP)
Iquitos, Peru

ABSTRACT

The Institute for Investigation of the Peruvian Amazon (IIAP), a PD/A CRSP host country institution in Peru, is the leading governmental organization working in aquaculture and fisheries research in the Peruvian Amazon region. In addition, IIAP produces fingerlings, offers training courses, and works with nongovernmental organizations (NGOs) endeavoring to promote fish culture. This report summarizes data collected from a sample of 146 practicing fish farmers in the Napo, Tamishiyacu, and Tahuayo River systems areas north and south of Iquitos, as well as in the Iquitos-Nauta Road area directly south of the city. Fish farmers were identified in selected communities that were provided technical assistance in aquaculture by CARE/Peru and several other NGOs. Results address perceptions of need for technical assistance based on gender and the type of operating arrangements for aquaculture. Results suggest women and group farmers have distinctive sets of experiences and preferences for technical assistance. About 38% of the women had no contact with extension versus 9% of the men. All the women respondents indicated that they desired extension contact in the future, but 5% of the men did not.

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-14

Staff

Auburn University, Alabama

Leonard L. Lovshin	US Co-Principal Investigator, Project Leader
Upton Hatch	US Co-Principal Investigator

University of Delaware, Newark, Delaware

Norman Schwartz	US Co-Principal Investigator

Cooperators

Panama
Hugo Perez Athanasiadis

Guatemala
Carol and Eduardo Godoy

Background

Constraints in the areas of socioeconomics (barriers to adoption of technologies) and human capacity (insufficient outreach/extension capacity; gender inequities) can limit the success of aquaculture projects. This study was an assessment of the impact of technology transfer to farmers in two Central American countries 9 and 14 years after development projects were discontinued. The findings can be used to design appropriate aquaculture research and outreach activities.

Work Plan Research

The following Eighth Work Plan study continued into the current reporting period:

- The influence of fish culture technology, extension methodology, and socioeconomics on success of fish culture on limited-resource farms/8ADR2. The report submitted for this study was a final report. The title of the submitted report ("Impacts of integrated fish culture on resource-limited farms in Guatemala and Panama: An ex-post evaluation") differs from the study title.

Networking

Lovshin distributed his final report to the USAID agriculture desks in Guatemala and Panama and the government agencies that participated in the research of both countries.

Publications

Lovshin, L.L. and N.B. Schwartz, 1999. Evaluation of integrated tilapia culture by resource limited farmers in Panama and Guatemala. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

Lovshin, L.L., N.B. Schwartz, and U. Hatch, 2000. The influence of fish culture technology, extension methodology and socio-economics on the success of fish culture on limited resource farms in Guatemala and Panamá: An ex-post evaluation. International Center for Aquaculture and Aquatic Environments Research and Development Series. Auburn University, Alabama (submitted).

Presentation

Lovshin, L. Integrated fish culture systems: Do they work? Presented to faculty and students of the Aquaculture Research Unit, University of the North, Pietersburg, South Africa, 20 April 1999.

IMPACTS OF INTEGRATED FISH CULTURE ON RESOURCE-LIMITED FARMS IN GUATEMALA AND PANAMA: AN EX-POST EVALUATION

Eighth Work Plan, Adoption/Diffusion Research 2 (8ADR2)
Final Report

Leonard L. Lovshin
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

Norman B. Schwartz
Department of Anthropology
University of Delaware
Newark, Delaware, USA

Upton Hatch
Department of Agricultural Economics and Rural Sociology
Auburn University, Alabama, USA

ABSTRACT

The study evaluated the status of fish pond projects initiated in the 1980s on resource-poor farms in Guatemala and Panama. In both places, the host country and the United States Agency for International Development (USAID) provided financial assistance and Auburn University provided technical support to the respective governments. The study examined the impact of aquaculture technology, extension services, and local socioeconomic conditions on the projects. The evaluation team (an aquaculturist, an agricultural economist, and a social anthropologist) had a rare opportunity to evaluate sustainability of two different types of fish farming projects. Other ex-post evaluations of aquaculture projects occur shortly after external support has ended, rather than after 14 and 9 years as was the case in Panama and Guatemala. In both Guatemala and Panama, the projects were designed to improve the nutrition and

increase the income of poor farmers, and participants were to become self-sufficient pond managers by the end of the project. The critical difference between the two projects is that in Guatemala fish ponds were managed by individual families on their farms, while in Panama more complex fish pond modules were managed by organized groups of farmers. In central and eastern Guatemala, the team visited 37 family and 2 cooperative fish pond projects between 9 and 19 June 1998. After the team left, a household survey was administered to these 37 families and another 9 families. So far as was possible, households were randomly selected from a list of 651 farm families known to have had functioning fish ponds when external financing was withdrawn in 1989. The team found that 39% of the ponds were abandoned, 48% were under-utilized; and 13% were well-managed. The fish did not have the intended impact on household nutrition and income for a combination of technical, domestic, economic, social, and broad political reasons. These include problematic water supplies to the ponds, lack of sufficient nutrients entering ponds to increase fish yield, theft, inconsistent technical assistance because of civil unrest and changing policy environments, and changing participant priorities linked to changes in household needs over the years. In Panama, the team visited 21 cooperative fish pond projects between 20 June and 3 July 1998. After the team left, a household survey was administered to 115 current or former project members. The team found that 6 projects had been completely abandoned, and 15 were being used to grow rice and/or fish. Only two projects still in use were well-managed. Fish did not have the intended impact on household nutrition and income for a combination of technical, domestic, economic, social, and broad political reasons. These include too little water to maintain pond water level during the dry season, lack of sufficient nutrients entering ponds to increase fish yield, inconsistent technical assistance related to changing government strategies, a lack of managerial and business skills on the part of project group leaders, over-dependence on local elites and/or government for various types of assistance, and macrosocial and political changes. Typically, abandonment or poor performance results from a combination of technical, economic, and social factors, each playing on and amplifying the others. In both countries, many project participants who maintained their ponds did so to irrigate gardens, water animals, or serve as flooded rice paddies. Thus, although the projects did not meet intended goals related to fish culture, participants found ways to profit from the existence of the ponds. In Panama 15 of 21 cooperatively managed pond projects and in Guatemala 28 of 46 individual household pond projects were still used at some level of proficiency.

DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

Staff

Oregon State University, Corvallis, Oregon

John Bolte	US Principal Investigator, Project Leader
Doug Ernst	Research Assistant
Charles Hillyer	Graduate Research Assistant

Cooperator

University of Georgia, Athens, Georgia
Shree Nath

Background

Aquaculture planners and managers are increasingly confronted with complex decisions regarding routine operations of culture facilities, effects of such operations on the surrounding environment, and the role of aquaculture production facilities within larger farming systems. Analytical tools for decision support systems integrate knowledge—as mathematical models, expert systems, and databases—into software systems.

CRSP research in Decision Support Systems has developed a Windows-based software package (POND©) that allows simulation modeling and economic analyses of entire pond facilities. POND© facilitates the assessment of economic and ecological impacts of alternative decisions on production and allows an increased understanding of the interrelationships that can affect production dynamics. By capturing the fundamental principles affecting pond production, coupling these with appropriate economic analyses, and presenting results in a readily understandable form, these decision support tools can improve the design, management, and analysis of production facilities.

The current research in Decision Support Systems focuses on improving the utility of POND© software for education and extension purposes; calibrating and validating POND© for additional culture organisms, including shrimp; and improving POND©s ability to address scheduling and other applied pond management issues. These enhancements should improve the usefulness of the software in addressing the needs of both educators and pond managers and allow improved decision-making in areas related to fertilization, feeding, stocking, water use and effluent discharge, and economic optimization.

Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan studies:

- Decision support systems for fish population management and scheduling in commercial pond aquaculture operations/9DSSR2. This study has not yet begun.
- Enhancing the POND© decision support system for economics, education, and extension/9DSSR3. The report submitted for this study was a progress report.

Note: The start date for 9DSSR2 that appeared in the *Ninth Work Plan* is incorrect; it should have been listed as 1 July 1999. Please see Appendix 5, "Completion Dates for Work Plan Studies," for correct schedule information. The studies grouped under the research theme 9DSSR2, "Decision support systems for fish population management and scheduling in commercial pond aquaculture operations," are collaborative projects between University of Arkansas at Pine Bluff (as a sub-project administered through Subcontract No. RD010A-01) and Oregon State University.

Networking

Oregon State University CRSP Project Leader John Bolte and Yang Yi, Asian Institute of Technology, arranged to collaborate on Ninth Work Plan research, which involves two studies, "Decision support systems for fish population management and scheduling in commercial pond aquaculture operations" and "Enhancing POND© decision support system for economics, education, and extension."

Bolte receives a number of requests weekly from aquaculture producers on the use of POND© software.

Educational Outreach

Bolte uses some of the models from POND©, a CRSP-developed software package, as examples in the graduate course Biosystems Modeling Techniques that he teaches at Oregon State University.

Publications

Bolte, J., S. Nath, and D. Ernst, 1999. Development of decision support tools for aquaculture: The POND experience. Aquacult. Eng. (in press).

Nath, S., J. Bolte, L Ross, and J. Aguilar-Manjarrez, 1999. Applications of geographical information systems (GIS) for spatial decision support in aquaculture. Aquacult. Eng. (in press).

ENHANCING THE POND© DECISION SUPPORT SYSTEM FOR ECONOMICS, EDUCATION, AND EXTENSION

Ninth Work Plan, Decision Support Systems Research 3 (9DSSR3)
Progress Report

John Bolte and Charles Hillyer
Department of Bioresource Engineering
Oregon State University
Corvallis, Oregon, USA

Shree Nath
Department of Biological and Agricultural Engineering
University of Georgia
Athens, Georgia, USA

ABSTRACT

Decision support systems (DSSs) are potentially valuable tools for assessing the economic and ecological impacts of alternative decisions on aquaculture production. This report discusses the latest design, functional modules, and application areas of POND©, a decision tool that has been developed to allow analysis of pond aquaculture facilities by the use of a combination of simulation models and enterprise budgeting. The software makes use of a simulation framework to provide much of the generic simulation, data handling, time flow synchronization, and communication features necessary for complex model-based DSSs. POND© contains representations for manipulating pond aquaculture and utilizes a series of mini-databases, a number of knowledge-based components ("experts"), models of the pond ecosystem, and various decision support features (e.g., assembling alternate management scenarios, economic analysis, and data visualization). A typical POND© simulation consists of assembling a number of appropriate objects or entities (e.g., multiple ponds and fish lots) and their management settings together with appropriate experts (e.g., an aquaculture engineer, an aquatic biologist, and an economist), and projecting changes in the facility over time. Most recent efforts have focused on improving the economic analysis capabilities of POND© and improving the usefulness of the software for addressing specific needs of the education and extension community.

HONDURAS PROJECT

Subcontract No. RD010A-06

Staff

Auburn University, Auburn, Alabama

Bartholomew Green	US Co-Principal Investigator, Project Leader (stationed in Tegucigalpa, Honduras, through December 1998)
Claude Boyd	US Co-Principal Investigator
David Teichert-Coddington	US Co-Principal Investigator

Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras

Marco Polo Micheletti Bain	Host Country Principal Investigator

Laboratorio de Calidad de Agua La Lujosa, Choluteca, Honduras

Jaime Lopez	Lab Technician (through October 1998)
Delia Martinez	Chemist (through October 1998)
Eneida Ramírez	Assistant Chemist (through October 1998)

Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras

Carolina Cardona	Biologist (GOH staff)
Nelson Claros	Chemist (through November 1998)
Rene Palcios	Lab Technician (through November 1998)

Cooperators

Grupo Granjas Marinas, S.A., Choluteca, Honduras
Brian Boudreau
Hector Corrales
John Wigglesworth
Rafael Zelaya

Site Background

The PD/A CRSP has collaborated in aquacultural research with the Honduran government at two different sites since 1983. Until 1993, all work was done at the Centro Nacional de Investigación Piscícola El Carao, a freshwater site located at Comayagua, Honduras. In 1993, the principal focus of the program was shifted to Laboratorio de Calidad de Agua La Lujosa, a coastal site in southern Honduras. The program in southern Honduras was in collaboration with four Honduran groups.

At the same time, work at the inland site at El Carao continued with a concentration on aquacultural production systems and management regimes applicable to subsistence farmers and small to mid-sized commercial tilapia producers. In southern Honduras, work concentrated on determining the impact of shrimp farming on the estuarine environment and investigating techniques for reducing nutrient discharge from ponds. Research in Honduras in the reporting period was conducted at both inland and coastal sites.

The ME was apprised by Auburn University in September 1998 of a possible Honduras project subcontract shortfall, and the following month the project on-site principal investigator began close-down activities. In late October Tropical Storm Mitch forced the early termination of several Eighth Work Plan studies that were still underway. As a result of the storm, ponds at El Carao were flooded, resulting in an escape of fish. In southern Honduras, a farm participating in a CRSP water quality study was also flooded (along with most of the other farms on the area).

The US researcher was repatriated by Auburn University in December and formally declined an award for Ninth Work Plan funding in January 1999. A combination of factors likely contributed to this decision, among them USAIDs decision to discontinue funding for shrimp research in Honduras and the program's fiscal and management direction away from fully supporting expatriate researchers' salaries. The CRSP director was able to enlist the support of USAID to grant a one-time close-down award of $55,000 for the PD/A CRSP Honduras project. In April 1999, Auburn University dissolved its existing Memorandum of Understanding with the Secretaría de Agricultura y Ganadería in Honduras.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Intensification of tilapia production: Effects of feeding at different stocking rates on pond water quality/8HR1. The report submitted for this study was a final report.
- Estuarine water quality monitoring and estuarine carrying capacity/8HR2-1. The report submitted for this study was a final report.
- Water exchange to rectify low dissolved oxygen/8HR4. The report submitted for this study was a final report.

Note: The study 8HR2, "Estuarine water quality monitoring and estuarine carrying capacity," is a collaborative project between the University of Texas (under Subcontract No. RD010A-05) and Auburn University. The 8HR2 report (8HR2-1) submitted by Auburn University addresses the

first 8HR2 work plan objective; the second study objective is addressed in the 8HR2 report (8HR2-2) submitted by the University of Texas.

Networking

Green developed linkages in a number of different realms related to aquaculture planning, research, and development in Honduras. He provided support for a USAID project (Proyecto Mejoramiento del Uso y Productividad de la Tierra (LUPE)) in Honduras through the use of the La Lujosa Laboratory facilities. To facilitate awareness of the environmental aspects of development and better understand the dynamics of development of the coastal zone, Green planned a field trip for Government of Honduras ministers and agency heads visiting southern Honduras.

Attendance at meetings of the Shrimp Culture Advisory group allowed Green the opportunity to network with aquaculturists from a number of sectors of the aquaculture community in Honduras; he attended six meetings of the National Shrimp Culture Advisory Group between the months of August and October 1998. The meetings included attendees from the GOH—DIGEPESCA (Dirección General de Pesca y Acuicultura), the Forestry Agency, and Ministry of Environment and Natural Resources; Asociación Nacional de Acuicultores de Honduras (ANDAH), representing industry; USAID (USAID project PROARCA/Costas); Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (CODDEFFAGOLF), a local NGO; and the PD/A CRSP.

Green attended the semiannual general assembly of the Asociación Nacional de Acuicultores de Honduras (ANDAH), where he presented results of estuarine water quality monitoring and production research. Additionally, he authored and distributed a Spanish-language extension bulletin on using a dissolved oxygen meter. Green provided advice on process to tilapia farmers working on forming a producers' association. Additionally, he visited Nuestros Pequeños Hermanos (NPH) orphanage to provide technical assistance on pond siting, construction, and management. NPH is developing a plan for a fish pond complex that will be built as part of a wastewater polishing system.

The PD/A CRSP in Honduras also extended its regional linkages through the establishment of contacts with researchers from Ecuador. The CRSP hosted a biologist from the Universidad Técnica de Machala, Machala, Ecuador, who attended a three-week training in water quality analyses at the La Lujosa laboratory and participated in the estuarine water quality monitoring program. Green also attended a meeting with a biologist from Ecuador, where they discussed their situations with regard to post-larval shrimp production.

In October 1998 Green initiated close down of in-country project activities and met with representatives from the Government of Honduras and ANDAH to help develop plans for continuation of estuarine water quality monitoring activities. ANDAH assumed responsibility for continuing the estuarine water quality monitoring program.

Educational Outreach

To expand the CRSP information network in Honduras and Central America, Green wrote an extension bulletin entitled, "Manejo y cuidado de equipo de medición de oxigeno disuelto." Five hundred extension bulletins were distributed to aquaculturists and government officials in Honduras and Nicaragua, members of ANDAH, and aquaculture students of the Escuela Agrícola Panamericana Zamorano, Honduras, and the Escuela Agrícola de la Region Tropical Humeda (EARTH) in Costa Rica.

Green also translated the 1997 Estuarine Water Quality Monitoring Annual Report to Spanish and distributed it to government policy makers and technical personnel, university faculty, aquaculturists, and NGOs.

Publications

Green, B.W., 1999. Sistemas de producción de tilapia en Honduras. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

Green, B.W. and C.R. Engle, 1999. Commercial tilapia aquaculture in Honduras. In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana (in press).

INTENSIFICATION OF TILAPIA PRODUCTION: EFFECTS OF FEEDING AT DIFFERENT STOCKING RATES ON POND WATER QUALITY

Eighth Work Plan, Honduras Research 1 (8HR1)
Final Report

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Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

Nelson Claros and Carolina Cardona
Centro Nacional de Investigación Piscícola El Carao
Dirección General de Pesca y Acuacultura
Secretaría de Agricultura y Ganadería
Comayagua, Honduras

ABSTRACT

Commercial production of tilapia is expanding rapidly in Central America, and hyper-intensive production systems often are being promoted to potential fish farmers. There are few or no sustainable technological packages for profitable tilapia production available to tilapia farmers in Central America. Commercial tilapia farms in Honduras routinely stock 5 to 7 fish m^{-2}. The goals of the proposed research were to develop sustainable pond management practices for small- to medium-scale commercial tilapia farmers in Honduras by evaluating the effect of stocking rate on tilapia yield and production economics and on pond nutrient budgets. Tilapia stocking rates of 2, 5, or 8 fish m^{-2} during a 240-d grow-out were to be tested in 0.1-ha earthen ponds at the Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras. A total of 60,000 fish were needed

for stocking experimental ponds. Research ponds were not available until 11 June 1998 because the Eighth Work Plan Global Experiment (8FFR1H) had to be extended beyond its programmed duration because fish growth continued. In May 1998 the well at the El Carao station failed, leaving the wet lab and fish transport facilities without water. Water to the wet lab and for fish transport had been restored partially by mid-July. In order to avoid further delays in Eighth Work Plan implementation it was decided to proceed, albeit with some risk, with the transfer of tilapia from nursery ponds to grow-out ponds to begin this experiment. Transfer took place on 21 July 1998. Unfortunately, approximately 40,000 of the more than 60,000 fingerlings in the nursery ponds did not survive the transfer process because of inadequate supply of water to the wet lab. Initiation of this experiment was delayed until December 1998 while a new group of fingerlings were reared to 50 to 100 g. Fortunately, there were adequate fingerlings in inventory at the El Carao station to allow the revised schedule to be met. On 30–31 October 1998 the torrential rains of tropical storm Mitch caused the El Carao station (as well as many other places in Honduras) to flood, which resulted in mass escape of fish in ponds. Thus, it became impossible to complete experiment 8HR1.

Estuarine Water Quality Monitoring and Estuarine Carrying Capacity

Eighth Work Plan, Honduras Research 2-1 (8HR2-1)
Final Report

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Auburn University, Alabama, USA

Delia Martinez and Eneida Ramírez
Laboratorio de Calidad de Agua
La Lujosa, Choluteca, Honduras

Abstract

Water quality was monitored in estuaries of the shrimp-producing regions of southern Honduras. This project is a collaborative effort of universities, the private sector, and the public sector, with each group contributing time and resources to the overall effort. The project goal is to provide a scientific basis for estuarine management and sustainable development of shrimp culture in Honduras. Specific objectives are to: a) detect changes in estuarine water quality; b) formulate and validate predictive models for estuarine water quality; and c) estimate assimilative capacity of selected estuaries in the shrimp-producing region of southern Honduras based on water quality, farm chemical budgets, and estuarine fluid dynamics. Samples were collected from October 1996 to October 1998; during 1997–1998 data were collected from 20 sites on 12 estuaries. Nutrient sources for riverine estuaries include nutrient load in river discharge and rainfall or irrigation runoff from the watershed, and shrimp farm discharge. Changes in land-use patterns in the Gulf of Fonseca watershed also will affect estuarine water quality because of changes in runoff patterns and volumes. Water quality in riverine estuaries continues to be influenced directly by seasonal variation in river discharge and watershed runoff, while embayments of the Gulf of Fonseca experience less seasonal variation in water quality. The impact of the 1997–1998 El Niño in Honduras were delayed and reduced rains, which resulted in higher observed salinity, total nitrogen and chlorophyll *a* concentrations at sampling sites along riverine estuaries in comparison to 1996–1997. Embayment water quality was less affected by the El Niño. No trends for total nitrogen or total phosphorus enrichment were evident in riverine estuaries or embayments during the period 1993–1998. Total nitrogen and total phosphorus concentrations in riverine estuaries were reduced by 10–30% during the rainy season because of river discharge and watershed runoff.

Water Exchange to Rectify Low Dissolved Oxygen

Eighth Work Plan, Honduras Research 4 (8HR4)
Final Report

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Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

John Wigglesworth and Hector Corrales
Grupo Granjas Marinas, S.A.
Choluteca, Honduras

Delia Martinez and Eneida Ramírez
Laboratorio de Calidad de Agua
La Lujosa, Choluteca, Honduras

Abstract

In Central America semi-intensive shrimp production technology is used by many producers. Semi-intensive production technology is characterized by final stocking rates of 5 to 11 shrimp m^{-2}, daily water exchange at ≤ 10% of pond volume, and use of 20 to 25%-protein feeds. The role of water exchange in semi-intensive shrimp culture is being evaluated in Honduras. A recent study, "Influence of daily water exchange volume on water quality and shrimp production" (HR3), indicated that daily or emergency water exchange did not affect significantly shrimp production, but that water quality was better in ponds that received daily water exchange. However, differences in water quality generally did not become pronounced until the latter half of the 12- to 16-wk production cycle. Producers may find unacceptable the risk associated with utilizing an emergency-only water exchange policy. However, it appears that the current standard practice of initiating water exchange beginning the fourth week post-stocking is not the most efficient was exchange strategy. This experiment builds on the previous experiment by investigating the effects of time of initiation of water exchange early morning dissolved oxygen, water quality, and shrimp production in ponds. The objectives of this experiment are to evaluate the effect of time of initiation of water exchange on pond dissolved oxygen, water quality, and shrimp production. Nine 0.93-ha ponds located on a commercial shrimp farm in southern Honduras were used

for this completely randomized design study to test time of initiation of water exchange. Water was exchanged at 10% of pond volume per day, six days per week beginning four, seven, or ten weeks after stocking. The rainy-season experiment was initiated and was to be repeated during the dry season. Ponds for the rainy-season experiment were stocked with hatchery-spawned post-larval (PL) *P. vannamei* at 145,000 PL ha^{-1} (14.5 PL m^{-2}) on 15 August 1998. Shrimp were fed six days per week beginning three weeks after stocking. On 30–31 October 1998 the torrential rains of tropical storm Mitch resulted in massive flooding of farms and enormous losses to shrimp farmers in southern Honduras. Data were collected up until the ponds were flooded. Treatment effects on pond water quality appeared to begin to manifest themselves in those treatments where water exchange had been initiated (the four- and seven-week treatments). Shrimp growth appeared to be affected by treatment as shown by the divergence of growth curves, but because there are no harvest data available it is impossible to draw conclusions regarding effects of treatment on shrimp growth and yield. Shrimp farms suffered infrastructural damage and very large economic loss as a result of the flooding caused by tropical storm Mitch. Given this situation it was not possible to repeat the rainy season experiment nor conduct the dry-season experiment.

HONDURAS PROJECT

Subcontract No. RD010A-05

Staff

University of Texas, Austin, Texas

George Ward — US Principal Investigator, Project Leader

Background

A baseline of water quality has been established for the major estuaries supporting the shrimp culture industry in southern Honduras. Correlation between industry farm management and estuarine water quality can now be drawn by continued time-series measurements. The goal of this research was the development of models that serve both a diagnostic purpose, in assisting the interpretation of the results of the estuarine sampling program, and a prognostic purpose, in acting as a tool for predicting the effects on estuarine water quality conditions of shrimp farm operations.

Work Plan Research

The following Eighth Work Plan study continued into the current reporting period:

- Evaluation of shrimp farming impacts in Golfo de Fonseca region, Honduras/8HR2-2. The report submitted for this study was a final report.

Note: The study 8HR2, "Estuarine water quality monitoring and estuarine carrying capacity," is a collaborative project between Auburn University (under Subcontract No. RD010A-06) and the University of Texas. The following report addresses the second 8HR2 work plan objective; the first study objective is addressed in the 8HR2 report (8HR2-1) submitted by Auburn University.

Publication

Ward, G.H., B.W. Green, and D.R. Teichert-Coddington, 1999. Estimation of carrying capacity for shrimp aquaculture in the eastern estuaries of the Gulf of Fonseca. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999, San Pedro Sula, Honduras. Asociación Nacional de Acuicultores de Honduras, Latin American Chapter of the World Aquaculture Society, and Pond Dynamics/Aquaculture CRSP, Choluteca, Honduras (submitted).

EVALUATION OF SHRIMP FARMING IMPACTS IN GOLFO DE FONSECA REGION, HONDURAS

Eighth Work Plan, Honduras Research 2-2 (8HR2-2)
Final Report

George H. Ward, Jr.
Center for Research in Water Resources
The University of Texas at Austin
Austin, Texas, USA

ABSTRACT

An intensive data collection and modeling study has been underway for the past several years addressing two of the channel estuaries draining into the Gulf of Fonseca, namely Estero El Pedregal and Estero San Bernardo. Data have been compiled on the shrimp farm configurations, exchange rates, and effluent chemistry. Temperature/salinity/dissolved oxygen profiles have been measured in the estuary channels in both rainy and dry seasons. Physiographic, hydrographic, and meteorological data have been obtained to supplement the estuary data. This report examines the assimilative capacity of these estuaries with respect to dissolved oxygen (DO). The oxygen demand of organics is measured by biochemical oxygen demand (BOD). Shrimp farm BOD loadings were estimated from effluent data and exchange. A transport model for salinity and DO in the estuaries was applied to predict the tidal-mean, section-mean concentrations of salinity and DO. The model predictions of DO given 1995 BOD loadings were satisfactory. Future loadings based upon full shrimp farm development along these two estuaries were then input to determine the resulting DO under these conditions. It was found that the 1995 configuration is already pressing the carrying capacity of both systems, and the DO will be worsened at full development. Shrimp farms placed farther upstream than about 20 km from the mouth will most likely have excessive impact on the DO in the estuary. The impact is exacerbated under dry season conditions. Negative impacts of a specific farm can be ameliorated by reducing or eliminating pond discharges during the dry season, and by reducing the level of water exchange employed. This work needs to be extended to address additional water-quality parameters and to incorporate larger spatial scales, especially to establish the interaction between different estuaries draining into Fonseca.

HONDURAS PROJECT

Subcontract No. RD010A-16 (UG)
Subcontract No. RD010A-17 (AU)

Staff

University of Georgia, Athens, Georgia

Brahm Verma	US Co-Principal Investigator, Project Leader
E. William Tollner	US Co-Principal Investigator

Auburn University, Auburn, Alabama

Joe Molnar	US Co-Principal Investigator
Tom Popma	US Co-Principal Investigator

Escuela Agrícola Panamericana El Zamorano, Honduras

Dan Meyer	Host Country Co-Principal Investigator
Freddy Arias	Host Country Co-Principal Investigator

Cooperators

Auburn University, Auburn, Alabama
Robert Nelson

Centro Internacional de Agricultura Tropical, Cali, Colombia
E. Bronson Knapp

Site Background

The PD/A CRSP is continuing its 15-year presence in Honduras with a Ninth Work Plan award to the University of Georgia and Auburn University. Honduras has been a host country since the program's inception in 1983 (excluding a brief interruption from 1987 to 1988); Thailand is the only host country in which the CRSP has enjoyed a longer presence.

Earlier CRSP research in Honduras (see previous project summaries) established a network of relationships with aquaculture producers in the country. The new project in Honduras will build on this experience, making use of the pool of trained individuals—many of them with previous CRSP involvement—now present there. In doing so, the new Honduras project seeks to help Honduran tilapia farmers take better advantage of the strong potential for aquaculture in Honduras and to help ensure that small- and medium-scale aquaculture production will remain viable in Honduras when the CRSP is no longer active there. These efforts will be addressed by strengthening institutional support for aquaculture in Honduras through a multidisciplinary approach. The University of Georgia is the lead US institution on this project; Auburn University is a collaborating US institution.

In July 1999 the Escuela Agrícola Panamericana (Zamorano) and the University of Georgia entered into a Memorandum of Understanding, making Zamorano the newest CRSP host country institution. Founded in 1942, Zamorano is a private, non-profit, international educational organization, offering degrees related to agriculture, social development, and the environment. Since 1976 El Zamorano has offered coursework in aquaculture and subsequently has developed aquaculture infrastructure and training programs that presently form an integral part of its academic curriculum.

Work Plan Research

Ninth Work Plan activities have not yet begun; they will be reported on in next year's annual report.

PERU PROJECT

Subcontract No. RD010A-12

Staff

Southern Illinois University at Carbondale, Illinois

Christopher C. Kohler	US Co-Principal Investigator, Project Leader
Susan T. Kohler	US Co-Principal Investigator
Marcos J. De Jesus	Researcher (Peru)

Ohio State University, Columbus, Ohio

Konrad Dabrowski	US Co-Principal Investigator
Jacques Rinchard	Postdoctoral Research Associate

Instituto de Investigaciones de la Amazonia Peruana (IIAP), Iquitos, Peru

Gonzalo Llosa Talavera	Host Country Project Leader (to February 1999)
Salvador Tello	Host Country Co-Principal Investigator, Host Country Project Leader (from February 1999)
Fernando Alcántara	Host Country Co-Principal Investigator
Palmira Padilla Perez	Aquaculturist
Lamberto Arevalo	Technician
Cesar A. Flores	Technician
Arturo Flores Huang	Technician

Universidad Nacional de la Amazonia Peruana (UNAP), Iquitos, Peru

Enrique Rios Isern	Host Country Co-Principal Investigator

Site Background

In 1996 a new PD/A CRSP site was developed in South America. The Peru project is located at Iquitos, in the heart of the Peruvian Amazon (Loreto Region). The CRSP collaborates with the Instituto de Investigaciones de la Amazonia Peruana (IIAP) and the Universidad Nacional de la Amazonia Peruana (UNAP). In the past ten years these institutions, along with the Peruvian government, have produced thousands of fry and have developed various aquacultural techniques. *Colossoma* and *Piaractus* are considered by local aquaculturists as the best fish species for commercialization in the tropical part of Peru. (Tilapia have been introduced to all eight USAID-presence countries in South America. However, they are illegal in the Peruvian Amazon basin.)

Work Plan Research

All final reports for Eighth Work Plan studies appeared in the *Sixteenth Annual Technical Report*. Ninth Work Plan research has not yet begun; the studies to be undertaken, grouped under the research study code 9NS3, "Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*," will be carried out collaboratively among the University of Arkansas at Pine Bluff (under Subcontract No. RD010A-13), Ohio State University (as a sub-project administered by Subcontract No. RD010A-12), and Southern Illinois University at Carbondale.

While Ninth Work Plan research has not yet begun, activities including the training of Peruvian personnel continue, focusing on water quality analyses, the use of hormones as spawning aids, and proper nutrition of broodstock.

Networking

CRSP researchers enhanced existing institutional linkages and further expanded the program's network through relationships with nongovernmental organizations, farmers, and the government of Peru. CRSP researchers provided logistical support, contacts, and information to representatives from the Yukon Development Education Centre (YEDC), a nonprofit registered charitable organization based in Canada. The organization intends to conduct a two-year pilot project—a fish farm to be located in the Rio Yarapa watershed of the Peruvian Amazon—and is seeking funding from the Canadian Government International Development Agency (CIDA). Additionally the YEDC is proposing a cage culture study of *Colossoma* or *Piaractus* spp. at IIAPs facilities, which presents excellent possibilities for collaboration with the CRSP.

CRSP researchers from Southern Illinois University at Carbondale, IIAP, and UNAP have maintained regular contact to plan research, share study results, and address issues related to the project's progress. In November Marcos De Jesus traveled to Peru to meet with Gonzalo Llosa and Fernando Alcántara, organize the research protocol for the Ninth Work Plan, and begin breeding trials. De Jesus brought human chorionic gonadotropin donated by Intervet, Incorporated, to Peru to facilitate the initial trials for a hormone study. Joseph Molnar also visited Iquitos, Peru, and met with Llosa and Alcántara. Additionally he conducted a preliminary study to aid in the design of a survey for local aquaculturists in preparation for future research (see Adoption/Diffusion research, p. 49). In July 1999 De Jesus, Jacques Rinchard (Ohio State University), and Rebecca Lochmann (University of Arkansas at Pine Bluff) traveled to Peru to collect data and meet with representatives from UNAP. Rinchard collected blood plasma samples from the broodstock used for CRSP research, and Lochmann collected diet and ingredients samples and visited farms and feed mills in the area. In addition to the work of Rinchard and Lochmann, Steven Lochmann, a fisheries professor at UAPB has provided literature on plankton and may donate equipment for zooplankton collection, which is valuable for

fingerling production. During their trip De Jesus, Rinchard, and Lochmann also met with a number of officials from UNAP—the Director of the Graduate School, coordinator of the Ecology and Development Graduate Program, and the Zoology Department Chair. In addition to UNAP officials De Jesus, Lochmann, and Rinchard met with the Director of the Aquaculture Division of the Peruvian Ministry of Fisheries, who visited CRSP research facilities.

CRSP researchers in Peru are forming enduring relationships with fish farmers, aquaculturists, scientists, and fishermen throughout the region via extension programs and information dissemination. Alcántara and Palmira Padilla Perez work with an aquaculture extension program involving two nongovernmental organizations, Terra Nuova, and Fe y Alegria. These organizations work to promote the development of aquaculture along the Nauta-Iquitos Road. The project constructs and rehabilitates ponds, provides *Colossoma*, *Piaractus*, and *Prochilodus* fingerlings for stocking, prepares diets, offers permanent technical support for farmers, and facilitates three four-day workshops every two weeks. Additionally, IIAP receives a steady stream of requests for aquaculture information. Representatives from Spain and Bolivia, as well as locals, visited IIAP to speak with Llosa and Alcántara about the successful culture of several Amazon species. With the assistance of regional fishermen (and with authorization from the Peruvian Ministry of Fisheries), the CRSP researchers collected wild gamitana fingerlings to supplement the numbers of study fish produced at the hatchery for CRSP experiments.

Educational Outreach

Kohler teaches an upper division undergraduate course entitled "Fish Culture." Examples taken from CRSP activities are integrated into the course.

Llosa and Alcántara, with assistance from several IIAP biologists and UNAP professors, conducted an aquaculture seminar for approximately 30 individuals at the IIAP CRI-Loreto research facility in October 1998. The seminar was designed for regional farmers who already have fish ponds or who were interested in semi-intensive aquaculture. Lectures and presentations addressed topics such as limnology, water quality, pond dynamics, culture species, and feed and nutrition.

CRSP researchers are incorporating students into the research agenda through volunteer work at CRSP research facilities and participation in research processes. Alcántara has been involved with the research of several fisheries students from UNAP. Under Alcántara's guidance the students volunteer at IIAP and learn culture techniques used by CRSP researchers, which is useful to their own research. Another student who is studying communal effects on the fishery in Iquitos has asked De Jesus for information on the regional fishery.

Publications

De Jesus, M.J., C.C. Kohler, and S.T. Kohler, 1998. Sustainable aquaculture in Peru. Aquaculture Magazine, 24(4):23-25.

De Jesus, M.J. and C.C. Kohler, 1999. The commercial fishery of the Peruvian Amazon: Is it sustainable? Fisheries Magazine (American Fisheries Society) (submitted).

Presentation

Alcántara, F., C. Kohler, S.T. Kohler, and M.J. De Jesus. Performance of *Piaractus brachypomus* and *Colossoma macropomum* stocked in ponds at different densities. Presented to World Aquaculture '99 at Sydney, Australia, 26 April–2 May 1999.

Conference

World Aquaculture '99, Sydney, Australia, 26 April–2 May 1999. (Kohler)

PERU PROJECT

Subcontract No. RD010A-13

Staff

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann — US Co-Principal Investigator, Project Leader

Background

A component of the Peru Project's Ninth Work Plan research (9NS3) will involve the design of feeds using locally available ingredients for use in broodstock maintenance.

Work Plan Research

Ninth Work Plan research has not yet begun; the studies to be undertaken, grouped under the research study code 9NS3, "Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*," will be carried out collaboratively among the Southern Illinois University at Carbondale (under Subcontract No. RD010A-12), Ohio State University (as a sub-project administered by Subcontract No. RD010A-12), and the University of Arkansas at Pine Bluff. See the Kenya Project (p. 71) for other funded studies under this subcontract.

Networking

Lochmann maintains contact with and advises Master's student Wilson Maina Gichuri from the University of Nairobi regarding the use of data obtained from CRSP research in his thesis. Additionally, Lochmann is frequently in contact with Kenya Project colleagues to exchange data and other project information related to CRSP research.

Lochmann presented a talk at UAPB entitled "The role of fish nutrition in aquaculture development efforts by the CRSP in Kenya and Peru" to a group of visiting Indonesian scholars. For another group, visiting from Brazil, Lochmann did a presentation entitled "Broodstock diet development for *Colossoma* and *Piaractus* in Peru," which was a direct outgrowth from her involvement with CRSP research in Peru. Both groups of international visitors showed a great deal of interest in Lochmann's work with the CRSP. As a result of Lochmann's presentation to the Brazilian visitors, the Brazilian Government decided to sponsor a postdoctoral research assistant to do research with Lochmann on *Piaractus* spp. at UAPB.

Educational Outreach

Lochmann teaches a course, Aquatic Animal Nutrition, at the University of Arkansas at Pine Bluff and uses examples from CRSP research in her lectures on the use of stable carbon isotopes as a tracking technique to pinpoint food sources for fish in aquaculture ponds.

Publication

Perschbacher, P. and R. Lochmann, 1999. Effects of feeding pelleted versus non-pelleted defatted rice bran on Nile tilapia *Oreochromis niloticus* production and water quality in ponds. Asian Fish. Sci. (in press).

KENYA PROJECT

MOU No. RD009A (OSU)
Subcontract No. RD010A-08 (AU)

Staff

Oregon State University, Corvallis, Oregon

Jim Bowman	US Co-Principal Investigator, Project Leader
Christopher Langdon	US Co-Principal Investigator
Gene Wooden	Student Assistant (through June 1999)

Auburn University, Auburn, Alabama

Tom Popma	US Co-Principal Investigator
Karen Veverica	US Co-Principal Investigator (stationed in Sagana, Kenya)

Fisheries Department, Nairobi, Kenya

Fred Pertet	Host Country Principal Investigator, Director of Fisheries, Kenya

Sagana Fish Farm, Sagana, Kenya

Bethuel Omolo	Research Associate, Senior Fisheries Officer, and Head of Station
Stephen Njau	Fisheries Officer, Deputy Head of Station
Felix Lagat	Fisheries Officer, Fish Production Unit
Judith M. Amadiva	Social Development Officer
William Kabethe	Storekeeper
John Maina Kamau	Fisheries Assistant, Computer Operator/Storekeeper
Charles Kariuki	Fishing Crew Leader
William Kibe	Fisheries Assistant
John Kogi	CRSP Pond Manager
James Karuri Maina	Lab Technician/Water Quality Analyses
Jonathan Makau	Fisheries Assistant
Raphael Mbaluka	Fisheries Officer, Hatchery
Thomas Ndegwa	Assistant Lab Technician
John Ngofia	Driver
D.M. Njoroge	Executive Assistant (Bookkeeping/Purchasing)
Francis Wasane	Labor Foreman
Wilson Maina Gichuri	Graduate Student, University of Nairobi
Paul Bilal Izaru	Graduate Student, University of Nairobi
Bernard Meso	Graduate Student, University of Nairobi
Patricia Mwau	Graduate Student, University of Nairobi
Daniel Oenga Nyanchiri	Graduate Student, Moi University
Winifred S. Kaki	Undergraduate Student, Moi University, Fisheries
David Mirera	Undergraduate Student, Moi University
Cosmos Munga	Undergraduate Student, Moi University
Daniel Ndegwa Nderitu	Undergraduate Student, Mombassa Polytechnic
William Nyaga	Undergraduate Student, Moi University
Wabitah Paul Wamwea	Undergraduate Student, Kenyatta University

Cooperator

International Center for Living Aquatic Resources Management (ICLARM)/Malawi
Daniel Jamu

Site Background

The Kenya project operates out of Sagana Fish Farm, in Central Province, in collaboration with the Kenya Fisheries Department under a Memorandum of Understanding between Oregon State University and the Fisheries Department of Kenya's Ministry of Tourism and Wildlife.

Research activities in the reporting period address aquaculture development constraints and research priorities identified in the *PD/A CRSP Continuation Plan 1996–2001*. These include optimization of production/management strategies through more efficient use of fertilizers and feeds, use of supplemental feeds, increasing control over tilapia reproduction and fingerling production, conducting training activities in basic pond management practices, regionalizing the benefits of the CRSP research program through outreach activities, and establishing a companion site in Africa.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- New site development and characterization/8KR1. The report submitted for this study was a final report.
- Strain variations in sex ratio inheritance/8KR2. The

report submitted for this study was a final report.
- Relative contribution of supplemental feed and inorganic fertilizers in semi-intensive tilapia production/8KR3. The report submitted for this study was a final report.
- Regional outreach in Africa/KR5. The report submitted for this study was a final report.
- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/8FFR1K. The report submitted for this study was a progress report.

These subcontracts were awarded funding to conduct the following studies:
- Aquaculture training for Kenyan fisheries officers and university students/9ADR3. The report submitted for this study was a progress report.
- Establishment of companion sites in the Africa region/9ADR4. The report submitted for this study was a progress report.
- Regional outreach in Africa/9ADR5. The report submitted for this study was a progress report.

Note: Research under this subcontract was revised from that described in the *Addendum to the Eighth Work Plan*. The decision to terminate 8KR2 will be documented in a forthcoming work plan addendum. The studies listed above are collaborative projects between Oregon State University and Auburn University. In addition, the Eighth Work Plan study 8KR3A, "Nutritional contribution of natural and supplemental foods for Nile tilapia: Stable carbon isotope analysis," (under Subcontract No. RD010A-13, University of Arkansas at Pine Bluff) brings in UAPB as a third US collaborator (please see project description, p. 71). The Ninth Work Plan study 9ER1, "Use of pond effluents for irrigation in an integrated crop/aquaculture system" (under Subcontract No. RD010A-07, Auburn University) is another collaborative project (please see project description, p. 72).

Networking Activities

CRSP researchers in Kenya are establishing connections and developing relationships with a number of educational institutions and NGOs in Kenya and surrounding countries. Linkages have been established with the University of Nairobi, Moi University, Kenyatta University, and Egerton University. A Master's candidate from the University of Nairobi is participating on a CRSP effluent study for his thesis research. CRSP on-site researcher Karen Veverica has discussed collaborative possibilities in terms of scholarships and funding of thesis projects with Moi University administrators. Sagana Fish Farm was visited by officials from Moi University, who were provided with information and guidance on pond and hatchery design and construction for their own station. Additionally, three undergraduate students from Moi University are completing their practicals at Sagana Fish Farm, and Veverica has agreed to teach a course at Moi University. Kenyatta University is also participating in CRSP research; an undergraduate from Kenyatta University is doing senior project research at Sagana Fish Farm. Also, Kenyatta University has requested that a graduate student be placed at Sagana Fish Farm to work on CRSP research. A researcher from Egerton University advised CRSP researchers on biotic indices developed by W. Deutsch and tested in Rwanda. In addition to building relationships with Kenyan universities, the CRSP has discussed the possibility of shared research with Katholieke Universiteit Leuven (KUL).

Bernard Meso and Daniel Oenga, graduate students conducting CRSP research have also been instrumental in strengthening CRSP networks. Meso and Oenga have submitted a proposal to FARMESA, a Swedish NGO, to conduct on-farm trials of integrated fish/horticulture systems in the Central Province.

While attending the "Shallow Water Bodies in the Tropics Conference" in Naivasha, Veverica met with the Executive Director of the Center for Field Research (the research affiliate of Earthwatch Institute) and Program Director for Earth/Marine Sciences. Future research efforts were discussed. Subsequently, these discussions led to a contact with the Discovery Center—a small-scale commercial venture that is interested in producing several different species of fish in combination with bee-keeping and silkworm production.

Kenya Project staff have also developed relationships with several nongovernmental organizations. Sustainable Agricultural Centre for Research and Development in Africa (SACRED Africa) requested assistance with farmer training and fingerling supply in Bungoma, located in Western Kenya. The CRSP is also discussing the possibility for collaboration with the International Center for Research in Agroforestry. In addition CRSP researchers met with the Programme Officer, Projects Officer, and Field Officer of the World Conservation Union (IUCN), Nairobi.

The CRSPs regional connections have multiplied with visits from the Agricultural Commissioner of Fisheries, Uganda; the Director of Fisheries, Tanzania; and the Director of the Tanzania Fisheries Research Institute. During the visit the aims of the CRSP were discussed in addition to potential training opportunities when the CRSP "training-of-trainers" program is initiated.

The Director and nine staff members from USAID/Kenya expressed interest and support for CRSP research during a visit to Sagana Fish Farm. While visiting they observed pond harvesting and inquired about fixed and variable costs of fish production. The Director of USAID/Kenya was provided with an outline of an enterprise budget for CRSP-identified best management practices.

To continue the establishment of relationships with small- and commercial-scale farmers in Kenya, the CRSP has provided information and monosex fingerlings to small-scale farmers as well as recommendations on tilapia culture. Farmers also have been identified who will be assisting with student training in the area of feed formulation. Veverica and Omolo met with a private farmer who is investigating the construction of an intensive tilapia farm with water reuse. Omolo and Veverica have attended three of four meetings held by a new fish farmers' association, the Mt. Kenya Fish Farmers Association (KFFA), which was initiated in the Central Province. Association membership fees collected for the KFFA are being considered for the purchase

of a seine net and as well as to contribute towards transport costs for training sessions to be held at Sagana.

The CRSP has hosted a number of field days for farmers in an effort to disseminate CRSP research results, alert small-scale farmers of the resources available via the CRSP and Sagana Fish Farm, and assist the extension service in Kenya. Farmers were requested to propose subject areas to be covered for one of the field days; for another field day the KFFA designed a list of important topics to cover at the field day. In total, approximately 80 individuals have attended the field days. CRSP researchers hope to continue to hold one or two field days per month.

In the US, Project Leader Jim Bowman responds to occasional calls for information from small-scale farm owners in Oregon who are interested in developing farm ponds or in finding solutions to pond management problems. Additionally, Bowman was contacted by extension personnel from the Clackamas County Extension Office in Oregon with regard to pond management literature. The contact led to the development of two farm pond workshops held at Clackamas Community College on two occasions in April. The subject areas of the first workshop were state permit requirements, site selection, and construction, and the second workshop addressed pond management issues.

Veverica has been asked to serve as a reviewer for aquaculture-related proposals received by the International Foundation for Science (IFS); she has accepted the invitation.

Educational Outreach

A weekly seminar series was implemented at Sagana Fish Farm in July, which included the following topics: Useful calculations in evaluating aquaculture production; Basics of water quality; Fertilization; POND© software; Wilson Gichuri's poster presentation for FISA meeting; Veverica and Bowman FISA presentations; and Guidelines for transport of live fish.

Randy Brummett, of ICLARM/Africa, visited Sagana in April and presented a seminar to the staff entitled "Aquaculture Technology Development and Transfer."

To attract potential commercial-scale investors to Kenya, Veverica and Omolo wrote an informational fact sheet entitled "Criteria for investing in commercial aquaculture in Kenya." The fact sheet was distributed to commercial producers, fisheries officers, and interested investors for review.

Three fisheries officers from Sagana Fish Farm are involved with two supplemental research projects entitled "Electivity of natural foods by *Clarias* and tilapia in ponds receiving chemical fertilizers" and "Development and design of mechanical graders for commercial tilapia production." The projects were initiated via guidance and funding from the CRSP in Kenya.

Publication

Rodriquez, F. and T. Popma, 1999. Tilapia aquaculture in Colombia. In: B.A. Costa-Pierce and J.E. Rakocy, (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana (in press).

Presentations

Bilal, P., K.M. Mavuti, J.G. Omondi, and K.L. Veverica. Plankton dynamics in tilapia (*Oreochromis Niloticus*) and catfish (*Clarias Gariepinus*) Polyculture ponds in Central Kenya. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.

Gichuri, W.M., J.G. Omondi, and K.L. Veverica. Relative condition factors (K_n) for *Oreochromis niloticus* (Cichlidae) and *Clarias gariepinus* (Clariidae) in small managed ponds. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.

Mwau, P.N., K.M. Mavuti, P.I. Bilal, and K.L. Veverica. Nitrogen and phosphorus budgets in polyculture fish ponds. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.

Oenga, D., B. Wangila, M. Muchiri, and K.L. Veverica. The history of largemouth bass *Micropterus salmoides* introduction and transfers in East Africa at Presented to Shallow Water Bodies in the Tropics Conference, Naivasha, Kenya, 12–16 April 1999.

Conferences

Fisheries Society of Africa Meeting at Rhodes University, Grahamstown, South Africa, 13–19 September 1998. (Bowman, Veverica, Popma, Gichuri, and DeVos)

Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999. (Omolo, Njao, Lagat, and Veverica)

NEW SITE DEVELOPMENT AND CHARACTERIZATION

Eighth Work Plan, Kenya Research 1 (8KR1)
Final Report

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ABSTRACT

Site development and characterization activities for the new prime site at Sagana, Kenya, began on 31 March 1997. Major undertakings that were required to make the site suitable for CRSP research included modification of the existing ponds, refurbishment of the water quality laboratory, acquisition of suitable laboratory and farm supplies and equipment, installation of a weather monitoring and recording (data-logger) system, and acquisition of a new computer system and an appropriate four-wheel-drive vehicle. Pond and laboratory renovations proceeded rapidly, and the major portions of these tasks were complete by the end of September 1997. Four existing 4,000-m^2 production ponds were modified to create twelve 800-m^2 ponds of uniform size and

shape for CRSP research. Extra soil from the pond renovation was used to make seven additional ponds, ranging from 800 m^2 to 1,500 m^2, which will be used as holding ponds, for fry production, or for activities requiring the use of hapas. Three of the extra ponds have dimensions appropriate for experimental work. Farm and laboratory supplies and equipment arrived at Sagana in September 1997. A Land Rover was purchased from the United Kingdom and shipped to Kenya on 1 July , becoming available for project use in mid-September. Installation of the weather monitoring system was begun at the end of November, and weather data were recorded beginning the first week of December. In addition, observations on pond soil and source water chemistry and annual weather patterns were undertaken to allow characterization of the site. Initial pond soil samples were collected in October 1997, and water samples for source water characterization were collected starting in October 1997. Weather data recording was begun in December 1997. Solar radiation, photosynthetically active radiation (PAR), precipitation, relative humidity, wind speed, and air temperature were recorded hourly. Four temperature probes were suspended in one pond (D6) to record pond temperature at depths of 5, 25, 50, and 75 cm as of April 1998. Preliminary analyses of pond soil samples indicate that they are mainly of the "black cotton soils" variety, high in 2:1-type clay minerals (70 to 90% clay), with cation exchange capacities typical for that type of soil (30 to 55 meq 100 g^{-1}), and pH values ranging from 5.4 to 7.5. Lime will be required to ensure that carbon is not limiting in fertilization experiments or during production cycles. Lime requirements of 5 to 10 t ha^{-1} have been calculated. The phosphorus adsorption capacity of these soils is quite high. Total alkalinity and total hardness levels of water provided to the Sagana ponds through the 2-km canal system are typically 10 to 20 mg l^{-1} as $CaCO_3$. Source water conductivity was measured at 0.05 mmho cm^{-1}. Detailed characterization of the pond soils and source waters for the Sagana station, as well as a summary of the first year's weather, are included in this report.

STRAIN VARIATIONS IN SEX RATIO INHERITANCE

Eighth Work Plan, Kenya Research 2 (8KR2)
Final Report

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ABSTRACT

Three distinct subspecies of *Oreochromis niloticus* have been identified in Kenya, including *O. niloticus eduardianus*, *O. niloticus baringoensis*, and *O. niloticus vulcani. O. niloticus vulcani* is cultured at the Sagana Fish Farm, Kenya, the PD/A CRSP prime site in Africa. During 1997 and early 1998, well over 50 individual pair spawns of tilapia from the Sagana stock of *O. niloticus vulcani* were attempted in support of a larger CRSP study designed to evaluate the sex ratios of offspring from a number of strains of *O. niloticus* from collaborating CRSP sites. Pond D3 at Sagana Fish Farm was dedicated to this activity and equipped with hapas. All fry produced in spawning hapas were transferred to rearing hapas. Although more than 100 fry were obtained from most spawns, survival to 5 cm was very low in the rearing hapas, and usually fewer than 25 fingerlings per spawn were obtained. This number was too low to complete the proposed Eighth Work Plan protocol and the fingerlings were discarded. Survival of about 80% is obtained during sex reversal in similar hapas in a similar pond. The only procedural difference is that during sex reversal fry are reared at higher densities. Only six batches of single-spawn fingerlings with adequate survival beyond a length of 5 cm were obtained. These were initially reared in hapas, followed by three weeks in the hatchery. However, these batches still contained no more than 60 fish, which was an insufficient number for this study. In mid-1998 a blower was installed in the hatchery and a complete diet became available, so the probability of success in rearing fry to 5 cm in the hatchery was greatly improved. However, information obtained in mid-1998 suggests that the population of tilapia at Sagana is not a pure strain of *O. niloticus vulcani* as originally believed, but is contaminated with *O. spirulis* and perhaps other species. If true, this greatly reduces the value of conducting further pair spawns. In consultation with the principal investigators of the parent study, it was decided not to conduct additional pair spawns. Provided funding is available, blood samples from this population and, if possible, from other Kenyan strains (e.g., *O. niloticus baringoensis*, from Lake Baringo) will be sent to Auburn University to assess the purity of these populations by electrophoretic analysis before undertaking any possible related follow-on activity.

RELATIVE CONTRIBUTION OF SUPPLEMENTAL FEED AND

INORGANIC FERTILIZERS IN SEMI-INTENSIVE TILAPIA PRODUCTION

Eighth Work Plan, Kenya Research 3 (8KR3)
Final Report

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ABSTRACT

A 20-week experiment was conducted at Sagana Fish Farm, Kenya, to characterize the productive capacity of ponds at this new CRSP research site and to determine least-cost combinations of rice bran and inorganic fertilizer. Twelve 800-m^2 ponds were stocked with juvenile (32 g each) *Oreochromis niloticus* at 20,000 ha^{-1} and *Clarias gariepinus* fingerlings (average weight 4.6 g) at 2,400 ha^{-1}. Ponds contained about half sex-reversed and half mixed-sex tilapia, with an estimated ratio of approximately 75% males to 25% females at stocking. Four treatments were applied in triplicate as follows: 1) Urea and DAP to provide 16 kg N ha^{-1} wk^{-1} and 4 kg P ha^{-1} wk^{-1}; 2) Urea and DAP applied to give 8 kg N and 2 kg P ha^{-1} wk^{-1}, plus rice bran fed at 60 kg ha^{-1} d^{-1}; 3) Rice bran fed at 120 kg ha^{-1} d^{-1}; and 4) Rice bran as in Treatment 3 and fertilizer as in Treatment 2. Net fish yield averaged 1,127, 1,582, 1,607, and 2,098 kg ha^{-1} for Treatments 1 through 4 respectively. Fish in ponds receiving rice bran (Treatments 2, 3, and 4) were still growing rapidly at harvest time, but the growth rate of fish in Treatment 1 was beginning to decrease near the end of the experiment. Treatment 1 was the most cost-effective, but Treatments 1, 2, and 4 all resulted in fairly similar net profits. Input costs for Treatments 1 and 2 will be of interest to fish farmers, although it is possible that fish raised using only fertilizer at the rates used in Treatment 1 may never reach market size at this stocking density. Fish had reduced growth towards the end of the culture period and resulting low final average weights, which were less than 100 g. If rice bran had cost 3.5 KSh or less per kilogram, profit for Treatment 3 would have surpassed that of Treatment 1. If rice bran had cost less than 5.8 KSh per kg, Treatment 2 would have been more profitable than Treatment 1.

REGIONAL OUTREACH IN AFRICA

Eighth Work Plan, Kenya Research 5 (8KR5)
Final Report

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ABSTRACT

Regional outreach activities were undertaken under the Eighth Work Plan as a means of disseminating information developed through CRSP research; giving CRSP researchers opportunities to learn about fish culture practices, research priorities, and research activities in other parts of Africa; encouraging efforts to create linkages between research and extension activities in the region; and in general continuing the process of making contacts and regionalizing CRSP efforts in Africa. CRSP researchers in Kenya attended meetings of District Fishery Officers of Central Province and a meeting for Provincial Fisheries Officers (Kenya). During these meetings the PD/A CRSP was described, pond management recommendations were outlined, proposed on-farm trials were discussed, pond census forms were distributed, information was provided on sex-reversed tilapia, and the results of a feeds and fertilizer experiment at Sagana Fish Farm were presented. Students doing research at Sagana in connection with that experiment also presented short summaries of their research findings. Several regional meetings were attended by CRSP personnel during the reporting period. The first was the 5th Session of the Organization of African Unity's Scientific, Technical, and Research Commission (OAU/STRC) Inter-African Committee and Symposium on Oceanography, Sea and Inland Fisheries, Mombasa, Kenya, 4–8 May 1998. The meeting was hosted by Fred Pertet, member of the OAU/STRC and host country Principal Investigator for CRSP research in Kenya. Karen Veverica and Bethuel Omolo also attended this meeting, which provided an excellent opportunity to publicize the CRSP and to present Sagana Fish Farm as an ideal aquaculture training site. Veverica and Omolo also attended the 8th Annual East African Environmental Network (EAEN) conference, 29–30 May 1998, Nairobi, where they presented an invited paper entitled "An overview of aquaculture practices in East Africa: Potential environmental impacts and prospects for sustainable livelihoods." CRSP participants from Kenya and the US attended the PARADI/FISA conference held in Grahamstown, South Africa, 13–19 September 1998. Nine aquaculture

and fisheries presentations (oral and poster) were made by CRSP or Kenya Fisheries Department participants. CRSP PIs helped organize and conduct a workshop (*Aquaculture in Africa—Quo Vadis*) to examine what has previously been done to promote aquaculture in Africa, to look at successes and failures among those efforts, and to discuss how the sub-Saharan region might become an important player in aquaculture in the future. Through contacts made at these meetings and conferences, CRSP researchers, collaborating scientists, and students are developing a better understanding of the research and extension needs for aquaculture development in Africa. Other participants are also gaining a better understanding of the research and extension needs of the region, as well as learning about the CRSP. Linkages have been established that will enhance further correspondence and exchanges of ideas on these issues and on how future programs can be more effective.

GLOBAL EXPERIMENT: OPTIMIZATION OF NITROGEN FERTILIZATION RATE IN FRESHWATER TILAPIA PRODUCTION PONDS

Eighth Work Plan, Feeds and Fertilizers Research 1 (8FFR1K)
Progress Report

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ABSTRACT

Two experiments to determine the optimum nitrogen fertilization rates for freshwater tilapia production ponds at Sagana Fish Farm, Sagana, Kenya, were conducted during 1998 and 1999. Twelve 800-m^2 earthen research ponds managed by the PD/A CRSP at Sagana were used for the experiments. Diammonium phosphate and urea were used to apply nitrogen to the ponds at rates of 0, 10, 20, and 30 kg N ha^{-1} wk^{-1}. Triple superphosphate or diammonium phosphate (DAP) and sodium carbonate were applied to ponds to assure that phosphorus and carbon were not limiting. A completely randomized design was used, with three replicates for each of the four treatments. The experiment was conducted once during the 1998 cool season (May to October) and again during the warm season of 1998-1999 (November to March). In the cool-season experiment, ponds were stocked with sex-reversed Nile tilapia, *Oreochromis niloticus*, averaging 16.9 g at a rate of 1,000 kg ha^{-1} and with *Clarias gariepinus* fingerlings averaging 37 g at a rate of 37 kg ha^{-1}. In the warm-season experiment, all ponds were stocked with sex-reversed *O. niloticus* averaging 90 g at 1,000 kg ha^{-1} and with *C. gariepinus* juveniles averaging 166 g at 125 kg ha^{-1}. Pond assignments were re-randomized prior to the second experiment. Ponds were drained when fish growth appeared to have stopped in all treatments. In both experiments, a highly significant ($P < 0.01$) quadratic relationship best described gross (as well as net) fish yield as related to weekly N input. Presence of *Clarias* had little impact on the relationship but it appeared the high nitrogen input rates had no negative effect on *Clarias* production. Increasing nitrogen input from 20 kg N ha^{-1} wk^{-1} did not result in increased tilapia yield. Total nitrogen and all mineral forms of nitrogen increased with increasing nitrogen input, as did chlorophyll *a*. Partial budget analysis indicated that greatest marginal returns were at the calculated rates of 19.9 and 16.0 kg N ha^{-1} wk^{-1} for the cool- and warm-season experiments respectively. A carryover effect of the first experiment is suggested. Results from this experiment are similar to those obtained at the CRSP site at El Carao, Honduras.

AQUACULTURE TRAINING FOR KENYAN FISHERIES OFFICERS AND UNIVERSITY STUDENTS

Ninth Work Plan, Adoption and Diffusion Research 3 (9ADR3)
Progress Report

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ABSTRACT

A lack of technical training was cited as a major reason for the low output of fish ponds in Kenya. The need for training was observed at all levels, from the lowest level extension agent through university levels. The training program undertaken by PD/A CRSP researchers in Kenya seeks to improve training and to provide a cadre of trainers who have extensive practical fish production experience. Stipends for student research have allowed undergraduate university students to remain longer at Sagana Fish Farm and gain valuable field experience. A small research projects program has allowed the station staff to further their professional development and carry out their own research, which can have a positive impact on station management. Following requests from farmers, a program of farmer education days was developed. During the first half of 1999, five farmer education days were held, in which 107 farmers and 40 extensionists participated. All districts in the Central Province were covered and one district each from the Eastern and Rift Valley Provinces was included. The farmer education days are being continually improved, following feedback from farmers. Programs for more specialized training are planned, as well as demonstration visits held at farmers' ponds.

ESTABLISHMENT OF COMPANION SITES IN THE AFRICA REGION

Ninth Work Plan, Adoption and Diffusion Research 4 (9ADR4)
Progress Report

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ABSTRACT

The establishment of one or more companion sites in the Africa Region was proposed as a way of verifying the results of CRSP research at its prime site and of expanding the regional effort of the CRSP by assisting with the conduct of needed research at other sites in the region. The objectives specifically listed for this effort in the Ninth Work Plan were: 1) to identify and establish one or more companion sites for the Africa Region and 2) to define and implement investigations at the companion site in support of PD/A CRSP and companion site goals. The first of these two objectives was to be achieved during the first year of the Ninth Work Plan. Sites previously identified for possible companion sites included Bunda College of Agriculture (Malawi), Kingolwira Aquaculture Center (Tanzania), and Akosombo Aquaculture Research and Development Center (Ghana), but investigation of additional sites could also be undertaken. During this first year of the Ninth Work Plan (late 1998 and 1999), discussions have focused on collaboration at sites in Malawi, resulting in a recent decision to propose companion site efforts in collaboration with ICLARM at the National Aquaculture Center (Zomba) and Bunda College, near Lilongwe.

REGIONAL OUTREACH IN AFRICA

Ninth Work Plan, Adoption and Diffusion Research 5 (9ADR5)
Progress Report

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ABSTRACT

Personnel involved with PD/A CRSP research in Kenya attended a conference entitled "Shallow Water Bodies in the Tropics," held in Naivasha, Kenya, from April 12 to 16 1999. Four presentations were made, of which two were based on CRSP Eighth Work Plan feeds and fertilizers research ("Relative Contribution of Supplemental Feed and Inorganic Fertilizers in Semi-Intensive Tilapia Production"). Attendance is also planned for the 17th Conference and Silver Jubilee of the Soil Science Society of East Africa, to be held in Kampala, Uganda, 6 to 10 September 1999 and a conference on the Lake Victoria Basin, to be held in Jinja, Uganda, 23 to 26 November 1999. If possible, CRSP personnel will also attend meetings of the Southern Africa Development Community (SADC) and the Fisheries Society of Africa (FISA). Participation in these meetings is part of the CRSPs effort to promote communication and the establishment of linkages among aquaculture research and extension workers and to better understand the needs and constraints in Kenya and surrounding regions.

KENYA PROJECT

Subcontract No. RD010A-13

Note: Additional project information on Networking, Educational Outreach, and Publications appears in the Peru Project section, p. 63.

Principal Investigators

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann	US Co-Principal Investigator, Project Leader
Peter Perschbacher	US Co-Principal Investigator (through February 1999)

Background

Research on the efficient utilization of nutrients and feeds requires knowledge of both nutritional requirements and feeding strategies. Efficient use of pond inputs should result in reduced effluent loads and thus reduced environmental degradation. Isotope analysis holds promise as a useful tool to measure the relative nutritional contribution of supplemental feeds and natural foods to tilapia production at different rates of supplemental feeding. Eighth Work Plan research investigated the stable carbon isotope ratios in natural foods, supplemental feeds, and fish flesh. Ninth Work Plan research, which has not yet begun, is planned to build on prior work, incorporating commercially available pelleted feeds and analyzing nitrogen as well as carbon stable isotope ratios.

Work Plan Research

The following Eighth Work Plan study continued into the current reporting period (see the Peru Project (p. 63) for information on other funded studies under this subcontract):

- Nutritional contribution of natural and supplemental foods for Nile tilapia: Stable carbon isotope analysis/ 8KR3A. The report submitted for this study was a final report.

Ninth Work Plan Kenya Project research under this subcontract has not yet begun.

Note: This study is a collaboration between the University of Arkansas at Pine Bluff, Oregon State University (under MOU No. RD009A), and Auburn University (under Subcontract No. RD010A-08).

NUTRITIONAL CONTRIBUTION OF NATURAL AND SUPPLEMENTAL FOODS FOR NILE TILAPIA: STABLE CARBON ISOTOPE ANALYSIS

Eighth Work Plan, Kenya Research 3A (8KR3A)
Final Report

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ABSTRACT

Stable carbon isotope analysis can be used to obtain quantitative estimates of the relative contributions of different food sources to the nutrition of aquatic animals in ponds. Results can be used to make recommendations for feeding and fertilization practices that will minimize feed costs while maximizing fish production. This technique was used in conjunction with fish gut content analysis to obtain estimates of the contribution of natural and supplemental feeds to the nutrition of *Oreochromis niloticus* and *Clarias gariepinus* in ponds receiving different inputs in Sagana, Kenya. Four combinations of fertilizers and supplemental feed (rice bran) were used as experimental treatments: 1) Urea (16 kg N ha^{-1} wk^{-1}) + DAP (4 kg P ha^{-1} wk^{-1}); 2) Urea (8 kg N ha^{-1} wk^{-1}) + DAP (2 kg P ha^{-1} wk^{-1}) + Rice bran (60 kg ha^{-1} d^{-1}); 3) Rice bran (120 kg ha^{-1} d^{-1}); and 4) Rice bran (120 kg ha^{-1} d^{-1}) + Urea (8 kg N ha^{-1} wk^{-1}) + DAP (2 kg P ha^{-1} wk^{-1}). Samples of *Oreochromis*, *Clarias*, chemical fertilizers (DAP and urea), rice bran, plankton, and mud taken from ponds in Sagana at three times (initial, midpoint, final) during a 143-day feeding trial were analyzed for carbon isotope content. The most distinct trend in the isotope data was the more positive values for plankton, *Oreochromis*, and *Clarias* in treatment 1 versus treatments 2 through 4 for initial, midpoint, and final samples. The addition of rice bran to ponds in treatments 2 through 4 clearly increased fish production relative to ponds where the only inputs were DAP and urea. Gut content analysis indicated that the two most important food categories for *Oreochromis* and *Clarias* in treatments that included rice bran were plankton and rice bran. However, the isotope data did not allow further clarification of the relative nutritional importance of the two categories between treatments because the isotope ratios of plankton and rice bran were not isotopically distinct.

KENYA PROJECT

Subcontract No. RD010A-07

Staff

Auburn University, Auburn, Alabama
Wesley Wood — US Principal Investigator

Sagana Fish Farm, Sagana, Kenya
Bernard Meso — Graduate Student, University of Nairobi

Cooperator

University of Nairobi, Kenya
Nancy Karanja

Background

Integration of aquaculture and agriculture systems can result in higher productivity of each component. In Kenya fish are grown in both irrigation-water reservoirs and fish ponds. Farmers may be reluctant to fertilize irrigation water due to a lack of information on the effects of fertilization on irrigated crops. On the other hand, water from fish ponds may be used to irrigate agricultural crops. One goal of the Government of Kenya is to encourage multiple uses of irrigation waters. This investigation was designed to assess the effects of fertilizing irrigation water and of using fishpond effluent to water crops.

Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan study:

- Use of pond effluents for irrigation in an integrated crop/aquaculture system/9ER1. The report submitted for this study was a progress report.

Note: This study is a collaboration among Auburn University, Oregon State University (under MOU No. RD009A), and Auburn University (under Subcontract No. RD010A-08).

Networking

Through Wood's Effluents and Pollution Research study, the CRSP has developed several contacts with organizations and individuals in Kenya. Representatives from the International Center for Research in Agroforestry (ICRAF) have shown an interest in fish farming and are in contact with Karen Veverica, CRSP on-site researcher. Wood visited Kenya in April 1999 where he had the opportunity to meet with Bernard Meso, a graduate student from the University of Nairobi who is working on the project, and his advisor Dr. Nancy Karanja, the Chairperson of the Department of Soil Science at the University of Nairobi. During meetings they discussed project progress and future research. Veverica also met with a chicken processor in Kenya to discuss the possibility of setting up several ponds for *Clarias* production using the wastes from the chicken processing plant. Veverica has been closely involved in on-site implementation of this investigation.

USE OF POND EFFLUENTS FOR IRRIGATION IN AN INTEGRATED CROP/AQUACULTURE SYSTEM

Ninth Work Plan, Effluents and Pollution Research 1 (9ER1) Progress Report

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ABSTRACT

Kenya's annual production from aquaculture is estimated at 1,100 Mg, the largest portion of this being harvested from fish ponds. The value of pond effluents in flood irrigation of crops has been demonstrated, but little research has addressed use of pond water in more efficient systems such as drip irrigation of high-value vegetable crops. A field experiment was conducted on a vertisol at Sagana, Kenya, to determine the suitability of polyculture (tilapia (*Tilapia aureus*) and African catfish (*Clarius gariepinus*)) fish-pond effluent for drip irrigation of french bean (*Phaseolus vulgaris* cv. Samantha). Treatments included nonirrigated, unfertilized (-I -F); nonirrigated, fertilized (-I +F); irrigated with canal water, unfertilized (+I -F); irrigated with canal water, fertilized (+I +F); irrigated with fish pond effluent, unfertilized (+P -F); and irrigated with equal parts canal and pond water, unfertilized (+IP -F). Canal water supplied to polyculture production ponds and to treatments +I -F, +I +F, and +P -F contained 0.49 and 0.04 mg l^{-1} of nitrogen (N) and phosphorus (P), respectively. For treatments utilizing fish-pond effluent, water was transferred from nearby polyculture ponds that received 20 kg N ha^{-1} wk^{-1} and

8 kg P $^{-1}$ha^{-1}wk^{-1} over a 17-week cycle. Pond water contained higher concentrations of N (6.03 mg kg^{-1}) and P (3.89 mg kg^{-1}) than canal water. French bean harvest began 46 days after planting and continued for 28 days. Significant differences were observed among treatments ($P \leq 0.001$) with -I -F yielding 1.2 Mg fresh beans ha^{-1}, and +I +F providing the highest yields: 9.1 Mg fresh beans ha^{-1}. Irrigation alone (+I -F) resulted in 7.7 Mg fresh beans ha^{-1} with stepwise yield decline as fish-pond water was substituted for canal water: +IP -F and +P -F yielded 6.1 and 4.3 Mg fresh beans ha^{-1}, respectively. Yield decline with increasing amounts of pond effluent may be owing to particulates that clog drip line emitters. The 41% yield decline from pond-water substitution represents an economic loss of KSh 89,850 ha^{-1} (≈ US $1,404). Given the potentially high N and P concentrations of fish-pond effluent, its direct discharge into water bodies should be discouraged. Either pre-treatment filtration or alternative irrigation methods are required before advantage may be obtained from application of nutrient-enriched pond water.

PHILIPPINES PROJECT

Subcontract No. RD010A-15

Staff

University of Hawaii, Manoa, Hawaii

Chris Brown	US Co-Principal Investigator, Project Leader
James Szyper	US Co-Principal Investigator
Robert Howerton	Associate Investigator
Claudia Farfan	Graduate Student (Mexico) (from October 1998)

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Remedios B. Bolivar	Host Country Principal Investigator (from September 1998); Deputy Director, Freshwater Aquaculture Center
Ruben C. Sevilleja	Interim Host Country Principal Investigator (August 1998); Director and Professor, Freshwater Aquaculture Center; Vice President of Central Luzon State University
Eddie Boy T. Jimenez	Research Assistant (from August 1998)

Site Background

The PD/A CRSP has been active in the Philippines since the program's inception in 1982. Until 1998, research in the Philippines was reported as part of the Thailand work plan as the Philippines functioned as a companion site to the CRSP site in Thailand. A restricted Request for Proposals (RFP) was issued to find lead US and host country institutions for the Philippines Project. The University of Hawaii was awarded funding under the Ninth Work Plan, with the Eighth Work Plan Global Experiment as an additional investigation. The lead US institution award was made in July 1998, and a Memorandum of Understanding was executed between University of Hawaii (UH) and Central Luzon State University (CLSU) through the Freshwater Aquaculture Center (FAC) in August 1998.

CRSP Philippines project research in this reporting period emphasized production optimization. A study to determine optimal timing to begin supplemental feeding of tilapia in ponds is underway.

Work Plan Research

This subcontract was awarded funding to conduct the following Eighth Work Plan study:

- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/8FFR1Ph. This study has not yet begun; a work plan schedule change has been filed.

This subcontract was awarded funding to conduct the following Ninth Work Plan study:

- Timing of the onset of supplemental feeding of tilapia in ponds/9FFR4. The report submitted for this study was a progress report.

Note: The schedule and methods for 9FFR4 have been modified. The revised methods will appear in the *Addendum to the Ninth Work Plan*. The schedule for 8FFR1Ph has been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information for both studies.

Site Improvements

To establish more efficient communication between UH and CLSU, the CRSP sponsored the installation of project-specific telephone lines and the purchase of a project computer. Host country Principal Investigator Remedios Bolivar currently has daily access to email, which has vastly improved project communications.

Networking

CRSP participants from CLSU and UH directed their efforts toward the successful launch of CRSP research in the Philippines. Project Leader Chris Brown and Associate Investigator Robert Howerton visited CLSU in October 1998 to formalize the CRSPs relationship with CLSU. Brown and Howerton met with their primary contacts at CLSU, host country Principal Investigator Remedios Bolivar and Director of the FAC and Vice President of CLSU Ruben Sevilleja, to discuss practical, scientific, and logistical issues of the research partnership. A Memorandum of Understanding was executed between UH and CLSU in August 1998. Howerton and Brown also met extensively with executives from the Bureau of Fisheries and Aquatic Resources (BFAR); in-person meetings with officials of the Bureau of Fisheries and Aquatic Resources have continued throughout the reporting period to identify the mutual interests of BFAR and the CRSP.

During a second visit to CLSU in February of 1999, Brown built on the progress made during the October 1998 visit, moving project planning into a more active phase of implementation. Highlights of the second visit included the execution of a new and broader Memorandum of Understanding, including an Academic Exchange Agreement, in March 1999. This agreement broadens the mutual commitments of the universities to joint participation in a variety of academic activities. Another exchange of visits is in the planning stage.

In addition to strengthening institutional partnerships, Brown has been in contact with the AID mission in Manila regarding an Indefinite Quantity Contract (IQC) initiative entitled "Rural Agriculture Incomes in a Sustainable Environment" (RAISE). This initiative is funded through several large contractors who subcontract agriculture research and demonstration work to public and private entities. CRSP scientists participating in Philippines research plan to discuss the possibility of organizing a project in the next reporting period.

The implementation of CRSP research has established direct connections with farmers and the Genetically Improved Farmed Tilapia (GIFT) Foundation in the Philippines. Fry and fingerlings are being supplied by the GIFT Foundation at no charge for CRSP on-farm feeding trials, in exchange for the promotional value and exposure that will result throughout the course of the experimental work.

During their October 1998 visit, Brown and Howerton visited eight farms requesting their participation in CRSP on-farm trials. Of the eight farm sites visited, seven are fully engaged in the scientific activities that were proposed.

Brown provided information and contacts for an individual who was referred to him by the CRSP Program Management Office interested in methods for milkfish culture in the Philippines. Brown sent literature describing alternate methods of milkfish culture and, during a trip to the Philippines, identified extension agents who would be able to offer advice and support for the start-up of a milkfish culture operation.

Educational Outreach

Brown has been involved in volunteer teaching at Lanikai Elementary School in Oahu.

Presentation

Brown, C. and R. Howerton. Hormone effects on development in larval marine fishes. Presented at Central Luzon State University, Muñoz, Nueva Ecija, Philippines, October 1998.

Conference

Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999. (Bolivar, Brown, Howerton)

TIMING OF THE ONSET OF SUPPLEMENTAL FEEDING OF TILAPIA IN PONDS

Ninth Work Plan, Feeds and Fertilizers Research 4 (9FFR4)
Progress Report

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Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Philippines

Chris Brown
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Manoa, Hawaii, USA

ABSTRACT

Supplemental feeding has been a common practice among tilapia farmers in the Philippines. However, the timing of the start of supplemental feeding is variable. This study aims to demonstrate efficient supplemental feeding strategies for tilapia production in fertilized ponds through on-farm trials. Seven farmer cooperators were enlisted for this experiment. Two ponds of nearly the same size were stocked with all-male Nile tilapia fingerlings of the Genetically Improved Farmed Tilapia (GIFT) strain at a stocking rate of 4 fish m^{-2}. The ponds were fertilized weekly with urea and 16-20-0 fertilizer at a rate of 4 kg N ha^{-1} d^{-1} and a N:P ratio by weight of 5:1. Supplemental feeding commenced 45 days after stocking in one pond while in the other pond, supplemental feeding started 75 days post-stocking. Preliminary results show a trend of better growth of fish in ponds fed early during the culture period.

PHILIPPINES PROJECT

Subcontract No. RD010A-15

Staff

University of Arizona, Tucson, Arizona

Kevin Fitzsimmons — US Principal Investigator, Project Leader

Background

While the search for a lead US and host country institutions for the Philippines was underway, the University of Arizona was contracted to conduct one study at the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU). The experiment attempted to develop low-cost supplemental feeds by using agricultural by-products instead of fish meal as a protein source. The project was designed to determine if agriculture by-products including rice straw could be used in pelleted diets. Yeast and composted rice straw were tested as possible ingredients.

Work Plan Research

This subcontract was awarded funding to conduct the following Eighth Work Plan study:

- Development of low cost supplemental feeds for tilapia in pond and cage culture/8PHR1. The report submitted for the *Sixteenth Annual Technical Report* satisfied the final report requirements.

Networking

Philippines Eighth Work Plan Principal Investigator Kevin Fitzsimmons established contact with aquaculturists and organizations interested in aquaculture research and facilitated linkages between private farmers and Central Luzon State University. Fitzsimmons made email introductions with several tilapia farms in Central and South America: Exportadores del Inca, Peru, Aquasol, located in Venezuela and Suriname, and Acuacultura del Paraiso, Mexico. Fitzsimmons also referred several private fish farmers from the Philippines, Malaysia, Indonesia, and the US to Central Luzon State University to purchase Genetically Improved Farmed Tilapia (GIFT) and Genetically Male Tilapia (GMT) fish. Additionally, Fitzsimmons maintains correspondence with the Pea Research Center in Canada, which is interested in funding aquaculture feed studies in the Philippines.

Fitzsimmons conferred with CRSP scientists involved with research in both the Philippines and Thailand and researchers and farmers involved with the Fifth International Symposium on Tilapia in Aquaculture. While attending the World Aquaculture Society Meeting, Fitzsimmons had the opportunity to discuss future collaboration on feeding trials with Ninth Work Plan Philippines Project Leader Chris Brown. He also visited CRSP researchers at the Asian Institute of Technology in Thailand. In preparation for his work as Chair of the Fifth International Symposium on Tilapia in Aquaculture to be held in Brazil in September of 2000, Fitzsimmons has met with tilapia farmers and researchers in Brazil.

Publications

Fitzsimmons, K., 1999. Future trends for tilapia aquaculture in the Americas. In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society and American Tilapia Association, Baton Rouge, Louisiana (in press).

Fitzsimmons, K., 1999. Tilapia aquaculture in Mexico In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society and American Tilapia Association, Baton Rouge, Louisiana (in press).

Presentation

Fitzsimmons, K. High school students and aquaculture projects. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Conferences

Aquaculture America '99 at Tampa, Florida, 27–30 January 1999. (Fitzsimmons)

Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999. (Fitzsimmons)

Fifth Roche Aquaculture Conference at Bangkok, Thailand, 26 August 1999. (Fitzsimmons)

THAILAND PROJECT

Subcontract No. RD010A-04

Staff

University of Michigan, Ann Arbor, Michigan

James S. Diana	US Co-Principal Investigator, Project Leader
C. Kwei Lin	US Co-Principal Investigator (stationed in Pathum Thani, Thailand)
Yang Yi	Postdoctoral Researcher (China) (stationed in Pathum Thani, Thailand)
Barbara Diana	Research Assistant

Asian Institute of Technology, Pathum Thani, Thailand

Amrit Bart	Host Country Principal Investigator (from October 1998)
Peter Edwards	Host Country Principal Investigator (through October 1998)
M.A. Kabir Chowdhury	Research Associate (through August 1998)
Raghunath B. Shivappa	Research Associate (through September 1998)
Hoang Tung	Research Associate (through March 1999)
Chumpol Srithong	Research Associate

Site Background

The PD/A CRSP has worked collaboratively with the Asian Institute of Technology (AIT), Thailand, since the program's inception in 1982. AIT is an important regional training center, providing not only excellent research facilities but also regional networking opportunities for outreach activities. In recent years the Thailand project has included outreach activities out of Udorn and other fisheries stations in the region.

Studies conducted in the reporting period have concentrated on two areas of emphasis: environmental impacts of aquaculture and production optimization. All research activities were selected for their strong regional importance, and the CRSP has been in close collaboration with AITs extensive outreach network in order to extend research results throughout continental Southeast Asia.

CRSP research on semi-intensive culture of tilapia has continued on mud turbidity, supplemental feeding, and polyculture of tilapia with predatory snakehead, all of which are related to farmer practices in the wet and dry seasonal climates of the region.

Work Plan Research

The following Eighth Work Plan studies continued into the current reporting period:

- Effects of mud turbidity on fertilization, and an analysis of techniques to mitigate turbidity problems in wet season/8TR1. The report submitted for this study was a final report.
- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds during cool season/8FFR1T. The report submitted for this study was a final report.

This subcontract was awarded funding to conduct the following Ninth Work Plan studies:

- Culture of mixed-sex Nile tilapia with predatory snakehead/9NS2. An abstract was submitted for this study.
- Integrated recycle systems for catfish and tilapia culture/9ER3. This study has not yet begun; a work plan schedule change has been filed.

Note: The report for 8TR1 submitted for the *Sixteenth Annual Technical Report* satisfied final reporting requirements. However, the researchers repeated the experiment during the wet season, and submitted a revised final report this year. The schedules for 9NS2 and 9ER3 have been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information.

Site Improvements

The water supply canal for ponds and the water quality laboratory at AIT were renovated.

Networking

CRSP researchers in Thailand worked to establish relationships with a broad range of individuals—small-scale farmers, fisheries officers, governmental and nongovernmental organizations and private business—throughout the aquaculture community in Southeast Asia and internationally. Five small-scale fish farmers from Thailand consulted with Lin regarding pond management practices. Six provincial fisheries officers of the Thai Department of Fisheries attended a workshop about on-station research that was organized by Lin. In addition, Lin offered guidance to hatchery operators on seed production and supplied advice to representatives from three companies who inquired about shrimp production in Thailand. Lin worked to strengthen regional connections in Vietnam through assistance in building the environmental education and research capacity of the Research Institute for Aquaculture No. 1. In Tra Vin Province in the Mekong Delta, Lin conducted a United Nations Development Programme (UNDP) study on capacity building to alleviate poverty. Additionally, Lin has discussed potential partners for the development of coastal aquaculture with the NGO, Socio-Economic Development Centre (SEDEC), sponsored by the European Community and Germany, in Binh Thuan Province, Vietnam. Lin also chairs the Integrated Coastal Zone Management Program of AIT sponsored by the Danish International Development Agency (DANIDA). Thailand researchers Lin, Bart, and Yi met with Aquaculture and Aquatic Resources Management (AARM) faculty members at AIT to discuss potential collaboration on training and research projects with the preliminary survey teams for inland fishery improvement and extension projects and for the third country training

course on freshwater aquaculture arranged through the Japan International Cooperation Agency (JICA). CRSP and AARM/AIT researchers also discussed the potential for collaboration with members of the Bangladesh Parliament Standing Committee and the Director of Roche Aquaculture Center Asia Pacific. In cooperation with the Asian Fisheries Society and the Fisheries Society of Taiwan, the CRSP assisted in the initiation of the First Cage Culture Symposium in Asia.

In addition to establishing relationships at the regional scale, CRSP researchers discussed the possibility of developing collaborative relationships with private business, government agencies, and fish farmers in Pakistan, Cuba, and China. Lin met with a representative from the Agri-based company in Pakistan and the National Director of Aquaculture of the Republic of Cuba. In China, Lin and Yi were invited to visit fish farms and reservoir fisheries in Ziyang prefecture, Sichuan Province, and Lin attended a shrimp culture meeting of the Wanning Shrimp Company in the Hainan Province. Lin and Yi also gave two presentations "Cage culture and its impacts in reservoirs" and "Cage culture in ponds" to the Sichuan Provincial Fisheries Association. Subsequently Lin and Yi were invited to be technical advisors for the Association's aquaculture projects.

Educational Outreach

Lin taught a course entitled "Water Quality Analysis and Management" to graduate students at the University of Fisheries in Nhatrang, Vietnam, 8–24 December 1998. He also presented a lecture on general aquaculture to 80 trainees for a program organized by Chulalongkorn University and sponsored by JICA.

Lin, Bart, and Yi conduct year-round training courses on water quality analysis and management, seed production, and grow-out at AIT.

Publications

Cao, T.B., C.K. Lin, and H. Demaine, 1999. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: I. Selection of supplemental diets. J. Asian Fish. Sci. (in revision).

Cao, T.B., C.K. Lin, and H. Demaine, 1999. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: II. Supplemental feeding rates in fertilized ponds. J. Asian Fish. Sci. (in revision).

Diana, J.S. and C.K. Lin, 1998. The effects of fertilization on growth and production of Nile tilapia in rain-fed ponds. J. World Aquacult. Soc., 29:405–413.

Edwards, P., C.K. Lin, and A. Yakupitiyage, 1999. Semi-intensive pond aquaculture. In: M. Beveridge and B. McAndrew (Editors), Tilapia Culture and Exploitation. Chapman and Hall, London (in press).

Shrestha, M. and C.K. Lin, 1998. Recycling of pond mud nutrients to cowpea and taro crops. Nutrient Cycling in Agro-Ecosystems (submitted).

Tain, F.H., 1999. Impacts of aquaculture extension on small-scale *Oreochromis niloticus* production in northeastern Thailand. M.S. thesis, University of Michigan, Ann Arbor.

Yi, Y., 1998. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Aquacult. Eng., 18:157–173.

Yi, Y. and C.K. Lin, 1999. Analyses for various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): Profitability and possible environmental impacts. Aquacult. Econ. Manage. (in press).

Presentations

Kaewprakaisaengkul, C., C.K. Lin, and Y. Yi. Construction and application of hapa washer. Poster presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Lin, C.K. Inland marine shrimp culture and its legislative, environmental and socio-economic implications in Thailand. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Lin, C.K. Cage culture and its impacts in reservoirs. Seminar presented to the Sichuan Provincial Fisheries Association, Sichuan, China, 9–20 June 1999.

Lin, C.K., and Y. Yi. Comparative economic analyses for different grow-out strategies of Nile tilapia in earthen ponds. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Lin C.K., Y. Yi, and J.S. Diana. Effects of management strategy on nutrient budgets in Nile tilapia (*Oreochromis niloticus*) ponds. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Lin C.K., M.K. Shrestha, J.S. Diana, and D.P. Thakur. Management to minimize the environmental impacts of pond draining: Harvest draining technique and effluent quality. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Muthuwan V. and C.K. Lin. Green water recirculating system for intensive culture of marine shrimp (*Penaeus monodon*). Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Pant J., P. Promthong, C.K. Lin, and H. Demaine. Fertilization of ponds with inorganic fertilizers: Low cost technologies for small-scale farmers. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Yi, Y. An integrated cage culture system in earthen ponds: A bioenergetics growth model for Nile tilapia. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Yi, Y. Cage culture in ponds. Seminar presented to the Sichuan Provincial Fisheries Association, Sichuan, China, 9–20 June 1999.

Yi, Y., C.K., Lin, J.S. Diana, R.B. Shivappa, and M.A.K. Chowdhury. Management of organic matter and nutrient regeneration in pond bottoms. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Conferences

Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998. (Lin, Bart, Yi)

Joint FAO/NACA Expert Consultation for the Development of a Regional Collaborative Programme on Sustainable Aquaculture for Rural Development (SARDev) at Chiang Rai, Thailand, 29–31 March 1999. (Lin, Edwards)

Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999. (Lin, Bart)

EFFECT OF MUD TURBIDITY ON FERTILIZATION, AND AN ANALYSIS OF TECHNIQUES TO MITIGATE TURBIDITY PROBLEMS IN WET SEASON

Eighth Work Plan, Thailand Research 1 (8TR1)
Final Report

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ABSTRACT

The experiment was conducted in fifteen earthen ponds at the Asian Institute of Technology, Thailand, from June to November 1998 to assess the effects of various turbidity mitigation techniques on fish growth and water quality. The five treatments were: A) control; B) covering the upper 50 cm of pond dikes with black plastic to prevent turbidity from runoff; C) covering pond bottoms with green manure (terrestrial weeds) to alter soil texture; D) covering pond bottoms with small-mesh (1-cm) net to prevent turbidity from fish disturbance; and E) covering pond dikes with rice straw. All ponds were fertilized weekly with chicken manure at a rate of 500 kg ha^{-1} (dry matter basis) supplemented with urea and triple superphosphate (TSP) to provide 28 kg N ha^{-1} wk^{-1} and 7 kg P ha^{-1} wk^{-1}. Sex-reversed all-male Nile tilapia (*Oreochromis niloticus*) were stocked at 2 fish m^{-2} at a size of 19.0 ± 1.0 g. No significant differences of fish survival were found among all treatments. The straw- and weed-covered treatments resulted in significantly higher fish growth and yield. In contrast, the edge- and bottom-covered treatments neither increased fish yield nor improved water quality compared with the control, indicating that those mitigating techniques were not effective. The straw-covered treatment was the innovation of the experiment. Pond water in straw-covered ponds was green throughout the experimental period with low colloidal turbidity, which resulted in the highest fish yield among all treatments. The straw-covered treatment was probably the best mitigating technique in wet season.

OPTIMIZATION OF NITROGEN FERTILIZATION RATE IN FRESHWATER TILAPIA PRODUCTION PONDS DURING COOL SEASON

Eighth Work Plan, Feeds and Fertilizers Research 1T (8FFR1T)
Final Report

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ABSTRACT

An experiment was conducted in twelve 200-m^2 earthen ponds at the Asian Institute of Technology, Thailand, for 91 days from 11 September to 11 December 1998. The experiment was designed to determine the optimal rate of nitrogen fertilization in cool season, to determine which of the nitrogen fertilization rates evaluated to produce Nile tilapia had the greatest profitability, and to develop a full-cost enterprise budget for the fertilization level that resulted in greatest profitability. Treatment ponds were fertilized with TSP at a rate of 8 kg ha^{-1} wk^{-1}, and with urea at 0, 10, 20, and 30 kg N ha^{-1} wk^{-1}, respectively. Sex-reversed male Nile tilapia were stocked at 1,000 kg ha^{-1} at a size of 23.1 to 25.5 g in all ponds (4.1 fish m^{-2}). Sodium bicarbonate was applied to all ponds weekly to attain and maintain the minimum alkalinity (75 mg l^{-1} as $CaCO_3$) based on weekly measurement of alkalinity in pond water. The experiment showed that greater nitrogen inputs resulted in better growth performance of Nile tilapia. Growth in the treatment without N inputs declined after the first fish sampling, which was earlier than the decline (around day 70) in treatments with N inputs. During the entire culture period, the estimated fish biomass was highest in the treatment with 30 kg N ha^{-1} wk^{-1}, intermediate in the treatments with 10 and 20 kg N ha^{-1} wk^{-1}, and lowest in the treatment without N inputs. The highest gross yield of Nile tilapia was obtained in the treatment with 30 kg N ha^{-1} wk^{-1} (1,938 ± 257 kg ha^{-1}, mean ± SE), intermediate in the treatments with 10 and 20 kg N ha^{-1} wk^{-1} (1,628 ± 190 and 1,755 ± 190 kg ha^{-1}, respectively), and the lowest in the treatment without N inputs (818 ± 109 kg ha^{-1}). The partial budget analysis indicated that the treatment with 30 kg N ha^{-1} wk^{-1} was most profitable. The full-cost enterprise budget showed that US$2.1 net return could be produced from a 200-m^2 pond in this treatment during a three-month culture period.

CULTURE OF MIXED-SEX NILE TILAPIA WITH PREDATORY SNAKEHEAD

Ninth Work Plan, New Aquaculture Systems/
New Species Research 2 (9NS2)
Abstract

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Ann Arbor, Michigan, USA

ABSTRACT

An experiment was begun in eighteen 200-m^2 earthen ponds at the Asian Institute of Technology, Thailand, during May and will terminate in October 1999. This experiment will assess the efficiency of snakehead (*Channa striata)* in controlling overpopulation of mixed-sex Nile tilapia (*Oreochromis niloticus*) in ponds. Also, the growth and production characteristics of Nile tilapia in monoculture and polyculture with snakehead will be analyzed. The six treatments were: (A) monoculture of sex-reversed tilapia; (B) monoculture of mixed-sex tilapia; (C) polyculture of mixed-six tilapia and snakehead at 10:1 ratio; (D) polyculture of mixed-six tilapia and snakehead at 20:1 ratio; (E) polyculture of mixed-six tilapia and snakehead at 40:1 ratio; and (F) polyculture of mixed-six tilapia and snakehead at 80:1 ratio. All ponds are fertilized weekly with urea and TSP at rates of 28 kg N and 7 kg P ha^{-1} wk^{-1}. Sex-reversed all-male and mixed-sex Nile tilapia were stocked at 2 fish m^{-2} at sizes of 42.3 ± 1.0 g and 31.0 ± 0.5 g, respectively. Fish growth performance will be evaluated for different treatments. Partial budget analysis will be conducted to estimate input costs and fish value.

APPENDIX 1. PD/A CRSP HISTORY

The PD/A CRSP was initiated formally on 1 September 1982 as a Title XII program under the International Development and Food Assistance Act of 1975. The Consortium for International Fisheries and Aquaculture Development (CIFAD), Auburn University, and the University of California at Davis were chosen to participate in a tripartite management of the PD/A CRSP, and CIFAD was designated as the lead group in the management of the program, with Oregon State University serving as lead institution. CIFAD, no longer a functional entity, consisted of the University of Arkansas at Pine Bluff, the University of Hawaii, the University of Michigan, Michigan State University, and Oregon State University. Most of the CIFAD institutions continue to participate in the PD/A CRSP. However, beginning with this Grant and the dissolution of CIFAD, a new advisory structure allows greater equity among participating institutions and provides an effective mechanism for new institutions to be represented on the Board of Directors.

HISTORICAL OVERVIEW OF PROGRAM OBJECTIVES

In 1980, the First PD/A CRSP Preliminary Design Proposal was approved by the Joint Committee on Agricultural Research and Development (JCARD). The approach for designing the PD/A CRSP included a review and synthesis of the state of the art of pond aquaculture, overseas site visits to determine research needs in cooperating countries, and negotiation of provisional administrative agreements with collaborating institutions. Findings from the literature and field surveys were translated into planning guidelines. The most important needs identified for improving the efficiency of pond culture systems were 1) the need for technological advances to improve the reliability of pond production and 2) the need for economic optimization based on local conditions. The common link was to improve the understanding of pond dynamics.

The 1980 Preliminary Proposal identified four systems which were considered to have the greatest potential for contributing to the supply of low-cost animal protein. These systems, listed in priority sequence according to the proportion of rural poor they would expect to serve, are:

- small, low-intensity tropical pond systems characterized by limited external inputs of feed or fertilizers;
- cooler-water (15-25°C) tropical ponds at medium to high elevations;
- brackishwater and hypersaline ponds, including those in tropical mangrove zones; and
- higher-intensity tropical pond systems, characterized by high external inputs of feed and fertilizers.

The main research objectives for the first five years of the PD/A CRSP (1982–1987 PD/A CRSP Grant) were:

- to compile a quantitative baseline of chemical, physical, and biological parameters for each work location, and to correlate responses of these parameters to various levels of organic and inorganic fertilizer applications to pond culture systems (referred to as the "Global Experiment");
- to compile a baseline of information on hydrology, locally available nutrient inputs, geography, and water quality in each participating country, utilizing available host country resources;
- to observe and document technical constraints limiting fry availability in each participating host country, and to test alternative fry production methods where appropriate;
- to develop models describing the principles of pond culture systems.

These objectives were modified in 1986 because of technical, geopolitical, and financial considerations. A data analysis and synthesis component (later referred to as Data Analysis and Synthesis Team or DAST) was added in 1987 with the following objectives:

- to statistically analyze data from the field experiments to describe global and site-specific variations in pond culture systems;
- to synthesize data from the Global Experiment and develop descriptive models of the physical, chemical, and biological processes that regulate the productivity of pond culture systems;
- to develop conceptual frameworks for one or more pond management models and develop operating instructions consistent with each conceptual framework;
- to compile a manual of operating instructions describing pond management procedures for optimizing yields, increasing the reliability, and improving the efficiency of pond culture systems.

The 1987–1990 Continuation Plan addressed the most important objectives of the original plan, with the goal of synthesizing the results of the first three work plans as a staged progression into a conceptual model of pond aquaculture systems. This model was used to identify research needs which were prioritized and translated into objectives for field research projects specific for each host country.

The programmatic and operational objectives in the 1990–1995 Continuation Plan were:

- to continue to develop technology, through research, to overcome major problems and constraints affecting the efficiency of pond aquaculture in developing countries;
- to maintain or improve environmental quality through proper management of aquacultural systems;
- to stimulate and facilitate the processing and flow of new technologies and related information to researchers, to extension workers, and ultimately, to fish farmers in developing countries;
- to promote activities that encourage faculty and researchers to build and maintain linkages;
- to create opportunities for greater multidisciplinary research in aquaculture and to enhance the socio-economic and ecological aspects of the PD/A CRSP;

- to encourage informational and data exchange among international agricultural research centers, universities, the non-government research community, and AID centrally funded and mission-funded projects;
- to expand results derived from the site-specific research to regional recommendations through a global analysis of the data; and
- to use an ecosystem approach to arrange the research agenda and integrate technologies.

While many program objectives have been met over the past decade of PD/A CRSP research, the original program goal, that advances in pond aquaculture are based on greater understanding of pond dynamics, continues to be relevant. It serves as an effective organizing principle for new research that aims at resolving constraints faced by farmers and commercial aquaculturists in the US and host countries.

1 August 1996 marked the beginning of the PD/A CRSPs first year of operations under its fourth 5-year USAID grant (the *Continuation Plan 1996–2001*).

HISTORICAL OVERVIEW OF THE PD/A CRSP—AGREEMENTS WITH HOST COUNTRIES, 1982 TO 1995

With the initiation of the 1987 CRSP Grant, host country and US institutions renewed their Memoranda of Understanding. These Memoranda reflected the structural changes that had occurred since 1982. While several US universities collaborated at each country site, only one represented the US in each Memorandum. This structure provided for a more equitable arrangement with the host country institutions.

For example, The University of Michigan, a CIFAD member, had separate Memoranda with the Thai Department of Fisheries and the Asian Institute of Technology. The University of Michigan and the Thai Department of Fisheries acted as the lead US university and host country institution, respectively, in Thailand. This provided a focal point for the other institutions that worked on the CRSP project in Thailand. The University of Michigan in turn had informal subagreements with Michigan State University and the University of Hawaii.

Likewise, the Université Nationale du Rwanda (UNR) held a Memorandum of Understanding with Oregon State University, the lead US university on the Rwanda Project. As lead, Oregon State University was the main contact for the Rwandan researchers and was responsible for overall coordination of US CRSP research activities in Rwanda. Auburn University and the University of Arkansas at Pine Bluff collaborated with Oregon State University in Rwanda.

In Honduras, Auburn University held a Memorandum with the Secretaría de Recursos Naturales (since renamed the Secretaría de Agricultura y Ganadería). In Egypt—a bilaterally funded project under USAID/Cairo—Oregon State University held the Memorandum of Understanding with the Egyptian National Agricultural Research Project (NARP).

This hierarchical structure differed from the contractual arrangements among US universities and the Management Entity (ME). While all participating institutions had access to the services of the ME, past contractual agreements were made directly with Auburn University, the University of California, Davis, and CIFAD. CIFAD in turn had formal contracts with its member universities: The University of Michigan, Michigan State University, Oregon State University, the University of Hawaii, and the University of Arkansas at Pine Bluff. When CIFAD was dissolved, all institutions were elevated to the same contractual status. The hierarchical arrangement arrived at through the designation of lead US universities was seen to promote a greater degree of cooperation among US universities and greater involvement of the host institutions at the highest level. Certain programmatic and fiscal responsibilities were delegated to participating US institutions through subagreements from the ME. For the Egypt Project, the ME had formal contracts with each participating university.

CRSP MEMORANDA OF UNDERSTANDING, 1996 TO 1999

Since the initiation of the current grant, the *Continuation Plan 1996–2001*, new lead projects have been established in Peru, Kenya, and the Philippines, and institutional relationships were restructured for the Honduras Project.

Southern Illinois University at Carbondale (SIUC) was awarded funding as the lead US institution for research in Peru. By 1997, MOUs were in place between SIUC and Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana, Peru. In Kenya, CRSP research was underway in 1997, under a new MOU between Oregon State University and the Kenya Department of Fisheries, Ministry of Wildlife and Tourism (the Department moved in 1998 to the Ministry of Natural Resources). OSU is the lead US institution for the Kenya Project, sharing responsibility with Auburn University for a joint research work plan. Under previous grants, the Philippines served as a companion site to the lead Southeast Asia site at the Asian Institute of Technology in Thailand; however, the *Continuation Plan 1996–2001* identified the Philippines as a potential lead site. In October 1997, the Management Entity issued a restricted Request for Proposals (RFP) for lead US and host country institutions for a new Philippines Project. Upon completion of internal and external peer reviews and evaluations of proposals, the University of Hawaii was awarded funding to serve as lead institution of the Philippines Project. A new subcontract with the University of Hawaii was established in July 1998; the host country collaborating institution is Central Luzon State University.

The ME learned in January 1999 that the extant Honduras Project, led by Auburn University, had decided to discontinue future operations by declining an award offer for Ninth Work Plan research. A combination of factors likely contributed to this decision, among them a USAID decision to discontinue funding for shrimp research and the program's fiscal and management direction away from fully supporting expatriate researchers' salaries. In April 1999, Auburn University dissolved its existing Memorandum of Understanding with

the Secretaría de Agricultura y Ganadería in Honduras. To identify new lead US and host country institutions for a new Honduras Project, the ME issued a restricted RFP in March 1999. The University of Georgia was selected as the new Honduras US lead institution with Escuela Agrícola Panamericana El Zamorano as the host country institution and Auburn University as a collaborating US institution.

At the close of the present reporting period, Memoranda of Understanding are in place among the following CRSP partner institutions:

- University of Georgia and the Escuela Agrícola Panamericana El Zamorano, Honduras;
- Southern Illinois University at Carbondale and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana, Peru;
- Oregon State University and the Department of Fisheries, Ministry of Wildlife and Tourism, Kenya (the Department moved in 1998 to the Ministry of Natural Resources);
- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico;
- The University of Michigan and the Asian Institute of Technology, Thailand; and
- University of Hawaii and Central Luzon State University, Philippines.

The PD/A CRSP also has formal agreements with the following organizations:

- West Africa InterCRSP
- CRSP Council

Many other informal agreements exist with nongovernmental organizations, private voluntary organizations, private industry, government agencies, universities, and other groups and organizations. A small sample of these linkages appears in Appendix 6.

APPENDIX 2. PROGRAM PARTICIPANTS

The Pond Dynamics/Aquaculture CRSP represents the joint efforts of more than 85 professional and support personnel from US universities. It also represents the collaborative efforts of over 70 scientists, technicians, and students from project sites in six host countries—Mexico, Honduras, Peru, Kenya, Thailand, and the Philippines. The expertise of host country and US personnel is broad-based and encompasses the major fields of specialization included in this CRSP: limnology and water quality; fisheries and aquaculture; soil science; engineering; information systems; data management, analysis, and modeling; endocrinology; genetics; environmental hazard management; sociology; agricultural economics; policy development; adult education; and research administration.

The program's United States–based participants are drawn from the CRSP partner institutions—Auburn University (AU), The Ohio State State University, Oregon State University (OSU), Southern Illinois University at Carbondale, the University of Arkansas at Pine Bluff (UAPB), the University of Arizona (UA), the University of California, Davis, the University of Delaware, the University of Georgia (UG), the University of Hawaii, The University of Michigan (UM), the University of Oklahoma (UO), and the University of Texas.

Host country staff participate in the CRSP though their involvement with:

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico
Escuela Agrícola Panamericana, Zamorano, Honduras
Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras
Laboratorio de Calidad de Agua La Lujosa, Choluteca, Honduras
Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras
Instituto de Investigaciones de la Amazonia Peruana (IIAP), Iquitos, Peru
Universidad Nacional de la Amazonia Peruana, Iquitos, Peru
Fisheries Department, Nairobi, Kenya
Sagana Fish Farm, Sagana, Kenya
Asian Institute of Technology (AIT), Pathum Thani, Thailand
Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Cooperating institutions include:

Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia
Grupo Granjas Marinas, S.A., Choluteca, Honduras
ICLARM, Zomba, Malawi
University of Nairobi, Kenya

Researchers and research project staff are named within each project report in the body of this report. Following are listings for staff of the Program Management Office as well as membership on the program's three advisory groups—Board of Directors, External Evaluation Panel, and Technical Committee.

PROGRAM MANAGEMENT OFFICE STAFF

Oregon State University, Corvallis, Oregon

Hillary Egna	Director
Brigitte Goetze*	Deputy Director (through January 1999)
Cormac Craven	Assistant Director (from March 1999)
Danielle Clair*	Program Assistant
Viji Sreenivasan*	Financial Manager
Xena Cummings*	Student Worker

*PMO staff employed at less than full-time

ADVISORY BODIES

Board of Directors

Russell Moll, Chair	The University of Michigan
L.J. (Kelvin) Koong	Oregon State University
Shadrach Okiror	University of Arkansas at Pine Bluff

Ex-Officio Board Members

Harry Rea	USAID
Hillary Egna	Oregon State University

External Evaluation Panel

Gary Jensen	US Department of Agriculture, Washington, DC
Kevan Main	Harbor Branch Oceanographic Institute, Sarasota, Florida
Edna McBreen	University of Nebraska, Lincoln

Technical Committee*

Technical Committee*	Institution	
Co-Chairs		
Bill Shelton	University of Oklahoma	
John Bolte	Oregon State University	
Material and Methods Subcommittee		*Research Area of Expertise*
Carole Engle	UAPB	Social and economic aspects
Doug Ernst	OSU	Environmental effects
Claude Boyd	AU	Production optimization
Technical Progress Subcommittee		
Joe Molnar	AU	Social and economic aspects
Yang Yi	UM	Environmental effects
Wilfrido Contreras-Sánchez	OSU	Production optimization**
Work Plan and Budget Subcommittee		
Kevin Fitzsimmons	UA	Environmental effects
Tom Popma	AU	Production optimization
Salvador Tello	IIAP	Social and economic aspects

External At-Large Member

Marc Verdegem	Wageningen Agricultural University, The Netherlands

Research Support At-Large Member

Marion McNamara	OSU

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	OSU
Brigitte Goetze	OSU (through February 1999)
Cormac Craven	OSU (from March 1999)

* Membership as of 1999 Technical Committee election; see 16th Annual Report for previous roster. Subcommittee members are listed in order of seniority.

** Shree Nath (UG) was voted in to fill this seat in the Technical Committee election; on his retirement from the CRSP, the runner-up, Wilfrido Contreras-Sánchez, was offered and accepted the position.

Financial Summary under Continuation Plan 1996–2001

November 1, 1998 - July 31, 1999

Research Project	Project Leader	Institution	USAID[1] 11/98-7/99	USAID[1] Since 8/96	Cost Share[2] 11/98-7/99	Cost Share[2] Since 8/96	Total US Funds	Host Country Contribution 11/98-7/99	Host Country Contribution Since 8/96
RESEARCH									
Global Research									
Pond Dynamics	Boyd	Auburn University	26,112	140,093	7,062	37,370	177,463		
Reproduction Control	Shelton	University of Oklahoma	24,240	141,520	6,819	38,013	179,533		
Reproduction Control	Phelps	Auburn University	37,472	92,303	9,368	21,408	113,711		
Reproduction Control	Fitzpatrick	Oregon State University	41,572	237,519	9,089	58,398	295,917		
Aquaculture Systems Modeling	Piedrahita	University of California, Davis	0	78,101	0	26,611	104,712		
Effluents & Pollution	Fitzpatrick	Oregon State University	26,331	26,331	9,088	9,088	35,419		
Marketing & Economic Analysis	Engle	University of Arkansas at Pine Bluff	75,948	174,812	19,750	44,830	219,642		
Marketing & Economic Analysis	Hatch	Auburn University	27,633	27,633	6,908	6,908	34,541		
Adoption/Diffusion	Molnar	Auburn University	0	68,293	0	23,166	91,459		
Adoption/Diffusion	Lovshin	Auburn University	0	67,168	0	16,792	83,960		
Decision Support Systems	Bolte	Oregon State University	63,842	259,286	21,908	71,618	330,904		
Decision Support Systems sub-project	*Killian*	*University of Arkansas at Pine Bluff*	7,900	7,900	4,148	4,148	12,048		
Regional Research									
Central America									
Honduras	Ward	University of Texas at Austin	0	19,767	0	4,066	23,833		
Honduras	Green	Auburn University	44,000	502,056	11,000	78,435	580,491	27,726	140,484
Honduras	Verma	University of Georgia	155,000	155,000	37,906	37,906	192,906		
Honduras	Molnar	Auburn University	65,001	65,001	16,250	16,250	81,251		
Africa									
Kenya	Bowman	Oregon State University	131,183	596,317	6,442	56,857	653,174	27,000	54,000
Kenya	Popma	Auburn University	67,586	389,692	15,891	87,272	476,964		
Kenya	Lochmann	University of Arkansas at Pine Bluff	11,865	29,251	1,917	7,228	36,479		
Kenya	Wood	Auburn University	5,449	30,449	0	8,254	38,703		
South America									
Peru	Kohler	Southern Illinois University	54,999	235,755	12,599	75,596	311,351	40,944	99,475
Peru sub-project	*Dabrowski*	*Ohio State University*	13,000	13,000	11,963	11,963	24,963		
Peru	Lochmann	University of Arkansas at Pine Bluff	8,023	20,065	4,288	8,576	28,641		
Asia									
Philippines	Fitzsimmons	University of Arizona	0	69,833	0	20,908	90,741	6,550	7,050
Philippines	Brown	University of Hawaii	109,850	209,912	27,462	52,477	262,389		
Thailand	Diana	University of Michigan	78,428	444,691	14,657	76,658	521,349	26,000	78,000
Research Support									
Central Database Management		Oregon State University	59,866	216,256	14,985	57,018	273,274		
Education Development		Oregon State University	0	241,845	0	95,512	337,357		
Information Management & Networking		Oregon State University	278,390	984,780	69,598	246,271	1,231,051		
Subcontract Administration		Indirect on Subs < 25,000	13,000	118,910			118,910		
Research Subtotal			1,426,690	5,663,539	339,098	1,299,597	6,963,136	128,220	379,009
MANAGEMENT									
Program Management[3]									
Operations and Administration		OSU Management	350,000	1,591,000			1,591,000		
Advisory Groups		OSU Advisory	66,945	270,002			270,002		
Program Management Subtotal			416,945	1,861,002			1,861,002		
Total			1,843,635	7,524,541	339,098	1,299,597	8,824,138	128,220	379,009

Notes:

1. Reflects funding received under four USAID allocations and obligations made to research projects by thematic and geographic emphases.
2. Cost share includes commitments made in association with the allocated funds in addition to cost share already accumulated.
3. Cost sharing is not required for management operations.

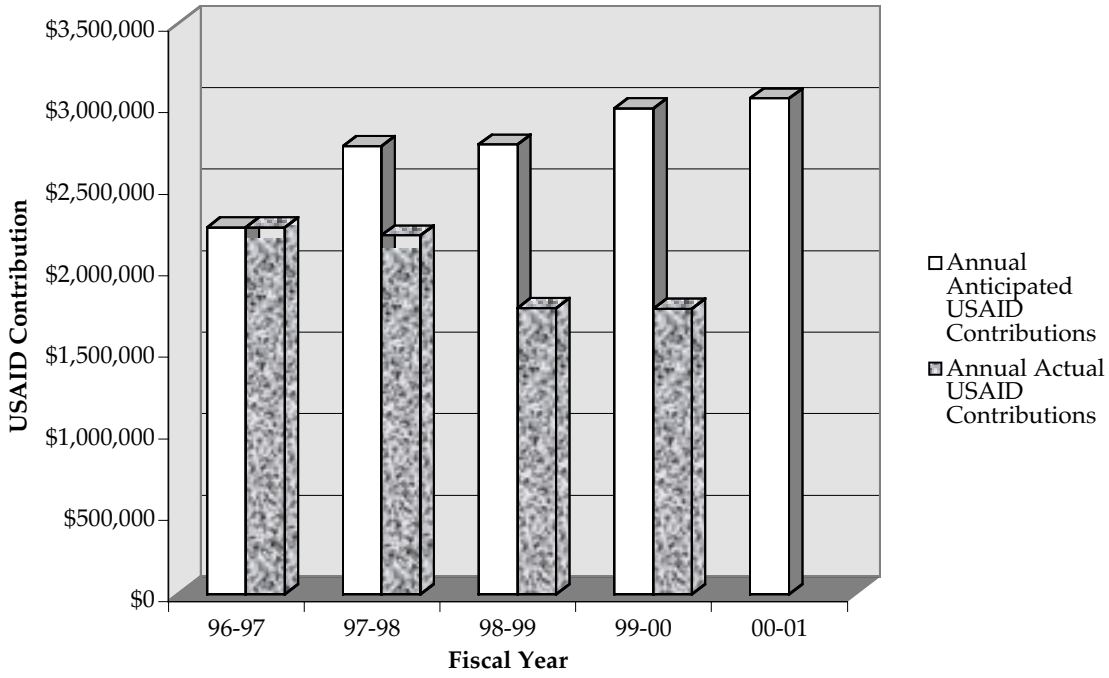

Figure 1. Comparison of anticipated USAID contributions (from grant-authorized budget) and actual USAID contributions on an annual basis for the *PD/A CRSP Continuation Plan 1996–2001*.

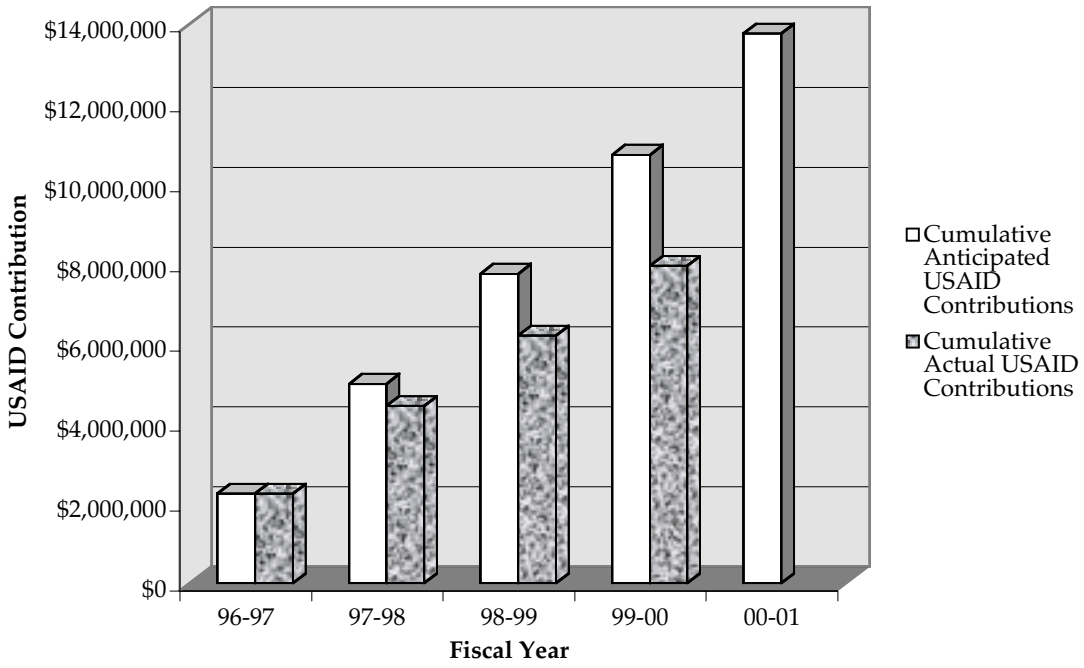

Figure 2. Comparison of anticipated USAID contributions (from grant-authorized budget) and actual USAID contributions on a cumulative basis for the *PD/A CRSP Continuation Plan 1996–2001*.

APPENDIX 4. STAGED START DATES

The PD/A CRSPs reduced FY98 budget necessitated a staged approach for the funding of Ninth Work Plan investigations to allow for funding of as much of the original research portfolio as possible. Projects having completed Eighth Work Plan research were first to receive funds for Ninth Work Plan investigations, in accordance with the policy established by the Management Entity (ME) that there be no overlap between the two work plans. Building into this policy some flexibility, the ME allowed a one-time exemption to this policy; by request to the ME, a principal investigator could carry forward one Eighth Work Plan study while receiving funds to commence Ninth Work Plan research.

(The following projects were granted exemptions to carry forward one Eighth Work Plan study: Kenya Project (Auburn University and Oregon State University); Adoption/Diffusion Project* (Auburn University); Reproduction Control Project (Auburn University); and Thailand Project (University of Michigan).)

Start Date	Research Project	Project Leader	Institution
8/98	Reproduction Control/Effluents	Fitzpatrick	Oregon State University
8/98	Decision Support Systems	Bolte	Oregon State University
8/98	Peru	Kohler	Southern Illinois University at Carbondale
11/98	Pond Dynamics	Boyd	Auburn University
12/98	Kenya	Popma	Auburn University
12/98	Kenya	Bowman	Oregon State University
12/98	Kenya	Wood	Auburn University
1/99	Marketing & Economic Analysis	Engle	University of Arkansas at Pine Bluff
1/99	Kenya	Lochmann	University of Arkansas at Pine Bluff
1/99	Peru	Lochmann	University of Arkansas at Pine Bluff
1/99	Philippines	Brown	University of Hawaii
1/99	Thailand	Diana	University of Michigan
5/99	Reproduction Control	Shelton	University of Oklahoma
5/99	Reproduction Control	Phelps	Auburn University
5/99	Marketing & Economic Analysis	Hatch	Auburn University
5/99	Honduras	Verma	University of Georgia, Athens
5/99	Honduras	Molnar	Auburn University

* With one exception, the Ninth Work Plan research of the projects granted exemptions was a direct continuance of the regional or thematic research for which Eighth Work Plan funding was awarded. The lone exception is the Auburn University Adoption/Diffusion Project, led by Joe Molnar. Molnar's Ninth Work Plan research is an integrated component of the new Honduras Project and is so listed above, instead of appearing as a new Adoption/Diffusion project.

RESEARCH AREA: PRODUCTION OPTIMIZATION

Research Theme	Project Leader	Report Title	Research Theme Code	Study End Date	Report Received
Pond Dynamics	Boyd	Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients *	8PDR1	05/98	Final
	Diana	Effect of Mud Turbidity on Fertilization, and an Analysis of Techniques to Mitigate Turbidity Problems in Wet Season	8TR1	07/98	Final
	Bowman	New Site Development and Characterization	8KR1	12/98	Final
	Boyd	Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients	9PDR2	06/00	Progress
Feeds and Fertilizers	Green	Intensification of Tilapia Production: Effects of Feeding at Different Stocking Rates on Pond Water Quality	8HR1	12/99	Final
	Bowman	Relative Contribution of Supplemental Feed and Inorganic Fertilizers in Semi-Intensive Tilapia Production	8KR3	08/98	Final
	Lochmann	Nutritional Contribution of Natural and Supplemental Foods for Nile Tilapia: Stable Carbon Isotope Analysis	8KR3A	12/98	Final
	Bowman	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds	8FFR1K	08/99	Progress
	Diana	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds during Cool Season	8FFR1T	01/99	Final
	Brown	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds	8FFR1Ph	04/01	None expected
	Brown	Timing of the Onset of Supplemental Feeding of Tilapia in Ponds	9FFR4	12/99	Progress
Reproduction Control	Shelton	Methods for Androgenesis Techniques Applicable to Tilapia	8RCR1B	06/99	Final
	Phelps	Methods for Contribution from the Male and Female Genome to Sex Inheritance	8RCR1C	08/99	None
	Phelps	Methods for Development of YY Lines of Male and Female *O. niloticus*	8RCR1D	08/99	None
	Phelps	Detection of MT in Pond Water after Treatment with MT Food	8RCR3B	04/99	Final
	Bowman	Strain Variations in Sex Ratio Inheritance	8KR2	08/98	Final
	Fitzpatrick	Masculinization of Tilapia by Immersion in Trenbolone Acetate: Effect of Treatment Timing and Dose on Masculinization with Trenbolone Acetate	9RCR5A	07/99	Final
	Fitzpatrick	Masculinization of Tilapia by Immersion in Trenbolone Acetate: Growth Performance of Trenbolone Acetate–Immersed Tilapia	9RCR5B	07/00	None expected
Aquaculture Systems Modeling	Piedrahita	Aquaculture Pond Modeling for the Analysis of Environmental Impacts and Integration with Agriculture: Model Evaluation and Application to the Ecological Analysis of Integrated Aquaculture/Agriculture Systems †	8ASMR1A	09/98	Final
	Piedrahita	Aquaculture Pond Modeling for the Analysis of Environmental Impacts and Integration with Agriculture: Modeling of Temperature, Dissolved Oxygen, and Fish Growth Rate in Stratified Ponds Using Stochastic Input Variables †	8ASMR1B	12/98	Final
New Aquaculture Systems/ New Species	Diana	Culture of Mixed-Sex Nile Tilapia with Predatory Snakehead	9NS2	01/00	Abstract

RESEARCH AREA: ENVIRONMENTAL EFFECTS

Research Theme	Project Leader	Report Title	Research Theme Code	Study End Date	Report Received
Effluents and Pollution	Green	Estuarine Water Quality Monitoring and Estuarine Carrying Capacity	8HR2-1	09/98	Final
	Ward	Evaluation of Shrimp Farming Impacts in Golfo de Fonseca Region, Honduras †	8HR2-2	09/98	Final
	Green	Water Exchange to Rectify Low Dissolved Oxygen	8HR4	05/99	Final
	Wood	Use of Pond Effluents for Irrigation in an Integrated Crop/Aquaculture System	9ER1	02/00	Progress
	Fitzpatrick	Fate of Methyltestosterone in the Pond Environment: Detection of MT in Soil after Treatment with MT Food	9ER2A	07/99	Final
	Fitzpatrick	Fate of Methyltestosterone in the Pond Environment: Detection of MT in Pond Soil from a CRSP Site	9ER2B	07/00	Abstract
	Diana	Integrated Recycle Systems for Catfish and Tilapia Culture	9ER3	03/00	None expected

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS

Research Theme	Project Leader	Report Title	Research Theme Code	Study End Date	Report Received
Marketing and Economic Analysis	Engle	Nonparametric Estimation of Returns to Investment in Honduras Shrimp Research	8MEAR1	12/98	Final
	Engle	Risk Analysis of Shrimp Farming in Honduras	8MEAR2	12/98	Final
	Engle	Development of Central American Markets for Tilapia Produced in the Region	9MEAR3	01/01	Progress
	Engle	Economic and Social Returns to Technology and Investment in Thailand	9MEAR4	04/01	Progress
Adoption/ Diffusion	Molnar	Fish Culture in the Peruvian Amazon: Producer Perceptions and Practices in Three River Systems †	8ADR1-1	12/98	Final
	Molnar	Sources of Technical Assistance for Fish Farmers in the Peruvian Amazon †	8ADR1-2	10/99	Progress
	Lovshin	Impacts of Integrated Fish Culture on Resource-Limited Farms in Guatemala and Panama: An Ex-Post Evaluation	8ADR2	12/98	Final
	Bowman	Regional Outreach in Africa	8KR5	07/98	Final
	Bowman	Aquaculture Training for Kenyan Fisheries Officers and University Students	9ADR3	03/01	Progress
	Bowman	Establishment of Companion Sites in the Africa Region	9ADR4	03/01	Progress
	Bowman	Regional Outreach in Africa	9ADR5	03/01	Progress
Decision Support Systems	Bolte	Decision Support Systems for Fish Population Management and Scheduling in Commercial Pond Aquaculture Operations	9DSSR2	04/01	None expected
	Bolte	Enhancing the POND© Decision Support System for Economics, Education, and Extension	9DSSR3	06/00	Progress

* The final report for 8PDR1 was combined with and is printed as the progress report for 9PDR2.
† Title of report is different than study title listed in the *Eighth Work Plan.*

Appendix 6. Linkages

Developing and maintaining links among collaborating universities and government ministries, departments of agriculture, and private-sector aquaculturists around the world forms a significant ancillary contribution to the CRSPs research effort and to the goal of expanding the role of aquaculture in the developing world. The following list includes informal linkages and connections made by CRSP researchers in the field and reported to the Program Management Office (PMO) during this reporting period as well as those maintained by the PMO. (Please see pages 3–4 for a listing of institutions with formal linkages to the CRSP.)

American Association for the Advancement of Science (AAAS), Washington, DC
American Fisheries Society, Bethesda, Maryland
American Tilapia Association, Arlington, Virginia
Asociación Nacional de Acuicultores de Honduras (ANDAH), Tegucigalpa, Honduras
Association for International Agriculture and Rural Development (AIARD), Washington, DC
Bean/Cowpea CRSP, East Lansing, Michigan
Board for International Food and Agricultural Development (BIFAD) Washington, DC
Brackish Water Shrimp Culture Station, Ranot, Thailand
Broadening Access and Strengthening Input Market Systems (BASIS) CRSP, Madison, Wisconsin
Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi
Bureau of Fisheries and Aquatic Resources, Manila, Philippines
Canadian International Development Agency (CIDA), Hull, Quebec, Canada
Cáritas del Perú, Iquitos, Peru
Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt
Chulalongkorn University, Bangkok, Thailand
Clackamas County Extension Office, Oregon City, Oregon
Coastal Resources Center, Narragansett, Rhode Island
Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (CODDEFFAGOLF), Tegucigalpa, Honduras
Consortium for International Earth Science Information Network (CIESIN), Washington, DC
Consultative Group on International Agricultural Research (CGIAR), Washington, DC
- Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia
- International Center for Living Aquatic Resources Management (ICLARM), Zomba, Malawi
- International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya
- West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire

Cooperative for Relief and Assistance Everywhere (CARE), Atlanta, Georgia
Danish International Development Agency (DANIDA), Copenhagen, Denmark
Department of Fisheries, Udorn Thani, Thailand
Egerton University, Njoro, Kenya
Empresa Brasileira de Pesquisa Agropecuária (Embrapa), Brasilia, Brazil
Escuela de Agricultura de la Region Tropical Humeda (EARTH), San José, Costa Rica
Escuela Superior Politécnica del Litoral (ESPOL), Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM), Guayaquil, Ecuador
European Union, Brussels, Belgium
Farm-level Applied Research Methods for East and Southern Africa (FARMESA), Swedish International Development Cooperation Agency (SIDA), Stockholm, Sweden
Fe y Alegria, Lima, Peru
Federación de Agroexportadores de Honduras (FPX), San Pedro Sula, Honduras
Fisheries Society of Africa (FISA), Nairobi, Kenya
Fishgen, Swansea, Wales
Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
- Aquaculture for Local Community Development Programme (ALCOM), Harare, Zimbabwe
- European Inland Fisheries Advisory Commission (EIFAC), Rome, Italy
- Inland Water Resources and Aquaculture Service (FIRI), Rome, Italy

Genetically Improved Farmed Tilapia Program (GIFT), Muñoz, Nueva Ecija, Philippines
Global Aquaculture Alliance, St. Louis, Missouri
Hofstra University, Hempstead, New York
Institute of Agricultural and Food Information, Prague, Czech Republic
Institut Pertanian Bogor (IPB), Bogor, Indonesia
Instituto Politécnico Nacional, Mexico City, Mexico
Integrated Pest Management CRSP, Blacksburg, Virginia
International Development Research Centre (IDRC), Ottawa, Canada

International Sorghum and Millet (INTSORMIL) CRSP, Lincoln, Nebraska
Japan International Cooperation Agency (JICA)
Katholieke Universiteit Leuven (KUL), Belgium
Kenya Medical Research Institute (KEMRI), Nairobi, Kenya
Kenyatta University, Nairobi, Kenya
Land Tenure Center, Madison, Wisconsin
Marine Institute, Callao, Peru
Mekong River Commission, Phnom Penh, Cambodia
Microcredit Summit Campaign, Washington, DC
Ministry of Agriculture, Animal Husbandry, and Fisheries, Entebbe, Uganda
Ministry of Agricultural Development, Panama
Ministry of Environment and Natural Resources, Tegucigalpa, Honduras
Ministry of Fisheries, Iquitos, Peru
Ministry of Tourism, Natural Resources, and Environment, Fisheries Division, Dar es Salaam, Tanzania
Moi University, Eldoret, Kenya
Mount Kenya Fish Farmers Association, Central Province, Kenya
National Agricultural Library, Washington, DC
National Aquaculture Centre, Zomba, Malawi
National Inland Fisheries Institute (NIFI), Bangkok, Thailand
National Shrimp Culture Advisory Group, Tegucigalpa, Honduras
National Technical Information Services, (NTIS) Springfield, Virginia
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok, Thailand
North Central Regional Aquaculture Center (NCRAC), East Lansing, Michigan
Nuestros Pequeños Hermanos (NPH), Honduras
Oceanic Institute, Waimanalo, Hawaii
Oregon Sea Grant, Corvallis, Oregon
Organization of African Unity, Addis Ababa, Ethiopia
    Inter-African Committee on Oceanography, Sea and Inland Fisheries
Patani Fisheries College, Patani, Thailand
Peanut CRSP, Griffin, Georgia
Post Harvest CASP, Mississippi State, Mississippi
Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (PRADEPESCA), Panama
Research Institute for Aquaculture No. 1, Hanoi, Vietnam
Roche Aquaculture Research Centre Asia Pacific, Bangkok, Thailand
Sichuan Provincial Fisheries Association, Ziyang, Sichuan Province, People's Republic of China
Small Ruminant/Global Livestock CRSP, Davis, California
Soil Management CRSP, Honolulu, Hawaii
Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines
Southern African Development Community (SADC), Harare, Zimbabwe
Socio-Economic Development Centre (SEDEC), Binh Thuan Province, Vietnam
Special Program for African Agricultural Research (SPAAR), Washington, DC
Sustainable Agricultural Centre for Research and Development in Africa (SACRED-Africa), Bungoma, Kenya
Sustainable Agriculture and Natural Resources Management (SANREM) CRSP, Watkinsville, Georgia
Terra Nuova (Institución Italiana de Cooperación Internacional), Lima, Peru
Texas A&M University, College Station, Texas
United States Department of Agriculture (USDA), Washington, DC
United States Fish and Wildlife Service (USFWS), Washington, DC
United States Food and Drug Administration (FDA), Washington, DC
Universidad Autónoma Metropolitana, Mexico City, Mexico
Universidad Técnica de Machala, Machala, Ecuador
Universidade de São Paulo, Brazil
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam
University of Cantho, Vietnam
University of Fisheries, Nhatrang, Vietnam
University of Nairobi, Kenya
University of the Philippines in the Visayas, Iloilo, Philippines
University of Washington, Seattle, Washington
Virginia Polytechnic Institute, Blacksburg, Virginia
Wageningen University, Holland
Western Regional Aquaculture Consortium (WRAC), Seattle, Washington
World Aquaculture Society (WAS), Baton Rouge, Louisiana
World Bank, Washington, DC
World Conservation Union (IUCN), Nairobi, Kenya

APPENDIX 7. PUBLICATIONS

Regional Research

CENTRAL AMERICA

Honduras

ASIAN INSTITUTE OF TECHNOLOGY

Publication

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

AUBURN UNIVERSITY

Thesis

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

Publications and Reports

Alvarenga, H.R. and B.W. Green, 1985. Production of hybrid tilapia (*Tilapia nilotica* × *Tilapia honorum*) fingerlings. CRSP Technical Report (unpubl.), 12 pp. (In Spanish.)

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

Alvarenga, H.R. and B.W. Green, 1989. Production and economic aspects of tilapia culture in ponds fertilized with chicken litter. Rev. Latinoamericana de Acuicultura, 40:35–39. (In Spanish.)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1984. A system for producing hybrid tilapia (*Tilapia nilotica* ×) fingerlings at the El Carao Aquaculture Experiment Station, Comayagua, Honduras. CRSP Technical Report (unpubl.), 9 pp. (In Spanish.)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1985. Pelleted fish feed vs. corn gluten as feed for tilapia and Chinese carp polyculture in ponds. CRSP Technical Report (unpubl.). (In Spanish.)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1987. Production of hybrid tilapia (*Tilapia nilotica* × *Tilapia honorum*) in ponds using corn gluten as a supplemental feed. CRSP Technical Report (unpubl.), 13 pp. (In Spanish.)

Ayub, M., C.E. Boyd, and D.R. Teichert-Coddington, 1993. Effects of urea application, aeration, and drying on total carbon concentrations in pond bottom soils. The Progressive Fish-Culturist, 55:210–213.

Berrios, J.M., 1986. Growth and survival of hybrid tilapia (*Tilapia nilotica* × *Tilapia honorum*) fingerlings during the nursery phase in ponds. CRSP Technical Report (unpubl.), 16 pp. (In Spanish.)

Boyd, C.E. and B. Green, 1998. Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*). Journal of the World Aquaculture Society, 29:125–128.

Boyd, C.E. and D.R. Teichert-Coddington, 1992. Relationship between wind speed and reaeration in small aquaculture ponds. Aquacultural Engineering, 11:121–131.

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

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

Green, B.W., 1985. Report on the induced spawning of the silver and grass carps. CRSP Technical Report (unpubl.), 8 pp. (In Spanish.)

Green, B.W., 1992. Substitution of organic manure for pelleted feed in tilapia production. Aquaculture, 101:213–222.

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

Green, B.W., 1997. Inclusion of tilapia as a diversification strategy for penaeid shrimp culture. In: D.E. Alston, B.W. Green, and H.C. Clifford (Editors), Asociación Nacional de Acuicultores de Honduras and the Latin American Chapter of the World Aquaculture Society. IV Symposium on aquaculture in Central America: focusing on shrimp and tilapia, 22–24 April 1997, at Tegucigalpa, Honduras, pp. 84–93.

Green, B.W. and H.R. Alvarenga, 1985. Tilapia and carp polyculture in ponds receiving organic fertilization and supplemental feed. CRSP Technical Report (unpubl.), 10 pp. (In Spanish.)

Green, B.W. and H.R. Alvarenga, 1989. The effect of different application rates of chicken litter on tilapia production. Rev. Latinoamericana de Acuicultura, 40:31–34. (In Spanish.)

Green, B.W. and C.R. Engle, 1999. Commercial tilapia aquaculture in Honduras. In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana. (in press)

Green, B.W. and L.A. López, 1990. Implementing the large-scale production of young males of *Tilapia nilotica* using hormonal sex inversion in Honduras. Agronomía Mesoamericana, 1:21–25. (In Spanish.)

Green, B.W. and D.R. Teichert-Coddington, 1990. Comparison of two sampler designs for use with automated data a cquisition systems in whole-pond community metabolism studies. Proceedings of FAO-EIFAC Symposium on Production Enhancement in Still-Water Pond Culture at Prague: Research Institute of Fish Culture and Hydrobiology, Vodnany, Czechoslovakia.

Green, B.W. and D.R. Teichert-Coddington, 1991. Comparison of two samplers used with an automated data acquisition system in whole-pond community metabolism studies. The Progressive Fish-Culturist, 53(4):236–242.

Green, B.W. and D.R. Teichert-Coddington, 1993. Production of *Oreochromis niloticus* fry for hormonal sex reversal in relation to water temperature. Journal of Applied Ichthyology, 9:230–236.

Green, B.W. and D.R. Teichert-Coddington, 1994. Growth of control and androgen-treated Nile tilapia during treatment, nursery and growout phases in tropical fish ponds. Aquaculture and Fisheries Management, 25:613–621.

Green, B.W., R.P. Phelps, and H.R. Alvarenga, 1989. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds. Aquaculture, 76:37–42.

Green, B.W., D.R. Teichert-Coddington, and T.R. Hanson, 1994. Development of semi-intensive aquaculture technologies in Honduras: summary of freshwater aquacultural research conducted from 1983 to 1992. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 39, Auburn University, Alabama, 48 pp.

Green, B.W., D.R. Teichert-Coddington, and R.P. Phelps, 1990. Response of tilapia yield and economics to varying rates of organic fertilization and season in two Central American countries. Aquaculture, 90:279–290.

Green, B.W., D.R. Teichert-Coddington, M.P. Micheletti, and C.A. Lara, 1997. A collaborative project to monitor water quality of estuaries in the shrimp producing regions of Honduras.

Proceedings of the IV Ecuadorian Aquaculture Symposium, 22–27 October 1997. CENAIM, ESPOL, Camera Nacional de Acuicultura, Guayaquil, Ecuador. CD-ROM.

Meckenstock, D., D.R. Teichert-Coddington, J.C. Rosas, H. van Es, M.S. Chinnan, and M.M. Murillo, 1991. CRSP Council - Honduras concept paper towards a sustainable agriculture in Southern Honduras. Proceedings of the International Sorghum and Millet CRSP Conference, 8–12 July 1991 at Corpus Christi, Texas, USA: INTSORMIL Publication No. 92-1, pp. 107–119.

Rodriguez, R., G. Nuñez, and D. Teichert-Coddington, 1993. Evaluación de dos dietas alimenticias con diferente porcentaje de proteina, bajo dos densidades de siembra epoca de invierno en Granjas Marinas San Bernardo. II Simposio Centralamericano Sobre Camarón Cultivado, Tegucigalpa, Honduras. Federación de Productores y Exportadores (FPX), San Pedro Sula, Honduras, 267 pp.

Sherman, C., 1986. Growth of all-female *Tilapia nilotica* in earthen ponds fertilized with chicken litter. CRSP Technical Report (unpubl.), 14 pp. (In Spanish.)

Teichert-Coddington, D.R., 1988. Effects of protein diet and sowing density on the production of *Penaeus vannamei* in land tanks. Rev. Latinoamericana de Acuicultura, 35:29–44.

Teichert-Coddington, D.R., 1993. Development of production technologies for semi-intensive fish farming during the past decade in Central America. Proceedings of Symposium on Aquacultural Research in Central America at Heredia, Costa Rica: Programa UNA/LUW Acuicultura, Escuela de Ciencias Biológicas, Heredia, Costa Rica, pp. 71–88.

Teichert-Coddington, D.R., 1995. Estuarine water quality and sustainable shrimp culture in Honduras. Proceedings of the Special Session on Shrimp Farming, Swimming Through Troubled Water, Aquaculture '95: World Aquaculture Society, pp. 144–156.

Teichert-Coddington, D.R., 1996. Effect of stocking ratio on semi-intensive polyculture of *Colossoma macropomum* and *Oreochromis niloticus* in Honduras, Central America. Aquaculture, 143:291–302.

Teichert-Coddington, D.R. and B.W. Green, 1993. Comparison of two techniques for determining community respiration in tropical fish ponds. Aquaculture, 114:41–50.

Teichert-Coddington, D.R. and B.W. Green, 1993. Influence of daylight and incubation interval on water column respiration in tropical fish ponds. Hydrobiologia, 250:159–165.

Teichert-Coddington, D.R. and B.W. Green, 1993. Tilapia yield improvement through maintenance of minimal oxygen concentrations in experimental grow-out ponds in Honduras. Aquaculture, 118:63–71.

Teichert-Coddington, D.R. and B.W. Green, 1993. Usefulness of inorganic nitrogen in organically fertilized tilapia production ponds. Abstracts of World Aquaculture Meeting at Torremolinos, Spain: European Aquaculture Society Special Publication No. 19, Oostende, Belgium, p. 273.

Teichert-Coddington, D.R. and B.W. Green, 1993. Yield improvement through maintenance of minimal oxygen concentration in tilapia growout ponds in Honduras. Aquaculture, 118:1–2.

Teichert-Coddington, D.R. and B.W. Green, 1997. Experimental and commercial culture of tilapia in Honduras. In: B.A. Costa-Pierce and J.E. Rakocy (Editors), Tilapia Aquaculture in the Americas, Vol. I. World Aquaculture Society, Baton Rouge, Louisiana, pp. 142–162.

Teichert-Coddington, D.R. and R. Rodriguez, 1994. Relationship of penaeid shrimp yields to diet protein level, stocking density and season: a field test on commercial farms of southern Honduras. Abstracts of World Aquaculture '94, New Orleans, Louisiana, World Aquaculture Society, Louisiana State University, Baton Rouge, LA.

Teichert-Coddington, D.R. and R. Rodriguez, 1995. Semi-intensive commercial growout of *Penaeus vannamei* fed diets containing differing levels of crude protein during wet and dry seasons in Honduras. Journal of the World Aquaculture Society, 26(1):72–79.

Teichert-Coddington, D.R., B.W. Green, and R.P. Parkman, 1991. Substitution of chicken litter for feed in production of penaeid shrimp in Honduras. The Progressive Fish-Culturist, 53(3):150–156.

Teichert-Coddington, D.R., B.W. Green, and R.P. Phelps, 1992. Influence of site and season on water quality and tilapia production in Panama and Honduras. Aquaculture, 105:297–314.

Teichert-Coddington, D.R., D. Martinez, and C.E. Boyd, 1997. Solubility of selected inorganic fertilizers in brackish water. Journal of the World Aquaculture Society, 28(2):205–210.

Teichert-Coddington, D.R., R. Rodriguez, and W. Toyofuku, 1994. Cause of cyclic variation in Honduran shrimp production. World Aquaculture, 25(1):57–61.

Teichert-Coddington, D.R., B.W. Green, N. Matamoros, and R. Rodriguez, 1990. The substitution of chicken litter for feed in the commercial production of penaeid shrimp in Honduras. Agronomia Mesoamericana, Vol. 1.

Teichert-Coddington, D.R., D. Martinez, E. Ramirez, J. Harvin, W. Toyofuku, R. Zelaya, and B.W. Green, 1997. Semi-intensive shrimp pond management and quality of effluents. In: D.E. Alston, B.W. Green, and H.C. Clifford (Editors), Asociación Nacional de Acuicultores de Honduras and the Latin American Chapter of the World Aquaculture Society. IV Symposium on aquaculture in Central America: focusing on shrimp and tilapia, 22–24 April 1997, at Tegucigalpa, Honduras, pp. 203–204.

Presentations

Alvarenga, H.R. and B.W. Green. Produccion y aspectos economicos del cultivo de tilapia en estanques fertilizados con gallinaza. (Production and economic aspects of tilapia culture in ponds fertilized with chicken litter). Presented by H. Alvarenga at the 34th Annual Meeting of the Programa Colaborativo Centro Americano para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Jose, Costa Rica, 1988.

Boyd, C.E. Shrimp farming and the environment. Presented to AAAS Annual Meeting at Philadelphia, Pennsylvania, 12–17 February 1998.

Boyd, C.E. and L. Massaut. Perspectives for sustainable aquaculture through use of better environmental management. IV Congresso Ecuatoriano de Acuicultura, Guayaquil, Ecuador, 1997.

Boyd, C.E. and J.F. Queiroz. Effluent management in pond aquaculture. III Symposium on Nutritional Strategies and Management of Aquaculture Wastes, Vila Real, Portugal, 1997.

Green, B.W. Substitution of organic manure for pelleted feed in tilapia production. Presented to the FAO-EIFAC Symposium on Production Enhancement in Still-Water Pond Culture at Prague, Czechoslovakia, May 1990.

Green, B.W. Mass production of *Oreochromis niloticus* and *Oreochromis aureus* fry in relation to water temperature. Presented to the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9–12 November 1997.

Green, B.W. and H.R. Alvarenga. Efecto de diferentes tasas de aplicacion de gallinaza en la produccion de tilapia. (The effect of different rates of chicken litter application on the production of tilapia.) Presented by H. Alvarenga to the 33rd Annual Meeting of the Programa Colaborativo Centro Americana para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at Instituto de Ciencia y Technologia Agricola, Guatemala, 30 March–4 April 1987.

Green, B.W. and H.R. Alvarenga. Intensive fingerling production of hybrid tilapia *Tilapia nilotica* × *Tilapia honorum* in earthen ponds. Presented by B. Green to the World Aquaculture Society Meeting at Guayaquil, Ecuador, 1987.

Green, B.W. and H. Alvarenga. Sistemas de produccion de tilapia utilizando fertilizacion organica y alimentacion. Presented by H. Alvarenga to the Annual Regional Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Pedro Sula, Honduras, 1989.

Green, B.W. and L. Lopez. Factabilidad de la produccion masiva de alevines machos de *Tilapia nilotica* atraves de la inversion hormonal de sexo en Honduras. Presented by L. Lopez to the

Annual Regional Meeting of the Programa Cooperativo Centroamericana para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Pedro Sula, Honduras, 1989.

Green, B.W., H.R. Alvarenga, and R.P. Phelps. The effect of stocking rate on the production of *Tilapia nilotica* in ponds. Presented by B. Green to the 34th Annual Meeting of the Programa Colaborativo Centro Americano para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Jose, Costa Rica, 1988.

Green, B.W., R.P. Phelps, and H.R. Alvarenga. The effect of nitrogen and phosphorous sources in fertilizers used for the production of *Tilapia nilotica*. Presented by B. Green to the World Aquaculture Society Meeting at Guayaquil, Ecuador, 1987.

Green, B.W., D.R. Teichert-Coddington, and L.A. Lopez. Production of *Oreochromis niloticus* fry in earthen ponds for hormonal sex inversion. Presented to the World Aquaculture Society Meeting at Orlando, Florida, May 1992.

Green, B.W., D.R. Teichert-Coddington, G.H. Ward, and C.E. Boyd. Collaborative research to support sustainable shrimp culture in Honduras: a model program. Presented to WAS '97 at Seattle, Washington, February 1997.

Martinez, D. and D.R. Teichert-Coddington. Solubility of inorganic fertilizers in brackish water. Presented to the Third Central American Shrimp Symposium at Tegucigalpa, Honduras, April 1995.

Milla, L., D.R. Teichert-Coddington, and D. Meyers. Biological demand of oxygen in shrimp farm water. Presented to the Third Central American Shrimp Symposium at Tegucigalpa, Honduras, April 1995.

Rodriguez, R. and D.R. Teichert-Coddington. Substitution of inorganic fertilization for feeding in the commercial production of *Penaeus vannamei* during the rainy and dry season in Honduras. Presented to the Third Central American Shrimp Symposium at Tegucigalpa, Honduras, April 1995.

Rodriguez, R., O.J. O'Hara, and D.R. Teichert-Coddington. Efecto de la tasa de fertilización inorgánica y calidad de agua sobre el crecimiento y economía en el cultivo semi-intensivo de camarón *Penaeus* spp. en Granja Marinas San Bernardo. Simposio Centroamericano Sobre Camarón Cultivado at Tegucigalpa, Honduras, April 1991.

Teichert-Coddington, D.R. Problemática detectada en la dinámica del Golfo de Fonseca Hondureño y su repercusión en el cultivo de camarones. Primera Gran Reunión Nacional Camaronera, Choluteca, Honduras, January 1994.

Teichert-Coddington, D.R. Water quality and its management in shrimp ponds. Presented to the Camarón '94 conference at Mazatlan, Mexico, February 1994.

Teichert-Coddington, D.R. Florecimiento de algas en el Rio Choluteca. Foro: La industria de la camaricultura buscando asegurar la viabilidad a largo plaza, Choluteca, Honduras, March 1994.

Teichert-Coddington, D.R. Relación entre calidad deagua de esteros y descarga de fincas camaroneras en el sur de Honduras. Encuentro Regional Sobre el Desarrolo Sostenido del Golfo de Fonseca y sus Cuencas at Choluteca, Honduras, May 1994.

Teichert-Coddington, D.R. Water quality in the shrimp farming estuaries and the "X" Syndrome: Are they related? Segundo Encuentro de Gerentes y Propietarios de la industria de la Camaronicultura (Second Conference of Managers and Owners in the Honduran Shrimp Culture Industry) at Choluteca, Honduras, January 1995.

Teichert-Coddington, D.R. Characterization of shrimp farm effluents in Honduras and chemical budget of selected nutrients. Presented to the Third Central American Shrimp Symposium at Tegucigalpa, Honduras, April 1995.

Teichert-Coddington, D.R. Pond management, estuarine water quality, and sustainable shrimp culture in Central America. Presented by Claude Boyd to the Sustainable Aquaculture '95 Conference at Honolulu, Hawaii, June 1995.

Teichert-Coddington, D.R. and B. Green. Influence of primary productivity, season and site on tilapia production in organically fertilized ponds in two Central American countries. Presented to the FAO-EIFAC Symposium on Production Enhancement in Still-Water Pond Culture at Prague, Czechoslovakia, May 1990.

Teichert-Coddington, D.R., B. Green, and M.I. Rodriguez. Efectos de la tasa de alimentacion sobre la producción de tilapia en estanques fertilizados con gallinaza. Presented by M.I. Rodriguez to the Annual Regional Meeting of the Programa Cooperativo Centroamericana para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Pedro Sula, Honduras, 1989.

Teichert-Coddington, D.R., R. Rodriguez, and W. Toyofuku. Causes of cyclical variation in Honduran shrimp production. Poster presented to the World Aquaculture Society Meeting at Torremolinos, Spain, 26–28 May 1993.

Teichert-Coddington, D., B. Green, N. Matamoros, and R. Rodriguez. Substitucion de alimento por gallinaza en la produccion comercial de camarones peneidos en Honduras. Presented by D. Teichert-Coddington at the Annual Regional Meeting of the Programa Cooperativo Centroamericana para el Mejoramiento de Cultivos Alimenticios (PCCMCA) at San Pedro Sula, Honduras, 1989.

Teichert-Coddington, D.R., W. Toyofuku, J. Harvin and R. Rodriguez. Stocking density effects on survival and production. Presented to the Third Central American Shrimp Symposium at Tegucigalpa, Honduras, April 1995.

Universidad Nacional Autónoma de Honduras

Theses

Echeverria, M.A., 1992. Primary production in *Tilapia nilotica* production ponds fertilized with triple superphosphate. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Garces, C., 1986. Quantitative analysis of zooplankton in fish ponds fertilized with triple superphosphate during the rainy season. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Gomez, R., 1988. Effect of fertilizer type on the production of male *Tilapia nilotica*. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Hernandez, Carlos, W.N., 1992. Respuesta de fitoplancton y zooplancton a fertilizante orgánico y alimento en estanques piscicolas. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Sherman, C., 1992. All female culture of *Tilapia nilotica* in ponds fertilized with chicken litter. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

University of Arkansas at Pine Bluff

Publication

Dasgupta, S. and C.R. Engle, 1999. Nonparametric estimation of the returns to the investment in shrimp research in Honduras. Aquaculture Economics and Management. (submitted)

University of Texas, Austin

Publication

Ward, G.H., B.W. Green, and D.R. Teichert-Coddington, 1999. Estimation of carrying capacity for shrimp aquaculture in the eastern estuaries of the Gulf of Fonseca. Proceedings of the Fifth Central American Symposium on Aquaculture at San Pedro Sula, Honduras. (in press)

Panama ~ Aguadulce

AUBURN UNIVERSITY

Thesis

Van Wyk, P., 1986. The relationship of pump discharge and fuel efficiency to tidal height for a brackish water aquaculture pumping station. M.S. thesis, Auburn University, Alabama.

Publication

Teichert-Coddington, D.R. and M. Arrue, 1988. Efectos de dietas de proteinas y densidades de siembra sobre la producción de *Penaeus vannamei* en estanques de terra. (Effects of protein diets and stocking density on production of *Penaeus vannamei* cultured in earth ponds.) Rev. Latinoamericana de Acuicultura, 35:29–33.

Presentations

Chavez, H. Estudio trofodinamico de *Penaeus vannamei* cultivado en estanques experimentales de aguas salobres. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

De Leon, A. El efecto de aplicar fertilizantes inorganicos en la produccion de *Penaeus vannamei* en estanques. Presented to the Second National Scientific Congress at University of Panama, Panama, November 1985.

Hughes, D.G. The marine shrimp culture industry in Panama. Presented to the First Annual Shrimp World Marketing Conference at Acapulco, Mexico, November 1984.

Hughes, D.G. Prediction of pond productivities: A challenge for aquaculture. Presented to the Pontifical Catholic University of Ecuador at Quito, Ecuador, November 1985.

Hughes, D.G. and O.M. Garcia A. La produccion de semilla de *Tilapia nilotica* en hapas: una comparacion de productividades de clima templada con clima tropical. Presented by David Hughes to First National Aquaculture Seminar at University Nacional, Heredia, Costa Rica, June 1984.

Hughes, D.G., A. Torres, and R.P. Phelps. Production and growth characteristics of *Penaeus stylirostris* and *P. vannamei* in monoculture and polyculture in fed and unfed earthen ponds. Presented by D. Hughes to the Annual Meeting of the World Mariculture Society at Orlando, Florida, January 1985.

Hughes, D.G., G. de Gomez, E. Lasso de la Vega, R.P. Phelps, and R. Pretto Malca. Rainy and dry season comparisons in *Penaeus vannamei* production ponds in Panama receiving various water exchange rates: Water quality variation. Poster session presented to World Aquaculture Society Meeting at Guayaquil, Ecuador, January 1987.

Kivers, A. Comparacion de dos rangos y dietas alimentacias con alevines de *Tilapia nilotica* en piletas de concreto. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

Kivers, A. Comparacion de tres densidades de seimbra de alevines de *Tilapia nilotica* en piletas de concreto. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

Lasso de la Vega, E. and M. Villareal. Variacion del zooplancton en estanques de cria de camarones blanco durante la estacion seca. Presented to the Second National Scientific Congress at University of Panama, Panama, November 1985.

Lore, D., H. Tunon, and R. Visuetti. Efecto de la aplicacion de abonos organicos, concentrados y pescado fresco (*Dormitator latifrons*) en la produccion de *Penaeus stylirostris* y *Penaeus vannamei*. Presented by H. Tunon to the First National Scientific Congress at University of Panama, Panama, December 1984.

Moreno, J.M. Alimentacion de la *Tilapia nilotica* en la etapa de alevinaje. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

Moreno, J.M. El uso del androgeno 17-metil-testosterona en alevinaje de *Tilapia nilotica* para la produccion de tilapia monosexuales en Panama. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

Pretto, R., G. Garson, V. Batista, and M. de Leon. Estudio preliminar del policultivo de peneidos con peces nativos de aguas salobres. Presented by R. Pretto to the Fifth Symposium of Latin American Aquaculture at Universidad Austral de Chile, Valdivia, Chile, September 1983.

Torres, A. Producción de *Penaeus stylirostris* bajo la influencia del *Penaeus vannamei*, en estanques experimentales de agua salobre con y sin alimentacion durante la epoca seca. Presented to the First National Scientific Congress at University of Panama, Panama, December 1984.

UNIVERSITY OF PANAMA

Theses

Abrego, R., 1985. Uso de androgenos en alevines de *Tilapia nilotica* para la produccion de tilapias monosexuales. B.S. thesis, University of Panama.

Chavez, H., 1984. Estudio trofodinamico de *Penaeus vannamei* cultivado en estanques experimentales de aguas salobres. B.S. thesis, University of Panama.

Hernandez de Santamaria, D., 1987. El efecto de dietas experimentales en el crecimiento y sobrevivencia de *Penaeus vannamei* cultivado en estanques. B.S. thesis, University of Panama.

Lasso de la Vega, E., 1985. Variacion del zooplancton en estanques de cria de camarones blanco durante la estacion seca. B.S. thesis, University of Panama.

Panama ~ Gualaca

AUBURN UNIVERSITY

Theses

Atencio, A., 1987. Phosphorus saturation of acidic soils in tropical fish culture ponds. Auburn University, Alabama.

Barrios, C.M., 1985. Analysis of water quality in new freshwater ponds at the Freshwater Aquaculture Station in Gualaca. Auburn University, Alabama.

Friele, M.E.F., 1985. Stomach analyses of *Macrobrachium rosenbergii*, *Tilapia nilotica*, *Colossoma macropomum* and the hybrid *Hypophthalmichthys molitrix* x *Aristichthys nobilis* in polyculture at the Gualaca Freshwater Aquaculture Experiment Station, Panama. Auburn University, Alabama.

Hughes, David G., 1988. Evaluation of seed production and sex-reversal methods for *Tilapia nilotica* and field verification in a tropical hatchery. Ph.D. dissertation, Auburn University, Alabama..

Perez, M.J., 1985. Economic and marketing study of fish and shrimp in polyculture systems in freshwater ponds at Gualaca, Chiriqui Province. Auburn University, Alabama.

Pimentel, C.A.B., 1984. Effect of liming on new unfertilized ponds at the Gualaca Aquaculture Experiment Station. Auburn University, Alabama.

Rios, R.A., 1986 Identification and dynamics of zooplankton found in tropical earthen ponds receiving chicken litter at four rates. Auburn University, Alabama.

Rodriguez, Ivonne., 1987. Feeding *Penaeus vannamei* and *Penaeus stylirostris* in nursery ponds. M.S. thesis, Auburn University, Alabama.

Serrano, A., 1987. Economics of tilapia production in monoculture or in polyculture with prawns, and utilizing manure or a commercial pellet as the nutrient input in Gualaca, Panama. Auburn University, Alabama.

Publications

Peralta, M. and D.R. Teichert-Coddington, 1989. Comparative production of *Colossoma macropomum* and *Tilapia nilotica* in Panama. Journal of the World Aquaculture Society, 20(4):236–239.
Teichert-Coddington, D.R. and R.P. Phelps, 1989. Effects of seepage on water quality and productivity of inorganically fertilized tropical ponds. Journal of Aquaculture in the Tropics, 4:85–92.
Teichert-Coddington, D.R., M. Peralta, and R.P. Phelps, 1989. Seepage reduction in tropical fish ponds using chicken litter. Aquacultural Engineering, 8:147–154.
Teichert-Coddington, D.R., N. Stone, and R.P. Phelps, 1988. Hydrology of fish culture ponds in Gualaca, Panama. Aquacultural Engineering, 7:309–320.

Presentation

Teichert-Coddington, D.R., D.B. Rouse, A. Khater, and R.O. Smitherman. Effects of two rates of organic fertilization and two levels of alkalinity on prawn production in a prawn-tilapia polyculture. Presented to the World Aquaculture Society Meeting at Guayaquil, Ecuador, January 1987.

Peru

Southern Illinois University at Carbondale

Publications

De Jesus, M.J. and C.C. Kohler, 1999. The commercial fishery of the Peruvian Amazon: Is it sustainable? Fisheries Magazine (American Fisheries Society). (submitted)
De Jesus, M.J., C.C. Kohler, and S.T. Kohler, 1998. Sustainable aquaculture in Peru. Aquaculture Magazine, 24(4):23–25.

Presentations

Alcántara, F., C. Kohler, S.T. Kohler, and M.J. DeJesus. Performance of *Piaractus brachypomus* and *Colossoma macropomum* stocked in ponds at different densities. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.
De Jesus, M.J., and C.C. Kohler. Analysis of the commercial fisheries in the Peruvian Amazon. Presented to the Illinois Renewable Natural Resources Conference, Springfield, Illinois, 4–6 March 1998.

Africa

Egypt

Auburn University

Publications

Green, B.W. and C.E. Boyd, 1995. Chemical budgets for organically fertilized fish ponds in the dry tropics. Journal of the World Aquaculture Society, 26(3):284–296.
Green, B. and C.E. Boyd, 1995. Water budgets for fish ponds in the dry tropics. Aquacult. Engineering 14:347–356.
Munsiri, P., C.E. Boyd, B.W. Green, and B.F. Hajek, 1996. Chemical and physical characteristics of bottom soil profiles in ponds on haplaquents in an arid climate at Abbassa, Egypt. Journal of Aquaculture in the Tropics, 11:319–326.

Presentations

Green, B. and C.E. Boyd. Chemical budgets for fish ponds in the dry tropics. Presented to the World Aquaculture Society Meeting at New Orleans, Louisiana, 1994.
Green, B. and C.E. Boyd. Water budgets for fish ponds in the dry tropics. Presented to the World Aquaculture Society Meeting at New Orleans, Louisiana, 1994.

Central Laboratory for Aquaculture Research, Abbassa, Egypt

Publications

Abdalla, A.A.F., C.D. McNabb, and T.R. Batterson, 1996. Ammonia dynamics in fertilized fish ponds stocked with Nile tilapia. The Progressive Fish-Culturist, 58:117–123.
Green, B., Z. Elnagdy, H. Hebida, and A.R. El Gamal, 1994. Pond management strategies for production of Nile tilapia in Egypt. NARP Harvest No. 2.

Presentations

Abdelghany, A. Optimum protein requirements for Nile tilapia. Presented to the Sixth International Symposium on Fish Nutrition and Feeding at Hobart, Tasmania, Australia, 1993.
Abdelghany, A. Optimum ratio of animal to plant protein in formulated diets for Nile tilapia. Presented to the Sixth International Symposium on Fish Nutrition and Feeding at Hobart, Tasmania, Australia, 1993.

Michigan State University

Publication

Abdalla, A.A.F. and C.D. McNabb, 1998. Acute and sublethal growth effects of un-ionized ammonia to Nile tilapia *Oreochromis niloticus*. In: D.Randall and D. MacKinlay (Editors), Nitrogen Production and Excretion in Fish. International Congress on the Biology of Fish, Symposium Proceedings, July 27–30, 1998. pp. 35–44.

Oregon State University

Thesis

Gale, W.L., 1996. Sexual differentiation and steroid-induced sex inversion in Nile tilapia (*Oreochromis niloticus*): 1. Characterization of a gonadal androgen receptor; 2. Masculinization by immersion in methyldihydrotestosterone. M.S. thesis, Oregon State University, Corvallis, Oregon.

Publications

Fitzpatrick, M.S., W.L. Gale, C.H. Slater, and C.B. Schreck, 1995. Gonadal androgen receptors in fishes. In: F.W. Goetz and P. Thomas (Editors), Proceedings of the Fifth International Symposium on Reproductive Physiology of Fish at Austin, Texas, p. 308.
Fitzpatrick, M.S., G. Feist, W.L. Gale, C.H. Slater, and C.B. Schreck, 1994. Gonadal sex differentiation in fishes. In: D.D. MacKinlay (Editor), High Performance Fish. Proceedings of an International Fish Physiology Symposium, Fish Physiology Association, Vancouver, B.C., pp. 146–149.
Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck, 1995. Immersion of Nile tilapia (*Oreochromis niloticus*) in 17α-methyltestosterone and mestanolone for the production of all-male populations. In: F.W. Goetz and P. Thomas (Editors), Proceedings of the Fifth International Symposium on Reproductive Physiology of Fish at Austin, Texas, p. 117.
Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck, 1996. Masculinization of Nile tilapia by short-term immersion in methyldihydrotestosterone. In: E.M. Donaldson and D.D. MacKinlay (Editors), Aquaculture Biotechnology Symposium. Proceedings of an International Fish Physiology Symposium. Cong. Biol. Fishes, Physiology Section, American Fisheries Society, Vancouver, B.C., p. 29.

Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck, 1998. Binding characteristics of a gonadal androgen receptor in Nile tilapia. Genetics and Comparative Endocrinology. (submitted)
Gale, W.L., M.S. Fitzpatrick, M. Lucero, W.M. Contreras-Sánchez, and C.B. Schreck, 1999. Masculinization of Nile tilapia by immersion in androgens. Aquaculture, 178:349–357.

Presentations

Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck. Binding sites for the masculinizing steroid mibolerone in the gonadal tissue of adult tilapia (*Oreochromis niloticus*). Presented to the Western Regional Conference on Comparative Endocrinology at San Diego, California, 1994.
Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck. Binding sites for the masculinizing steroid mibolerone in the gonadal tissue of adult tilapia (*Oreochromis niloticus*). Presented to the WAS Meeting at San Diego, California, 1–4 February 1995.
Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck. Binding characteristics of a gonadal androgen receptor in Nile tilapia (*Oreochromis niloticus*). Presented to the Western Regional Conference on Comparative Endocrinology at Berkeley, California, 1996.
Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck. Masculinization of Nile tilapia by short-term immersion in methyldihydrotestosterone. Presented to the International Congress on the Biology of Fishes at San Francisco, California, 1996.

Kenya

AUBURN UNIVERSITY

Presentation

Molnar, J., M. Lockhart, and J. Amadiva. Aquacultural development in central Kenya: Farming system, household, and community considerations. Poster presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

OTHER

Presentations

Bilal, P., K.M. Mavuti, J.G. Omondi, and K.L. Veverica. Plankton dynamics in tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) polyculture ponds in Central Kenya. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.
Gichuri, W.M., J.G. Omondi, K.L. Veverica. Relative condition factors (K_n) for *Oreochromis niloticus* (Cichlidae) and *Clarias gariepinus* (Clariidae) in small managed ponds. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.
Mwau, P.,N., K.M. Mavuti, P.I. Bilal, and K.L. Veverica. Nitrogen and phosphorus budgets in polyculture fish ponds. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.
Oenga, D., B. Wangila, M. Muchiri, and K.L. Veverica. The history of largemouth bass *Micropterus salmoides* introduction and transfers in East Africa. Presented to Shallow Water Bodies in the Tropics Conference at Naivasha, Kenya, 12–16 April 1999.

Rwanda

AUBURN UNIVERSITY

Theses

Hishamunda, N., 1993. The economic analysis of small-scale fish culture in Rwanda: a comparative study. M.S. thesis, Auburn University, Alabama.
Smith, E.S., 1996. Factors affecting sex reversal of tilapia: species characteristics and feed storage conditions. M.S. thesis, Auburn University, Alabama.

Publications

Hishamunda, N. and J.E. Moehl, 1989. Rwanda National Fish Culture Project. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 34, Auburn University, Alabama, 19 pp.
Moehl, J.F. and J.J. Molnar, 1996. Institutional requirements for aquacultural development in Africa: Lessons from Rwanda. In: C. Bailey, S. Jentoft, and P. Sinclair (Editors), Aquacultural Development: Social Dimensions of an Emerging Industry, Westview Press, Boulder, CO, USA/Oxford, United Kingdom, pp. 233–248.
Moehl, J.F., K.L. Veverica, B.J. Hanson, and N. Hishamunda, 1988. Development of appropriate pond management techniques for use by Rwandan farmers. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean, (Editors), The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15, Manila, Philippines, pp. 561–568.
Molnar, J.J., C.L. Cox, P. Nyirahabimana, and A. Rubagumya, 1994. Socioeconomic factors affecting the transfer and sustainability of aquacultural technology in Rwanda. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 38, Auburn University, Alabama, 16 pp.
Popma, T.J. and B.W. Green, 1990. Sex reversal of tilapia in earthen ponds. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 35, Auburn University, Alabama, 15 pp.
Verheust, L, K.L. Veverica, and E. Rurangwa, 1991. Comparative growth and mortality of *Oreochromis niloticus* and *Clarias gariepinus* fingerlings in earthen ponds (Rwanda). In: N. De Pauw and J. Joyce (Editors), Aquaculture and the Environment. EAS Special Publication No. 14 , pp. 318–319.
Veverica, K., 1997. The Pond Dynamics/Aquaculture CRSP-Sponsored Proceedings of the Third Conference on the Culture of Tilapias at High Elevations in Africa. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 42, Auburn University, Alabama, 26 pp.

Presentations

Hanson, B., V. Ndoreyaho, F. Rwangano, E. Rurangwa, M. Van Speybroeck, R. Tubb, and W. Seim. Relationship between water chemistry and the growth of *Tilapia nilotica* in Rwandan (Central Africa) fish ponds fertilized with chicken manure. Presented to the World Aquaculture Society Meeting at Honolulu, Hawaii, 4–8 January 1988.
Harwanimbaga, C., F. Rwangano, and B. Hanson. A descriptive study of plankton in Rwandan (Central Africa) fish ponds fertilized with chicken manure or triple superphosphate. Presented to the World Aquaculture Society Meeting at Honolulu, Hawaii, 4–8 January 1988.
Newman, J.R., T.J. Popma, and W.K. Seim. Effects of temperature on maximum feed consumption and growth of juvenile Nile tilapia. Poster presented to the World Aquaculture Society Meeting at Bangkok, Thailand, January 1996.
Veverica, K.L., N. Hishamunda, and P. Nyirahabimana. Aquaculture extension in Rwanda. Presented to the ALCOM Technical Consultation on Extension Methods for Small-holder Fish Farming in Southern Africa at Lilongwe, Malawi, 20–24 November 1995.
Veverica, K.L., W.K. Seim, T.J. Popma, and E. Rurangwa. Cut grass as fertilizer for tilapia ponds: composting methods, application rates and timing. Presented to the Pacific Conference on Marine Science and Technology (PACON) Symposium on Sustainable Aquaculture at Honolulu, Hawaii, 11–14 June 1995.

Veverica, K.L., W.K. Seim, T.J. Popma, and E. Rurangwa. Pond dynamics and tilapia production resulting from in-pond composting. Invited paper at the World Aquaculture Society Meeting at Bangkok, Thailand, January 1996.

NATIONAL UNIVERSITY OF RWANDA (UNR)

Theses

Bizimana, V., 1985. Essaies de triage mécanique de *Tilapia rendalli* Boulenger et *Tilapia macrochir* Boulenger en vue d'un élevage monosexe. (Mechanical grading to obtain mostly male fingerlings of *Tilapia rendalli* and *Tilapia macrochir*.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur, Université Nationale du Rwanda, Butare, Rwanda.

Gatera, A., 1990. Effet du taux d'empoissonnement et du mode de compostage sur la production des poissons en étang. (Effect of stocking rate and composting regime on production of fish in ponds.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Habineza, C., 1986. Analyse de l'effet de la fumure organique (fientes de poules) sur la croissance du *Tilapia nilotica* en étang. (The influence of chicken manure on the growth of *Tilapia nilotica* in ponds.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Hakziyaremye, E., 1984. Etude des effets de l'alimentation sur la croissance des tilapias: essaies en bacs sur *T. macrochir* et *T. rendalli*. Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Harwanimbaga, C., 1987. Etude préliminaire des populations planktoniques dans des étangs de Rwasave, Butare, Rwanda. (A preliminary study of the plankton populations in fish ponds at Rwasave, Butare, Rwanda.) Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Hatangimbabazi, J.D., 1989. Description des communautés planctoniques des différentes habitats de quelques étangs piscicoles de Rwasave (Butare). (Description of plankton communities in different habitats of fish ponds at Rwasave (Butare)). Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Hishamunda, N., 1984. Contribution a l'étude des effets de *Serranochromis macrocephala* Boulenger, sur la prolifération de *Tilapia macrochir* Boulenger, en etangs de pisciculture. (Effects of a predator fish, *Serranochromis macrocephala*, on the proliferation of *Tilapia macrochir* in fish culture ponds). Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Isangu, M.M., 1989. L'association porcs-poissons en station: étude de rentabilité financière. (Integrated pig-fish culture: an economic analysis.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Kakuze, A., 1989. Contribution à l'étude du régime alimentaire de *Tilapia nilotica* (L 1758) des étangs fertilisés de Rwasave (Butare). (A preliminary study of the feeding habits of *T. nilotica* in fertilized ponds at Rwasave, Butare.) Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Mbarererehe, F., 1992. Contribution à l'étude de l'influence de la température et de la durée de traitement sur la production des alevins monosexes du *Oreochromis niloticus*. (The influence of temperature and treatment duration on the production of all-male *O. niloticus* fry.) Mémoire présenté en vue de l'obtention du Diplôme d'Ingénieur Technicien A1, Institut Supérieur d'Agriculture et d'Elevage de Busogo, Ruhengeri, Rwanda.

Mukakarera, C., 1990. Etude hydrobiologique des ruisseaux Uwagatigita et Mbirurume de la fôret naturelle de Nyungwe. (An aquatic biology study of Uwagatigita and Mbirurume streams in the Nyungwe natural forest.) Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Munyangaju, A., 1990. Etude des lacs du Bugesera en vue de proposer l'effort de pêche optimale. (A study of the lakes in the Bugesera region in order to propose an optimal fishing effort.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Murangira, J., 1992. Contribution à l'étude de la productivité de quelques graminées fourragères vis à vis trois fréquences de coupe. (Comparative productivity of eight forage grasses at three cutting frequencies.) Rapport de stage, Ecole Agricole et Vétérinaire de Kabutare, Butare, Rwanda.

Murwanashyaka, J.N., 1989. Alimentation et parasitisme de *Clarias gariepinus* (Burchell, 1822) au Lac Ihema: impact de sa prédation sur l'évolution du stock en haplochromis. (Parisitism and feeding habits of *C. gariepinus* in Lake Ihema: impacts of its predation on haplochromis stocks.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Ndisebuye, A., 1986. Etude des conditions de reproduction de *Tilapia nilotica* en étangs de pisciculture. (A study of the conditions affecting the reproduction of *T. nilotica* in Rwandan fish ponds.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Ngarambe, O., 1986. Etude de l'influence de la fumure organique (fientes de poule) sur la dynamique des éléments fertilisants du sol de quelques étangs piscicoles de Rwasave. (The influence of chicken litter on soil and water fertility in several fish ponds at Rwasave.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Niyitegeka, D., 1990. Bilan d'azote dans les étangs piscicoles enrichis par les fertilisants de différents rapports C:N:P, Rwasave, Butare. (Nitrogen budgets in fish ponds enriched with fertilizers of different C:N:P ratios at Rwasave, Butare.) Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Nsengiyumva, D., 1985. Effet de l'alimentation sur la croissance de la carpe herbivore *Ctenopharyngodon idella* Valenciennes. (Growth of the grass carp, *Ctenopharyngodon idella* Valenciennes, in response to feeding.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Nsengiyumva, V., 1989. Production des alevins monosexes de *Tilapia nilotica* Linnaeus par la méthode du "sex-reversal." (Production of *T. nilotica* fingerlings by sex reversal methods.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Rutikanga, P., 1992. Contribution à l'étude des facteurs intervenant dans le taux d'infestation des *O. niloticus* par les Diplostomatidae (maladie des points noirs). (Factors affecting the infestation rate of *Oreochromis niloticus* by Diplostomatid cysts (black spot disease).) Rapport de stage, Ecole Agricole et Vétérinaire de Kabutare, Butare, Rwanda.

Rwalinda, P., 1990. Enrichissement du compost en azote et phosphore et ses effets sur la production du *Tilapia nilotica* (L.). (Enrichment of compost with nitrogen and phosphorus and its effects on the production of *Tilapia nilotica*, L.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Uwera, M., 1987. Une étude des modalités d'échantillonage des poissons en étangs piscicoles. (A comparative study of methods for sampling fish in ponds.) Mémoire présenté en vue de l'obtention du grade d'Ingénieur Agronome, Université Nationale du Rwanda, Butare, Rwanda.

Uzabakiriho, J.D., 1989. Etude hydrobiologique des lacs Rwanyakizinga, Mihindi, Hago et Kivumba (dépression de l'Akagera, Rwanda). (Hydrobiological study of Lakes Rwanyakizinga, Mihindi, Hago and Kivumba (Akagera river basin, Rwanda).) Mémoire présenté en vue de l'obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.

Publications

Hanson, B.J., J.F. Moehl, K.L. Veverica, F. Rwangano, and M. Van Speybroeck, 1988. Pond culture of tilapia in Rwanda, a high altitude equatorial African country. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean, (Editors), The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15, Manila, Philippines, pp. 553–559.

Karangwa, E., G.E. Mitchell, Jr., and R.E. Tucker, 1990. High-performance liquid chromatographic determination of 4-methyldiazole in sheep plasma and in ammoniated tall fescue hay. Journal of Chromatography, 532:105–133.

Karangwa, E., G.E. Mitchell, Jr., and R.E. Tucker, 1990. Pharmacokinetics of 4-methyldiazole in sheep. Journal of Animal Science, 68:3277–3284.

Presentations

Rurangwa, E. and L. Verheust. *Oreochromis niloticus* culture in Rwanda: Optimal density and feeding ration in earthen ponds. Poster presented to International Aquaculture Conference and Trade Show at Dublin, Ireland, June 1991.

Rurangwa, E. and L. Verheust. Fish culture in Rwanda: A high altitude, developing country in central Africa. Presented to the International Aquaculture Conference and Trade Show at Dublin, Ireland, June 1991.

OREGON STATE UNIVERSITY

Theses

Franco, L., 1991. Nile tilapia (*Oreochromis niloticus*) production in tropical microcosms fertilized with rabbit excreta. M.S. thesis, Oregon State University, Corvallis, Oregon.

Rwangano, F., 1990. Interactions of input types and water quality on the production of *Oreochromis niloticus* (L.) in Rwandan ponds. M.S. thesis, Oregon State University, Corvallis, Oregon.

Rwangano, F., 1998. Growth and reproduction of *Oreochromis niloticus* (L.) in tropical aquatic microcosms at fluctuating temperature regimes. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

Publications

Balakrishnan, R., K. Veverica, and P. Nyirahabimana, 1992. Proceedings of the colloquium on Rwanda women in aquaculture. Kigembe Station, Rwanda. Women in International Development, Oregon State University, Corvallis, Oregon, 11 pp.

Balakrishnan, R., K. Veverica, and P. Nyirahabimana, 1993. Rwanda women in aquaculture: context, contributions and constraints. Office of Women in International Development, Oregon State University, Corvallis, Oregon, 39 pp.

Balakrishnan, R., K. Veverica, P. Nyirahabimana, and R. Rainey, 1992. An approach to integrate gender variable in Rwanda Pond Dynamics and Aquaculture Collaborative Research Support Program. Women in International Development, Oregon State University, Corvallis, Oregon, 28 pp.

Bowman, J.R. and J.E. Lannan, 1995. Evaluation of soil pH-percent base saturation relationships for use in estimating the lime requirements of earthen aquaculture ponds. Journal of the World Aquaculture Society, 26(2):172–182.

Curtis, L.R., F.T. Diren, M.D. Hurley, W.K. Seim, and R.A. Tubb, 1991. Disposition and elimination of 17α-methyltestosterone in Nile tilapia (*Oreochromis niloticus*). Aquaculture, 99:192–201.

Sikoki, F.D., R.A. Tubb, and L.R. Curtis, 1986. Inhibition of hepatic UDP-glucuronyl transferase (UDP-GT) activity coincident with elevated plasma sex steroid concentrations during gonadal maturation in carp. In: R.S.V. Pullin and T. Bhukaswan (Editors), The Toxicologist, 6(1):553–559.

Sikoki, F.D., R.A. Tubb, and L.R. Curtis, 1988. Elevation of sex steroids and inhibition of UDP-glucuronyltransferase are out of phase during gonadal maturation in the common carp. Comparative Biochemistry and Physiology, 92(2):267–272.

Presentations

Balakrishnan, R. and P. Nyirahaimana. Rwanda women's role in integrated aquaculture systems for resource sustainability. Presented to the Farming Systems Research and Extension Symposium: working paper series at Michigan State University, East Lansing, Michigan, 1992.

Curtis, L., F. Diren, M. Hurley, and R. Tubb. Minimal residue levels after sex reversal of *Tilapia nilotica* by methyltestosterone but persistent alterations in hepatic detoxication systems. Presented to Federation of American Societies for Experimental Biology at Las Vegas, Nevada, April 1988.

Rwangano, F., M. Van Speybroeck, E. Rurangwa, K. Veverica, and B. Hanson. Fingerling production of *Tilapia nilotica* at the Rwasave Fish Culture Station of the National University of Rwanda. Presented to the World Aquaculture Society Meeting at Honolulu, Hawaii, 4–8 January 1988.

Seim, W. Using Eco-region classification to order pond management strategies. U.S. Forest Service Workshop on Warm Water Fish Management at Bend, Oregon, 1993.

Tubb, R. The reduction of estradiol by liver enzymes in carp and rainbow trout. Presented to Toxicology Meetings, New Orleans, March 1986.

UNIVERSITY OF ARKANSAS AT PINE BLUFF

Publications

Engle, C.R., 1997. Optimal resource allocation by fish farmers in Rwanda. Journal of Applied Aquaculture, 7(1):1–17.

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

Hishamunda, N., C.M. Jolly, and C.R. Engle, 1996. Estimating *Oreochromis niloticus* production function for small-scale fish culture in Rwanda. Journal of Aquaculture in the Tropics, 11:49–57.

Presentations

Engle, C., D. Brown, and N. Hishamunda. Economically optimum crop mix for subsistence fish farming in Rwanda. Pond Dynamics/Aquaculture CRSP Annual Meeting at San Diego, California, 1995.

Engle, C., D. Brown, and M. Thomas. Optimal resource allocation by fish farmers in Rwanda. Presented to the Tenth Biennial Research Symposium, Association of Research Directors at New Orleans, 1994.

SOUTHEAST ASIA

Indonesia

AGRICULTURAL UNIVERSITY OF BOGOR

Theses

Etnawati, N., 1987. The effect of *Oreochromis niloticus* Trewavas production by increasing surface area for attached microorganisms. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.

Gartini, T., 1986. Flow rate dependent changes in turbidity and phosphorus in the water conditioning system at Darmaga. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Harahat, I.S., 1987. Changes of nitrogen concentration of the Nile tilapia ponds which were fertilized with chicken manure. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Haryani, G.S., 1985. The growth rate, mortality and feeding habits of *Tilapia nilotica* (L.). B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Litasari, L., 1985. The composition and abundance of macrobenthos in relation to pond productivity. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Radiastuti, F., 1986. The balance of nitrogen from an irrigation canal that flows through a water conditioning system in Darmaga. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Subyakto, S., 1985. The relationship between chlorophyll *a* and Secchi disk visibility in tilapia fish ponds at Darmaga, Bogor. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Suratman, I.F., 1985. Composition and abundance of zooplankton in *Tilapia nilotica* (L.) fish ponds fertilized with triple superphosphate at Darmaga. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Tumbelaka, R., 1986. Primary productivity of aquaculture ponds at Darmaga. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Widjaja, 1985. Flushing rate of experimental *Tilapia nilotica* (L.) ponds at Darmaga and its relationship to some physical and chemical factors of the ponds. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Yulianti, S., 1986. Removal of detergents in irrigation canal water by the water conditioning system at Darmaga, Bogor. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.
Yulisto, 1985. Effect of fish predation on macrobenthos density in aquaculture ponds. B.S. thesis, Faculty of Fisheries, Agricultural University of Bogor, Indonesia.

MICHIGAN STATE UNIVERSITY

Theses

Abdalla, A.A.F., 1989. The effect of ammonia on *Oreochromis niloticus* (Nile tilapia) and its dynamics in fertilized tropical fish ponds. Ph.D. dissertation, Michigan State University, East Lansing, Michigan.
Yusoff, F., 1987. Fish production, primary productivity and nutrient availability in fertilized fish ponds in Malaysia. Ph.D. dissertation, Michigan State University, East Lansing, Michigan.

Publications

Knud-Hansen, C.F., T.R. Batterson, and I.S. Harahat, 1988. Nitrate and ammonia depletion in Indonesian aquaculture ponds fertilized with chicken manure [abstract]. Journal of the World Aquaculture Society, 19:42A.
Knud-Hansen, C.F., C.D. McNabb, and T.R. Batterson, 1991. Application of limnology for efficient nutrient utilization in tropical pond aquaculture. Proceedings of the International Association of Theoretical and Applied Limnology, 24:2541–2543.
Knud-Hansen, C.F., T.R. Batterson, C.D. McNabb, Y. Hadiroseyani, D. Dana, and H.M. Eidman, 1990. Hatchery techniques for egg and fry production of *Clarius batrachus* (Linnaeus). Aquaculture, 89:9–19.
Knud-Hansen, C.F., T.R. Batterson, C.D. McNabb, I.S. Harahat, K. Sumantadinata, and H.M. Eidman, 1991. Nitrogen input, primary productivity and fish yield in fertilized freshwater ponds in Indonesia. Aquaculture, 94:49–63.
McNabb, C.D., T.R. Batterson, H.M. Eidman, and K. Sumantadinata, 1988. Carbon limitation in fertilized fish ponds in Java [abstract]. Journal of the World Aquaculture Society, 19:51A.
McNabb, C.D., C.F. Knud-Hansen, T.R. Batterson, and K. Jaiyen, 1991. A systematic approach to maximizing nutrient efficient and growth of Nile tilapia (*Oreochromis niloticus*) under semi-intensive pond culture [abstract]. Journal of the World Aquaculture Society, 22:40A.
McNabb, C.D., K. Sumawidjaja, B.J. Premo, and K. Sumantadinata, 1984. Aquaculture-CRSP Indonesia project report, Cycle I, first 5-month experiment. Michigan State University, East Lansing, Michigan, 107 pp.
McNabb, C.D., T.R. Batterson, M. Eidman, C.S. Annett, and K. Sumantadinata, 1985. Aquaculture-CRSP Indonesia project report, Cycle II, first 5-month experiment (January-June 1985). Michigan State University, East Lansing, Michigan, 105 pp.
McNabb, C.D., T.R. Batterson, M. Eidman, B.J. Premo, and K. Sumantadinata, 1985. Aquaculture-CRSP Indonesia project report second five-month experiment. Michigan State University, East Lansing, Michigan, 71 pp.
McNabb, C.D., T.R. Batterson, B.J. Premo, C.F. Knud-Hansen, H.M. Eidman, C.K. Lin, K. Jaiyen, J.E. Hanson, and R. Chuenpagdee, 1990. Managing fertilizers for fish yield in tropical ponds in Asia. In: R. Hirano and I. Hanyu (Editors), Proceedings of The Second Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines, pp. 169–172.
Premo, B.J. and K. Sumantadinata, 1984. Laboratory manual of water quality techniques. Julia Press, Bogor, Indonesia, 43 pp.
Yusoff, F.M. and C.D. McNabb, 1989. Effects of nutrient availability on primary productivity and fish production in fertilized tropical ponds. Aquaculture, 78:303–319.

Presentations

Batterson, T.R. The problems of water quality for Indonesian fisheries. Presented to the Seminar series of the Bogor Chapter of the Indonesian Fisheries Society at Bogor, Indonesia, 20 November 1985.
Guttman, H. and C.F. Knud-Hansen. Fish pond management by algal assay. Presented to the World Aquaculture Society Meeting at Orlando, Florida, May 1992.
McNabb, C.D. Application of limnological technology to fish pond management. Presented to the National Institute of Biological Science at Bogor, Indonesia, December 1984.
McNabb, C.D. Limnology of fish ponds in Java. Presented as part of the Visiting Scientists Seminar Series to College of Fisheries and Marine Science, Agricultural University of Malaysia at Serdang, Malaysia, February 1986.
McNabb, C.D. Carbon limitation in fish culture ponds in Indonesia. Presented as part of the Visiting Scientists Seminar Series, at Lake Biwa Research Center, Shiga University, Otsu, Japan, March 1986.
McNabb, C.D., T.R. Batterson, B.J. Premo, and J.R. Craig. Photosynthetically active radiation in tropical and temperate zone habitats. Presented to the 88th Annual Meeting of the Michigan Academy of Science, Arts, and Letters at Grand Rapids, Michigan, March 1984.
Sumantadinata, K. Genetic characteristics of strains of Indonesian carps. Presented to Special Symposium of the Japanese Fisheries Society at Tokyo, Japan, February 1985.

Other

Batterson, T.R., 1985-1987. Indonesia PD/A CRSP data diskettes for Cycles I, II, and III using LOTUS 1-2-3.
Batterson, T.R. and C.D. McNabb, June–August 1986. MSU/CIFAD Visiting Scientist Program. Wardana Ismail, Head, Fisheries Research Facilities, Central Research Institute for Fisheries (CRIFI), Agency for Agricultural Research and Development (AARD), Department of Agriculture, Republic of Indonesia,

Jakarta. Eight-week program on water quality techniques, and laboratory equipment and design in support of freshwater aquaculture in Indonesia.
Kinnunen, R.E. and C.D. McNabb, March 1986. Collaborative aquaculture research: Institut Pertanian Bogor and Michigan State University. Improvement of pond culture technology and production. Broadcast: National Educational Television, Jakarta, Indonesia, 15 minutes.
Kinnunen, R.E. and C.D. McNabb, March 1986. Water treatment for small pond fisheries. Broadcast: National News Network, Television of the Republic of Indonesia (TVRI), Jakarta, Indonesia, 3 minutes.
Knud-Hansen, C.F., 23–29 November 1986. Workshop on water quality analyses for aquaculture ponds. Invited by Faculty of Fisheries, University of Brawijaya at Malang, East Java, Indonesia.
McNabb, C.D., March 1986. Fisheries in the tropics. World Food Day National Teleconference. Michigan State University. Response Panel, East Lansing, Michigan.
McNabb, C.D., H.M. Eidman, P. Suwignjo, D.L. Garling, K. Sumawidjaja, H.C. Lampe, S.M.H. Simandjuntak, R.E. Kinnunen, R.R. Nitibaskara, J. McAlister, T.R. Batterson, and C.F. Knud-Hansen, 1986. A research plan for Faculty of Fisheries, Institut Pertanian Bogor, Bogor, Indonesia. Michigan State University, East Lansing, Michigan. 30 pp. (Written in both English and Bahasa Indonesian.)
National Educational Television and Television of the Republic of Indonesia (TVRI), Jakarta, Indonesia, 1986. Collaborative aquaculture research: Institut Pertanian Bogor and Michigan State University. Improvement of pond culture technology and production. (Videotape, 33 minutes)

The Philippines

University of Hawaii

Publications and Reports

Carpenter, K.E., A.W. Fast, V.L. Corre, J.W. Woessner, and R.L. Janeo, 1986. The effects of water depth and circulation on the water quality and production of Penaeus monodon in earthen ponds. Proceedings of the First Asian Fisheries Forum at Manila, Philippines, 26–31 May 1986, pp. 21–24.
Chiu, Y., M.P. Macahilig, and M.A. Sastrillo, 1986. Preliminary studies of factors affecting the feeding rhythm of milkfish (*Chanos chanos* Forskal). Proceedings of the First Asian Fisheries Forum Meeting at Manila, Philippines, 26–31 May 1986, pp. 547–550.
Corre, V.L., K.E. Carpenter, E.J. Pudadera, and R.D. Fortes, 1986. The effects of feeds and fertilizer on the production of *Oreochromis niloticus* in brackish water ponds. (Unpublished paper.) University of Hawaii and University of the Philippines in the Visayas.
Fast, A.W., K.E. Carpenter, V.J. Estilo, and H.J. Gonzales, 1988. Effects of water depth and artificial mixing on dynamics of Philippines brackish water shrimp ponds. Aquacultural Engineering, 7:349–361.
Hopkins, K.D., 1988. Reporting fishpond yields to farmers. Aquabyte, 1(2):6.
Hopkins, K.D. and J.D. Bowman, 1993. A research methodology for integrated agriculture-aquaculture farming systems. In: Jaw-Kai Wang (Editor), Techniques for Modern Aquaculture. Proceedings of an Aquacultural Engineering Conference, 21–23 June 1993, at Spokane, Washington. American Society of Agricultural Engineers. St. Joseph, Michigan, pp. 89–98.
Hopkins, K.D. and D. Pauly, 1993. Instantaneous mortalities and multivariate models: applications to tilapia culture in saline water. In: M. Prein, G. Hulata and D. Pauly, (Editors), Multivariate methods in aquaculture research: case studies of tilapias in experimental and commercial systems. ICLARM, Manila, Philippines, pp. 105–111.
Szyper, J.P., 1996. Comparison of three mixing devices in earthen culture ponds of four different surface areas. Aquacultural Engineering, 15(5):381–396.
Szyper, J.P., 1996. Observations and model predictions of daily areal primary production in a eutrophic brackish water culture pond. Ecological Modelling International Journal on Ecological Modelling and Systems Ecology, 88:83–92.
Young, M.J.A., A.W. Fast, and P. Olin, 1989. Induced maturation and spawning of the Chinese catfish (*Clarias fuscus*). Journal of the World Aquaculture Society, 20(1):7–11.

Presentation

Fast, A.W., K.E. Carpenter, F.J. Estilo, and H.J. Gonzales. Effects of water depth on dynamics of Philippines brackish water shrimp ponds. Presented to the World Aquaculture Society Meeting at Guayaquil, Ecuador, January 1987.

University of The Philippines in the Visayas

Thesis

Pahila, I.G., 1986. Sorbed and soil solution phosphorus in relation to the optimum phosphorus level of lab-lab in some brackish water ponds. M.S. thesis, Dept. of Fisheries, University of the Philippines, Visayas, Philippines.

Publications

Fortes, R.D., V.L. Corre, Jr., and E. Pudadera, 1986. Effects of fertilizers and feeds as nutrient sources on *Oreochromis niloticus* production in Philippine brackish water ponds. Proceedings of the First Asian Fisheries Forum at Manila, Philippines, May 1986, pp. 121–124.
Minsalan, C.L.O. and Y.N. Chiu, 1986. Effects of teaseed cake on selective elimination of finfish in shrimp ponds. Proceedings of the First Asian Fisheries Forum at Manila, Philippines, May 1986, pp. 79–82.
Sanares, R.C., S.A. Katase, A.W. Fast, and K.E. Carpenter, 1986. Water quality dynamics in brackish water shrimp ponds with artificial aeration and circulation. Proceedings of the First Asian Fisheries Forum at Manila, Philippines, May 1986, pp. 83–86.
Ver, L.M.B. and Y.N. Chiu, 1986. The effect of paddlewheel aerators on ammonia and carbon dioxide removal in intensive pond culture. Proceedings of the First Asian Fisheries Forum, Manila, Philippines, 26–31 May 1986, pp. 97–100.

Thailand

Asian Institute of Technology

Theses

Ahmed, S., 1995. Assessment of chlorine as a piscicide in freshwater fish culture. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Amechi, E.O., 1995. An assessment of by-catch biomass in experimental fish ponds. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Arifin, Z., 1996. Efficacy of liming and uses of liming materials for shrimp pond management. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Baouthong, P., 1995. The effect of feeding regime on growth and body composition of shrimp (*Penaeus monodon*). M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Barte, M., 1996. Effect of aeration on water quality and fish growth in intensive culture of Nile tilapia. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Boonsong, S. Role of zooplankton in feeding juvenile tilapia (*Oreochromis niloticus*). M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.

Chan, R., 1997. Interactive effect of feeding frequency and time of feeding for tilapia. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.
Chughtai, M.A., 1995. Effects of water spinach (*Ipomoea aquatic*) on nutrient regime and fish growth. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Guttman, H., 1990. Assessment of nutrient limitation in fertilized fish ponds by algal assay. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Jatuporn, B., 1997. Effect of aeration on water quality and fish production in fertilized ponds. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.
Jiwyam, W., 1990. The role of sediments in pond fertility. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Md, R.I., 1995. A field survey of the factors involved in the use of ponds for fish culture in Bangladesh, with emphasis on water quality. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Muthuwam, V., 1991. Nutrient budget and water quality in intensive marine shrimp culture ponds. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Narong, V. Effects of phytoplankton on nursing walking catfish fry in static and flow-through water systems. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Nguyen, P.H., 1996. Effects of salinity on fertilization for tilapia culture. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Pautong, A.K., 1991. Role of urea in fertilizing fish ponds. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Qifeng, Y., 1991. Nutrient budget and water quality in integrated walking catfish-tilapia culture. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Rachada, M., 1997. Turbidity in fish ponds in northeast Thailand. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.
Raghunath, B. Shivappa., 1997. Efficacy of probiotics and disinfectant in controlling luminescent bacteria in shrimp postlarvae under normal and stressed conditions. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.
Rai, S., 1997. Co-culture of walking catfish with Indian major carps. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.
Rao, T.V.G., 1989. Gonadal development in environmentally induced breeding of walking catfish *Clarias batrachus* (Linnaeus). M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Rungruengwudhikrai, E.-O., 1995. Characterization and classification of off-flavour of Nile tilapia. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Ruttanagosrigit, W., 1997. Organic matter dynamics in a closed intensive culture system for black tiger prawn (*Penaeus monodon*). Ph.D. dissertation, Asian Institute of Technology, Bangkok, Thailand.
Shrestha, M.K., 1989. Impact of attached microorganism biomass on tilapia (*Oreochromis niloticus*) production. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Suresh, A.V. Influence of stocking density on red tilapia production in a recirculation system. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Thakur, D.P., 1996. Water quality and nutrient budget in closed intensive shrimp culture systems. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Ullah, Md. A., 1989. Nutrient release characteristics of duck manure for Nile tilapia production. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Ungsethaphan, T., 1995. An on-farm trial to investigate feeding strategies for Nile tilapia (*Oreochromis niloticus*) broodfish. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Vuthana, H., 1995. Fish pond turbidity in Cambodia. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Xie, J.J., 1995. Alternative methods for maggot production. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.
Yi, Y., 1997. An integrated rotation culture system for fattening large Nile tilapia (*Oreochromis niloticus*) in cages and nursing small Nile tilapia in open ponds. Ph.D. dissertation, Asian Institute of Technology, Bangkok, Thailand.

Publications

Cao, T.B., C.K. Lin, and H. Demaine, 1999. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: I. Selection of supplemental diets. Journal of Asian Fisheries Science. (in revision)
Cao, T.B., C.K. Lin, and H. Demaine, 1999. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: II. Supplemental feeding rates in fertilized ponds. Journal of Asian Fisheries Science. (in revision)
Edwards, P., C.K. Lin, and A. Yakupitiyage, 1999. Semi-intensive pond aquaculture. In: M. Beveridge and B. McAndrew (Editors), Tilapia Culture and Exploitation. Chapman and Hall, London. (in press)
Yi, Y., 1999. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Aquacultural Engineering. (in press)

Presentations

Yi, Y. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Presented to Aquaculture '98, WAS Annual Meeting in Las Vegas, Nevada, 15–19 February 1998.
Yi, Y. and C.K. Lin. An integrated rotation culture system for fattening large Nile tilapia in cages and nursing small Nile tilapia in open ponds. Presented to WAS '97 at Seattle, Washington, February 1997.

AUBURN UNIVERSITY

Publications

Boyd, C.E. and P. Munsiri, 1996. Phosphorus adsorption capacity and availability of added phosphorus in soils from aquaculture areas in Thailand. Journal of the World Aquaculture Society, 27(2):160–167.
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(2):165–170.

Presentation

Boyd, C.E. Water quality in laboratory soil-water microcosms with soils from different areas of Thailand. Presented to WAS '97 at Seattle, Washington, February 1997.

MICHIGAN STATE UNIVERSITY

Publications

Knud-Hansen, C.F., 1992. Analyzing standard curves in the chemistry of waters used for aquaculture. NAGA, 15:16–19.
Knud-Hansen, C.F., 1992. Pond history as a source of error in fish culture experiments: a quantitative assessment using covariate analysis. Aquaculture, 105:21–36.
Knud-Hansen, C.F. and A.K. Pautong, 1993. On the role of urea in pond fertilization. Aquaculture, 114:273–283.
Knud-Hansen, C.F. and T.R. Batterson, 1994. Effect of fertilization frequency on the production of Nile tilapia (*Oreochromis niloticus*). Aquaculture, 123:271–280.
Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb, 1993. The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture and Fisheries Management, 24:483–493.
Knud-Hansen, K.D. Hopkins, and H. Guttman, 1999. A comparative analysis of the fixed-input, computer modeling, and algal bioassay approaches for identifying pond fertilization requirements. Aquaculture. (in press)

McNabb, C.D., T.R. Batterson, C.K. Lin, K. Jaiyen, J.E. Hanson, and R. Chuenpagdee, 1989. Fish yield with nitrogen supplemented organic fertilizers. World Aquaculture Society, 20:56A.
Shevgoor, L., C.F. Knud-Hansen, and P.E. Edwards, 1994. An assessment of the role of buffalo manure for pond culture of tilapia, part 3: Limiting factors. Aquaculture, 126:107–118.
Shrestha, M.K. and C.F. Knud-Hansen, 1994. Increasing attached microorganism biomass as a management strategy for Nile tilapia (*Oreochromis niloticus*) production. Aquacultural Engineering, 13:101–108.

Presentations

Knud-Hansen, C.F. and C.K. Lin. Strategies for stocking Nile tilapia (*Oreochromis niloticus*) in fertilized ponds. Presented to the Third International Symposium on Tilapia in Aquaculture at Abidjan, Côte d'Ivoire, Africa, November 1991.
Knud-Hansen, C.F. and A.K. Pautong. The role of urea in fishpond fertilization. Presented to the World Aquaculture Society Meeting at Orlando, Florida, May 1992.

Other

Knud-Hansen, C.F. and T.R Batterson, 1987-1992. Thailand PD/A CRSP data diskettes for Work Plans IV, V, and VI experiments using LOTUS 1-2-3.

UNIVERSITY OF HAWAII

Publications

Hopkins, K.D., 1992. Reporting fish growth: a review of the basics. Journal of World Aquaculture Society, 23(3):173–179.
Hopkins, K.D. and A. Yakupitiyage, 1991. Bias in seine sampling of tilapia. Journal of the World Aquaculture Society, 22(4):260–262.
Hopkins, K.D., M.L. Hopkins, and D. Pauly, 1988. A multivariate model of tilapia growth, applied to seawater tilapia culture in Kuwait. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean (Editors),The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15, Manila, Philippines, pp. 29–39.
Szyper, J.P. and J.M. Ebeling, 1993. Photosynthesis and community respiration at three depths during a period of stable phytoplankton stock in a eutrophic brackish water culture pond. Marine Ecology Progress Series, 94:229–238.
Szyper, J. and K.D. Hopkins, 1996. Effects of pond depth and mechanical mixing on production of *Oreochromis niloticus* in manured earthen ponds. In: R.S.V. Pullin, J. Lazard, M. Legendre, and J.B. Amon Kothias (Editors), The Third International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 41, Manila, Philippines., pp. 152–159.
Szyper, J.P. and C.K. Lin, 1990. Techniques for assessment of stratification and effects of mechanical mixing in tropical fish ponds. Aquacultural Engineering, 9:151–165.
Szyper, J.P., K. Hopkins, and C.K. Lin, 1991. Production of *Oreochromis niloticus* (L.) and ecosystem dynamics in manured ponds of three depths. Aquaculture and Fisheries Management, 22:385–396.
Szyper, J.P., J.Z. Rosenfeld, R.H. Piedrahita, and P. Giovannini, 1992. Diel cycles of planktonic respiration rates in briefly incubated water samples from a fertile earthen pond. Limnology and Oceanography, 37:1193–1201.
Szyper, J.P., C.K. Lin, D. Little, S. Setboonsarng, A. Yakupitiyage, P. Edwards, and H. Demaine, 1995. Techniques for efficient and sustainable mass production of tilapia in Thailand. Proceedings, Sustainable Aquaculture 95. Pacific Congress on Marine Science and Technology, pp. 349–356.

Presentations

Emberson, C. and K. Hopkins. Intensive culture of *Penaeus stylirostris* in plastic-lined tanks. Poster presented to the World Aquaculture Society Meeting at San Diego, California, 1–4 February 1995.
Lin, C.K. and J. Szyper. Stratification of temperature and dissolved oxygen in tropical fish ponds. Presented to the World Aquaculture Society Meeting at Halifax, Canada, June 1990.

UNIVERSITY OF MICHIGAN

Theses

Tain, F.H., 1999. Impacts of aquaculture extension on small-scale *Oreochromis niloticus* production in northeastern Thailand. M.S. thesis, The University of Michigan, Ann Arbor, Michigan.
Wirat, J., 1996. Nutritional input of nitrogen in fish ponds through fixation by blue-green algae. Ph.D. dissertation, Asian Institute of Technology, Bangkok, Thailand.
Zaenal A., 1996. Efficacy of liming and uses of lime for shrimp pond management. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.

Publications

Buurma, B.J. and J.S. Diana, 1994. The effects of feeding frequency and handling on growth and mortality of cultured walking catfish, *Clarias fuscus*. Journal of the World Aquaculture Society, 25:175–182.
Cao, T.B. and C.K. Lin, 1995. Shrimp culture in Vietnam. World Aquaculture, 26:27–33.
Diana, J.S., 1993. Conservation and utilization of genetic resources in capture and culture fisheries. In: C.S. Potter, J.I. Cohen, and D. Janczewski (Editors), Perspectives on Biodiversity: Case Studies of Genetic Resource Conservation and Development. American Association for the Advancement of Science, Washington, D.C., pp. 89–104.
Diana, J.S., 1995. Biology and Ecology of Fishes. Biological Sciences Press, Carmel, Indiana, 441 pp.
Diana, J.S. and A. Fast, 1989. The effects of water exchange rate and density on yield of the walking catfish, *Clarias fuscus*. Aquaculture, 78:267–276.
Diana, J.S. and C.K. Lin, 1998. The effects of fertilization on growth and production of Nile tilapia in rain-fed ponds. Journal of the World Aquaculture Society, 29:405–413.
Diana, J.S. and D. Ottey, 1983. Biological principles of pond culture: Fish. In: J.E. Lannan, R.O. Smitherman, and G. Tchobanoglous (Editors), Principles and Practices of Pond Aquaculture: A State of the Art Review. Oregon State University Press, Corvallis, Oregon, pp. 55–66.
Diana, J.S., D.J. Dettweiler, and C.K. Lin, 1991. Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. Canadian Journal of Fisheries and Aquatic Sciences, 48(2):183–190.
Diana, J.S., S.L. Kohler, and D.R. Ottey, 1988. A yield model for walking catfish production in aquaculture systems. Aquaculture, 71:23–35.
Diana, J.S., C.K. Lin, and K. Jaiyen, 1994. Supplemental feeding of tilapia in fertilized ponds. Journal of the World Aquaculture Society, 25:497–506.
Diana, J.S., C.K. Lin, and P.J. Schneeberger, 1991. Relationships among nutrient inputs, water nutrient concentrations, primary production, and yield of *Oreochromis niloticus* in ponds. Aquaculture, 92:323–341.
Diana, J.S., C.K. Lin, and Y. Yi, 1996. Timing of supplemental feeding for tilapia production. Journal of the World Aquaculture Society, 27:410–419.
Diana, J.S., P.J. Schneeberger, and C.K. Lin, 1988. Relationships between primary production and yield of tilapia in ponds. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean (Editors), The Second International Symposium on Tilapia in

Aquaculture. ICLARM Conference Proceedings 15, Manila, Philippines, pp. 1–6.
Lin, C.K., 1983. Biological principles of pond culture: Phytoplankton and macrophytes. In: J.E. Lannan, R.O. Smitherman, and G. Tchobanoglous (Editors), Principles and Practices of Pond Aquaculture: A State of the Art Review. Oregon State University Press, Corvallis, Oregon, pp. 39–43.
Lin, C.K., 1986. Acidification and reclamation of acid sulfate soil fishponds in Thailand. In: J.L. MacLean, L.B. Dizon, and L.V. Hosillos (Editors), The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines, pp. 71–74.
Lin, C.K., 1986. Nutrient dynamics between inorganic and organic fertilization in tilapia culture ponds. Proceedings of the 24th Kasetsart University Conference on Fisheries, pp. 174–182.
Lin, C.K., 1989. Occurrence of mass mortality of black tiger prawns in Taiwan. Thai Fisheries Gazette, 42:209–216.
Lin, C.K., 1989. Prawn culture in Taiwan: What went wrong? World Aquaculture, 20:19–20.
Lin, C.K., 1990. Integrated culture of walking catfish (*Clarias macrocephalus*) and tilapia (*Oreochromis niloticus*) in earthen ponds. In: R. Hirano and I. Hanyu (Editors), Proceedings of The Second Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines, pp. 209–212.
Lin, C.K. and M. Boonyaratpalin, 1988. An analysis of biological characteristics of *Macrobrachium rosenbergii* in relation to pond production and marketing in Thailand. Aquaculture, 74:205–215.
Lin, C.K. and J.S. Diana, 1995. Co-culture of catfish (*Clarias macrocephalus* × *C. gariepinus*) and tilapia (*Oreochromis niloticus*) in ponds. Aquatic Living Resources, 8:449–454.
Lin, C.K., K. Jaiyen, and W. Muthuwana, 1990. Integrated culture of intensive and semi-intensive aquaculture: Concept and example. Thai Fisheries Gazette, 43:425–430.
Lin, C.K., V. Tansakul, and C. Apinhapath, 1988. Biological nitrogen fixation as a source of nitrogen input in fishponds. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean (Editors). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15, Manila, Philippines, pp. 53–58.
Liu, K.M. and W.Y.B. Chang, 1992. Bioenergetic modelling of effects of fertilization, stocking density, and spawning on growth of the Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture and Fisheries Management, 23:291–301.
Muthuwana, W., V. Tansakul, and C.K. Lin, 1986. Nutrient dynamics between inorganic and organic fertilized ponds for tilapia culture. Proceedings of the Kasetsart University Agricultural Conference, January 1985.
Nash, G., S. Chinabut, and C. Limsuwan, 1987. Idiopathic muscle necrosis in the freshwater prawn, *Macrobrachium rosenbergii* (de Man), cultured in Thailand. Journal of Fish Diseases, 10:109–120.
Nguyen, M.N. and C.K. Lin, 1996. *Penaeus monodon* seed production in central Vietnam. World Aquaculture, 27:6–18.
Shrestha, M.K. and C.K. Lin, 1996. Phosphorus fertilization strategy in fish ponds based on sediment phosphorus saturation level. Aquaculture, 142:207–219.
Shrestha, M. and C.K. Lin, 1999. Recycling of pond mud nutrients to cowpea and taro crops. Nutrient Cycling in Agri-Ecosystems. (submitted)
Suresh, A.V. and C.K. Lin, 1992. Effect of stocking density on water quality and production of red tilapia in a recirculated water system. Aquaculture Engineering, 11:1–22.
Suresh, A.V. and C.K. Lin, 1992. Tilapia culture in saline waters: A review. Aquaculture, 106:201–226.
Szyper, J.P. and C.K. Lin, 1990. Techniques for assessment of stratification and effects of mechanical mixing in tropical fish ponds. Aquaculture Engineering, 9:151–165.
Tavarutmaneegul, P. and C.K. Lin, 1988. Breeding and rearing of sand goby (*Oxyeleotris marmoratus*, Blk.) fry. Aquaculture, 69:299–305.
Yi, Y., 1998. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Aquacultural Engineering, 18:157–173.
Yi, Y. and C.K. Lin, 1999. Analyses for various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): Profitability and possible environmental impacts. Aquaculture Economics and Management. (in press)
Yi, Y. and C.K. Lin, 1999. Comparative economic analyses for various grow-out strategies of Nile tilapia (*Oreochromis niloticus*) in earthen ponds. Aquaculture Economics and Management. (accepted for publication)
Yi, Y., C.K. Lin, and J.S. Diana, 1996. Influence of Nile tilapia (*Oreochromis niloticus*) stocking density in cages on their growth and yield in cages and in ponds containing the cages. Aquaculture, 146:205–215.

Presentations

Alimuzaman, C. and C.K. Lin. Aeration effects on erosion and water circulation in round and rectangular ponds. Presented to the World Aquaculture Society meeting at Bangkok, Thailand, February 1996.
Diana, J.S. and C.K. Lin. Effects of fertilization rate on primary production and yield of tilapia in ponds. Presented to the World Aquaculture Society Meeting at Honolulu, Hawaii, January 1988.
Diana, J.S. and C.K. Lin. Supplemental feeding for production of Nile tilapia *Oreochromis niloticus*. Presented to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.
Diana, J.S., C.K. Lin, and D. Dettweiler. Cascading trophic interactions: a test of the hypothesis using tilapia culture data. Presented to the World Aquaculture Society Meeting at Los Angeles, California, February 1989.
Diana, J.S., D. Clapp, P. Hudson, and G. Regal. Movements of brown trout in the AuSable River, Michigan. Presented to the American Fisheries Society meeting at Dearborn, Michigan, August 1996.
Kaewprakaisaengkul, C., C.K. Lin, and Y. Yi. Construction and application of hapa washer. Poster.presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Lin, C.K. and S. Auworatham. Effects of inorganic and organic fertilizers on zooplankton production in tilapia ponds. Presented to the 25th Kasetsart University Conference at Bangkok, Thailand, 1987.
Lin, C.K. and J.S. Diana. Fertilization effects on pond carrying capacity in extensive culture of tilapia (*Oreochromis niloticus*). Presented to the Second International Symposium on Tilapia in Aquaculture at Bangkok, Thailand, 1987.
Lin, C.K. and S. Kaewchum. Application of bioremediation in intensive culture of black tiger shrimp (*Penaeus monodon*). Presented to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.
Lin, C.K. and J. Szyper. Stratification of temperature and dissolved oxygen in tropical fish ponds. Presented to the World Aquaculture Meeting at Halifax, June 1990.
Lin, C.K., and Y. Yi. Comparative economic analyses for different grow-out strategies of Nile tilapia in earthen ponds. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Lin, C.K., S. Auworatham, and V. Tansakul. Dietary consumption of zooplankton by tilapia in fertilized ponds. Presented to the Thai Fisheries Academy Seminar, 1986.
Lin, C.K., M. Boonyaratpalin, and Y. Musig. Biological characteristics of *Macrobrachium rosenbergii* (de Man) in relation to pond production and marketing. Presented to the First Asian Fisheries Society Forum at Manila, Philippines, May 1986.
Lin, C.K., E. Sae-Loaw, and V. Tansakul. Rearing post-larvae of *Macrobrachium rosenbergii* at high stocking density in concrete tanks. Presented to the 25th Kasetsart University Conference at Bangkok, Thailand, 1987.
Lin C.K., Y. Yi, and J.S. Diana. Effects of management strategy on nutrient budgets in Nile tilapia (*Oreochromis niloticus*) ponds. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Lin C.K., M.K. Shrestha, J.S. Diana, and D.P. Thakur. Management to minimize the environmental impacts of pond draining: Harvest

draining technique and effluent quality, Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Lin, C.K., V. Tansakul, W. Muthuwana, and S. Auworatham. Production and utilization of organic carbon in tilapia culture and ponds. Presented to the Thai Fisheries Academy Seminar, 1986.
Lin, C.K., W. Muthuwana, V. Tansakul, S. Auworatham, and C. Apinapat. Nutrient dynamics between inorganic and organic fertilized ponds for tilapia culture. Presented to the Thai Fisheries Academy Seminar, 1986.
Musig, Y., M. Boonyaratpalin, and C.K. Lin. Water quality in *Macrobrachium* growout ponds. Presented to the 25th Kasetsart University Conference at Bangkok, Thailand, 1987.
Muthuwana, W. and C.K. Lin. Water quality and nutrient budget in intensive shrimp culture ponds. Presented to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.
Pant J., P. Promthong, C.K. Lin, and H. Demaine. Fertilization of ponds with inorganic fertilizers: Low cost technologies for small-scale farmers. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Tansakul, V., T. Sae-Lee, and E. Sae-Loaw. Acute toxicity and treatment effect of formalin on early larval prawns, *Macrobrachium rosenbergii* (de Man). Presented to the 25th Kasetsart University Conference at Bangkok, Thailand, 1987.
Yi, Y. An integrated cage culture system in earthen ponds: A bioenergetics growth model for Nile tilapia. Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Yi, Y. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Yi, Y. and C.K. Lin. An integrated cage culture system in earthen ponds: Stocking densities of caged Nile tilapia (*Oreochromis niloticus*). Presented to the Fourth Asian Fisheries Forum at Beijing, China, October 1995.
Yi, Y. and C.K. Lin. An integrated cage culture system in earthen ponds: Biomass of caged Nile tilapia (*Oreochromis niloticus*). Presented to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.
Yi, Y., C.K. Lin and J.S. Diana. Management of organic matter and nutrient regeneration in pond bottoms. Presented to the World Aquaculture Society Meeting at Sydney, Australia, 26 April–2 May 1999.
Yi, Y., C.K., Lin, J.S. Diana, R.B. Shivappa, and M.A.K. Chowdhury. Management of organic matter and nutrient regeneration in pond bottoms. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Other

Lin, C.K., 1989. Intensive pond culture of freshwater prawns and marine shrimps in Thailand. Seminar at Auburn University, Alabama, 23 May 1989.
Lin, C.K., 1989. Overview of current aquaculture in the Orient and the USA. Seminar at United States Agency for International Development, Bangkok, Thailand, 28 July 1989.
Lin, C.K., 1989. The problems of marine shrimp culture in Taiwan. Seminar at Royal Thai Government Department of Fisheries and Shrimp Farmers Association. Bangkok, Thailand, July 1989.
Lin, C.K., 1989. Aquaculture in Thailand and AITs Program. Seminar at Citizens Ambassadors, Bangkok, Thailand, August 1989.
Lin, C.K., 1990. Current status of freshwater prawn and marine shrimp culture in Thailand. Seminar at Great Lakes Fisheries Research Laboratory, Ann Arbor, Michigan.
Lin, C.K., 1990. Effects of intensive shrimp culture on coastal environment in upper Gulf of Thailand. Seminar at Royal Thai Government Department of Fisheries and Shrimp Farmers Associations, 15–16 February 1990.
Yi, Y. Cage culture in ponds. Seminar presented to the Sichuan Provincial Fisheries Association, Sichuan, China, 9–20 June 1999.

Global Activities

AUBURN UNIVERSITY

Theses

Gross, A., 1999. Nitrogen cycling in aquaculture ponds. Ph.D. dissertation, Auburn University, Alabama.
Massaut, L., 1998. Planktonic trophic interactions in catfish and sportfish ponds in the presence of an omnivorous filter-feeding fish. Ph.D. dissertation, Auburn University, Alabama.
Sonnenholzner, S., 1999. Chemical and physical properties of shrimp pond sediment in Ecuador and some management strategies for pond preparation. Ph.D. dissertation, Auburn University, Alabama.

Publications

Boyd, C.E., 1998. Water quality for pond aquaculture. Alabama Agricultural Experiment Station, Research and Development Series 43. Auburn University, Alabama, 37 pp.
Boyd, C.E. and J.R. Bowman, 1997. Pond bottom soils. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 135–162.
Boyd, C.E. and A. Gross, 1998. Use of probiotics for improving soil and water quality in aquaculture ponds, In: T.W. Flegel (Editor), Advances in Shrimp Biotechnology. BIOTEC, Bangkok, Thailand, pp. 101–106.
Boyd, C.E. and L. Massaut, 1999. Risks associated with the use of chemicals in pond aquaculture. Aquacultural Engineering, 20:113–132.
Green, B.W., K.L. Veverica, and M.S. Fitzpatrick, 1997. Fry and fingerling production. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 215–244.
Molnar, J., 1999. Sound policies for food security: The role of culture and social organization. Reviews of Agricultural Economics. (in press)
Molnar, J., T. Hanson, and L. Lovshin, 1996. Impacts of the Pond Dynamics/Aquaculture Collaborative Support Research Program as a development intervention. NAGA: The ICLARM Quarterly, 19(2):31–40.
Sonnenholzner, S. and C.E. Boyd, 1999. Aerobic organic matter decomposition in aquaculture pond soils as measured by respiration chambers. Journal of the World Aquaculture Society. (in press)
Sonnenholzner, S. and C.E. Boyd, 1999. Chemical and physical properties of shrimp pond bottom sediments in Ecuador. Journal of the World Aquaculture Society. (in press)
Sonnenholzner, S. and C.E. Boyd, 1999. Decomposition of organic matter as measured by soil respiration in shrimp ponds treated with chemical and biological amendments. World Aquaculture. (submitted)
Teichert-Coddington, D.R., T.J. Popma, and L.L. Lovshin, 1997. Attributes of tropical pond-cultured fish. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 183–198.
Veverica, K.L. and J.J. Molnar, 1997. Developing and extending aquaculture technology for producers. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 397–414.

Presentations

Boyd, C.E. Food safety considerations related to chemical use for water and soil quality enhancement in ponds. FAO/NACA/

WHO Study Group on Food Safety Issues Associated with Products of Aquaculture, Bangkok, Thailand, 1997.
Boyd, C.E. Farm level indicators and criteria for sustainable shrimp farming. FAO Ad-Hoc Expert Meeting on Indicators and Criteria for Sustainable Shrimp Farming, Rome, Italy, 1998.
Boyd, C.E. Phosphorus chemistry in pond soils. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Boyd, C.E. Water quality management in pond aquaculture. Presented to the International Aquaculture Conference at Sao Paulo, Brazil, 26–27August 1998.
Boyd, C.E. Environmental management in aquaculture. Presented to Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.
Boyd, C.E. Environmental and sustainability issues in aquaculture. Keynote address presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.
Boyd, C.E. Measurement of pH in pond bottom soils. Aquaculture '99, World Aquaculture Society Annual Meeting, Sydney, Australia, 26 April–2 May 1999.
Boyd, C.E. and C.W. Wood. Conceptual model of aquacultural pond soil development. Presented to the Soil Science Society of America Annual Meeting, Anaheim, California, 25–30 October 1997.
Boyd, C.E., A Gross, and M. Rowan. Laboratory studies of sedimentation as a technique for treating pond effluents. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Massaut, L. and C.E. Boyd. Risks associated with use of chemicals in pond aquaculture. Poster presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Molnar, J. Doing development by growing fish: a cross-national analysis of the impacts of aquacultural research. Presented to the Annual Meeting of the Rural Sociological Society, Toronto, Canada, 1997.
Molnar, J., T. Hanson, and L. Lovshin. Doing science, growing fish, teaching people: Human capital impacts of the pond dynamics aquaculture CRSP. Presented to WAS '97 at Seattle, Washington, February 1997.
Queiroz, J.F. (presented by C.E. Boyd). Soil consideration in site selection, pond construction, and pond management. Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Smith, E.S. and R.P. Phelps. Effect of feed storage time and storage temperature on growth rate of tilapia fry and efficacy of sex reversal. Presented to the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9–12 November 1997.
Wood, C.W., C.E. Boyd, and J. Queiroz. Aquaculture pond soil development. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Other

Boyd, C.E. Aquaculture pond soils with emphasis on shrimp culture. Soil Science Graduate Seminar, Texas A&M University, 1997.
Boyd, C.E. Workshop on soil management in shrimp ponds (4 days), Guayaquil, Ecuador, (32 participants) August 1997.
Boyd, C.E. Workshop on water quality and pond bottom soils (1/2 day), China, four locations (total of 385 participants) August 1997.
Boyd, C.E. Workshop on water quality in shrimp ponds (3 days), Guayaquil, Ecuador (22 participants) November 1997.
Boyd, C.E. Workshop on water and soil quality in shrimp farming (2 days), Mazatlan, Mexico (41 participants) January 1998.
Boyd, C.E. Workshop on water quality (1/2 day), Pietersburg, South Africa (25 participants) March 1998.
Boyd, C.E. Workshop on shrimp pond water quality (2 hr), Chantaburi and Surat Thani, Thailand (total 73 participants) May 1998.
Boyd, C.E. Shrimp pond fertilization. Three two-hour lectures at Machelle, Perdinalis and Guayaquil, Ecuador, 11–14 August 1998.
Boyd, C.E. Workshop on pond soil and water quality management. Conducted in Tumbes, Peru, 18–19 August 1998.
Boyd, C.E. Pond dynamics workshop. Conducted for commercial aquaculturists, Melbourne, Australia, 3 May 1999.
Boyd, C.E. Water quality in aquaculture workshop. Conducted for commercial aquaculturists, Adelaide, Australia, 4 May 1999.
Boyd, C.E. Aquaculture and the environment workshop. Conducted for the Western Australia Fisheries Department, Perth, Australia, 6 May 1999.
Boyd, C.E. Water quality in shrimp ponds workshop. Conducted for shrimp farm employees, Mahajama, Madagascar, 23 May 1999.
Boyd, C.E. Environment management in aquaculture. Conducted for the Conference sponsored by Pacific Economic Cooperation Council, Lima, Peru.
Boyd, C.E. Dissolved oxygen management in ponds workshop. Conducted for the Asociación Nacional de Acuicultores de Honduras, Choluteca, Honduras, 16 June 1999.
Boyd, C.E. Soil and water quality management in shrimp ponds and Water quality management in low-water use systems lectures. Presented to the Regional Shrimp Culture Conference, Panama City, Panama, 1999.
Lovshin, L. Integrated fish culture systems: Do they work? Presented to faculty and students of the Aquaculture Research Unit, University of the North, Pietersburg, South Africa, 20 April 1999.
Molnar, J. (Organizer and Chair). Global shrimp farming, mangroves, and people: finding a sustainable path. 1998 Annual Meeting of the American Association for the Advancement of Science at Philadelphia, Pennsylvania, 12–17 February 1998.

OREGON STATE UNIVERSITY

Theses

Bowman, J., 1992. Classification and management of earthen aquaculture ponds, with emphasis on the role of the soil, Ph.D. dissertation, Oregon State University, Corvallis, Oregon.
Egna, H.S., 1998. Network analysis of international aquaculture research and development efforts in Rwanda: Tracing the flows of knowledge and technology in a USAID-funded collaborative research support program. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.
Nath, S.S., 1992. Total and available nutrients in manures for pond aquaculture. M.S. thesis. Oregon State University, Corvallis, Oregon.
Nath, S.S., 1996. Development of a decision support system for pond aquaculture. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

Publications

Bolte, J., S. Nath, and D. Ernst, 1999. Development of decision support tools for aquaculture: The POND experience. Aquacultural Engineering. (in press)
Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck, 1998. Masculinization of Nile tilapia (*Oreochromis niloticus*) by single immersion in 17α-methyldihydrotestosterone and trenbolone acetate. In: K. Fitzsimmons (Editor), Tilapia Aquaculture: Proceedings from the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 783–790.
Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck, 1999. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. In: Proceedings of the Sixth International Symposium on Reproductive Physiology of Fish, Bergen, Norway, 4–9 July 1999. (submitted)
Egna, H.S., 1989. Fish pond management guidelines: A CRSP goal. Science and Technology Agricultural Reporter, US Agency for International Development, Washington, D.C.
Egna, H.S., 1990. The Pond Dynamics/Aquaculture CRSP. In: Global Research for Sustainable Food Production. The CRSP Council, US Agency for International Development, Washington, D.C., pp. 28–32.

Egna, H.S., 1991. Collaboration, aquaculture style. BIFADEC Briefs. Board for International Food and Agriculture Development and Economic Cooperation, USAID, Washington, D.C., Vol. XV, No. 6, 8 pp.
Egna, H.S., 1993. Introduced technologies and changes in food consumption in Rwanda. Proceedings of the Oregon Academy of Sciences, vol. XXIX.
Egna, H.S., 1994. Monitoring water quality in tropical freshwater fishponds: General applications of aircraft and satellite imagery. Fisheries Management and Ecology, 1(3):165–178.
Egna, H.S., 1995. Psychological distress as a factor in environmental impact assessment: Some methods and ideas for quantifying this intangible intangible. Environmental Impact Assessment Review, 12:115–137.
Egna, H.S., 1997. History of the Pond Dynamics/Aquaculture Collaborative Research Support Program. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 19–52.
Egna, H.S., 1999. Environment, aquaculture, and food poicy nexus: Case study of two USAID aquaculture projects in Rwanda. In: D.L. Soden and B.S. Steel (Editors), Global Environmental Policy and Administration. Marcel Dekker, Inc., New York. (in press)
Egna, H.S. and C.E. Boyd (Editors), 1997. Dynamics of Pond Aquaculture. CRC Press, Boca Raton, 437 pp.
Egna, H.S., C.E. Boyd, and D.A. Burke, 1997. Introduction. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 1–18.
Ernst, D.H., J.P. Bolte, and D. Lowes, 1997. PD/A CRSP Central Database: An information resource for pond-based aquaculture. In: K. Fitzsimmons (Editor), Tilapia Aquaculture: Proceedings from the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 683–700.
Kapetsky, J.M. and S.S. Nath, 1997. A strategic assessment of the potential for freshwater fish farming in Latin America. FAO COPESCAL Technical Paper, No. 10, FAO, Rome, 128 pp.
Lannan, J.E., 1990. Farming and ranching an aquatic system. Food Reviews International, 6:293–298.
Lannan, J.E., G.A.E. Gall, J.E. Thorpe, C.E. Nash, and B.A. Ballachey, 1989. Genetic resource management of fish. Genome, 31:798–804.
Nath, S., J. Bolte, L Ross, and J. Aguilar-Manjarrez, 1999. Applications of geographical information systems (GIS) for spatial decision support in aquaculture. Aquacultural Engineering. (in press)
Seim, W.K., C.E. Boyd, and J.S. Diana, 1997. Environmental considerations. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 163–182.

Presentations

Bolte, J. and S. Nath. POND©: A decision tool for warmwater aquaculture. Presented to WAS '97 at Seattle, Washington, February 1997.
Bolte, J., D. Lowes, and S. Nath. Geographic Information System technologies for aquaculture decision support. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Bolte, J.P., S.S. Nath, P. Darakjian, and J.M. Kapetsky. Regional-scale analysis of aquaculture development potential. Poster presented to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.
Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. Presented to 6th International Symposium on Reproductive Physiology of Fish at Bergen, Norway, 4–9 July 1999.
Egna, H. International Aquaculture: Research. Presented to WAS '97 at Seattle, Washington, February 1997.
Egna, H.S., C.K. Lin, and D.Z. Clair. The Pond Dynamics/Aquaculture CRSP: Developing technologies and networks for sustainable aquaculture and rural development. Presented to Joint FAO/NACA Expert Consultation on Sustainable Aquaculture for Rural Development at Chiang Rai, Thailand, March 1999.
Ernst, D.H. Computer tools for aquaculture management and design. Lecture presented to the Western Regional Aquaculture Expo at Sacramento, California, 1996.
Ernst, D.H., J.P. Bolte, and S.S. Nath. Application of decision support software for aquaculture facility design. Presented to WAS '97 at Seattle, Washington, February 1997.
Ernst, D.H., S.S. Nath, and J.P. Bolte. Software for design and management of aquaculture facilities. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.
Kapetsky, J.M., S. Nath, and J.P. Bolte. A fish farming GIS for Latin America. Presented to WAS '97 at Seattle, Washington, February 1997.
Nath, S. Planning, design, and management tools for aquaculture. Presented to National Aquaculture Extension Conference at Annapolis, Maryland, 9–10 April 1997.
Nath, S., J.P. Bolte, and D.H. Ernst. A fish bioenergetics model for pond aquaculture. Presented to WAS '97 at Seattle, Washington, February 1997.
Nath, S.S., J.P. Bolte, and D.H. Ernst. Decision support for pond aquaculture planning and management. Presented to Sustainable Aquaculture '95 at Honolulu, Hawaii, 11–14 June 1995.
Nath, S.S., J.P. Bolte, and D.H. Ernst. Simulation models and economic optimization techniques for pond aquaculture. Poster presentation to the World Aquaculture Society Meeting at Bangkok, Thailand, February 1996.

SOUTHERN ILLINOIS UNIVERSITY AT CARBONDALE

Publication

Kelly, A.M. and C.C. Kohler, 1997. Climate, site, and pond design. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 109–134.

UNIVERSITY OF ARKANSAS AT PINE BLUFF

Publications

Engle, C.R., R. Balakrishnan, T.R. Hanson, and J.J. Molnar, 1997. Economic considerations. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 377–396.
Perschbacher, P. and R. Lochmann, 1999. Effects of feeding pelleted versus non-pelleted defatted rice bran on Nile tilapia *Oreochromis niloticus* production and water quality in ponds. Asian Fisheries Science. (in press)

Presentation

Engle, C.R. Teaching aquaculture economics. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

UNIVERSITY OF CALIFORNIA, DAVIS

Theses

Culberson, S.D., 1993. Simplified model for prediction of temperature and dissolved oxygen in aquaculture ponds using reduced data inputs. M.S. thesis, University of California, Davis, California.
Giovannini, P., 1994. Water quality dynamics in aquaculture ponds: an investigation of photosynthetic production and efficiency variations. Ph.D. dissertation, University of California, Davis, California.
Jamu, D., 1998. Modeling organic matter and nitrogen dynamics in integrated aquaculture/agriculture systems: Effects of cycling pathways on nitrogen retention and system productivity. Ph.D. dissertation, University of California, Davis, California.

Publications

Culberson, S.D. and R.H. Piedrahita, 1993. Model for predicting dissolved oxygen levels in stratified ponds using reduced data inputs. In: Jaw-Kai Wang (Editor), Techniques for Modern Aquaculture. Proceedings of an Aquacultural Engineering Conference, 21–23 June 1993, at Spokane, Washington. American Society of Agricultural Engineers, pp. 543–552.

Culberson, S.D. and R.H. Piedrahita, 1996. Aquaculture pond ecosystem model: temperature and dissolved oxygen prediction—mechanism and application. Ecological Modeling, 89:231–258.

Eikebrokk, B., R.H. Piedrahita, and Y. Ulgenes, 1995. Rates of fish waste production and effluent discharge from a recirculating system (Biofish) under commercial conditions. Aquaculture Research, 26:589–599.

Fridley, R.B., R.H. Piedrahita, and T.M. Losordo, 1988. Challenges in aquacultural engineering. Agricultural Engineering, 69(4):12–15.

Giovannini, P. and R.H. Piedrahita, 1988. Analysis and modeling of dissolved oxygen in warm water aquaculture ponds. American Society of Agricultural Engineers, 88-5004, 30 pp.

Giovannini, P. and R.H. Piedrahita, 1989. Analysis and modeling of diel pond dynamics: measuring phytoplankton light adaptation and saturation. American Society of Agricultural Engineers, 89-7556, 29 pp.

Giovannini, P. and R.H. Piedrahita, 1990. Measuring primary production efficiency in aquacultural ponds. American Society of Agricultural Engineers, 90-7034, 24 pp.

Giovannini, P. and R.H. Piedrahita, 1991. Engineering of non-fed pond systems. Proceedings of WAS/ASAE sessions at World Aquaculture Society Meeting at San Juan, Puerto Rico, 16–20 June 1991. American Society of Agricultural Engineers, Saint Joseph, Michigan.

Giovannini, P., and R.H. Piedrahita, 1994. Modeling photosynthetic production optimization for aquaculture ponds. Aquacultural Engineering, 13:83–100.

Grace, G. and R.H. Piedrahita, 1989. Carbon dioxide removal in packed column aerators. American Society of Agricultural Engineers, 89-7011, 21 pp.

Grace, G. and R.H. Piedrahita, 1993. Carbon dioxide control with a packed column aerator. In: Jaw-Kai Wang (Editor), Techniques for Modern Aquaculture. Proceedings of an Aquacultural Engineering Conference, 21–23 June 1993, at Spokane, Washington. American Society of Agricultural Engineers, pp. 496–505.

Grace, G. and R.H. Piedrahita, 1994. Carbon dioxide control. In: M. Timmons and T.M. Losordo (Editors), Engineering Design and Management of Aquaculture Water Reuse Systems. Developments in Aquaculture and Fisheries Science, 27:209–234.

Jamu, D.M., Z. Lu, and R.H. Piedrahita, 1998. Secchi disk visibility and chlorophyll *a* relationships in aquaculture ponds. In: M.B. Timmons and T. Losordo (Editors), Advances in Aquacultural Engineering: Proceedings from the Aquacultural Engineering Society (AES) Technical Sessions at the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 159–162.

Jamu, D.M., Z. Lu, and R.H. Piedrahita, 1999. Relationship between Secchi disk visibility and chlorophyll *a* in aquaculture ponds. Aquaculture, 170(1999):205–214.

Losordo, T.M. and R.H. Piedrahita, 1991. Modeling temperature variation and thermal stratification in shallow aquaculture ponds. Ecological Modelling, 54:189–226.

Lu, Z. and R.H. Piedrahita, 1993. Nitrifying characteristics of a high rate packed column. In: Jaw-Kai Wang (Editor), Techniques for Modern Aquaculture. Proceedings of an Aquacultural Engineering Conference, 21–23 June 1993, at Spokane, Washington. American Society of Agricultural Engineers, pp. 345–351.

Lu, Z., R.H. Piedrahita, and C. Dos Santos Neto, 1999. Generation of daily and hourly solar radiation values for modeling water quality in aquaculture ponds. Transactions of the ASAE, 41:1853–1859.

Piedrahita, R.H., 1989. Simulation of short-term management actions to prevent oxygen depletion in ponds. American Society of Agricultural Engineers, 89-7555, 20 pp.

Piedrahita, R.H., 1990. Aquaculture: Engineering and construction. In: Y.H. Hui (Editor), Wiley Encyclopedia of Food Science and Technology. Wiley and Sons, New York, pp. 117–126.

Piedrahita, R.H., 1990. Calibration and validation of TAP, an aquaculture pond water quality model. Aquacultural Engineering, 9:75–96.

Piedrahita, R.H., 1990. Detritus-based aquaculture systems. Food Reviews International, 6(3):317–331.

Piedrahita, R.H., 1991. Engineering aspects of warmwater hatchery design. Proceedings of WAS/ASAE sessions at World Aquaculture Society Meeting at San Juan, Puerto Rico, 16–20 June 1991. American Society of Agricultural Engineers, Saint Joseph, Michigan, pp. 85–100.

Piedrahita, R.H., 1991. Modeling water quality in aquaculture ecosystems. In: D.E. Brune and J.R. Tomasso (Editors), Aquaculture and Water Quality, World Aquaculture Society, Baton Rouge, Louisiana, pp. 322–362.

Piedrahita, R.H., 1991. Simulation of short-term management actions to prevent oxygen depletion in ponds. Journal of the World Aquaculture Society, 22(3):157–166.

Piedrahita, R.H. and D.E. Brune, 1989. Aquacultural engineering: aquatic habitat commands innovative thrusts. Agricultural Engineering, 70(1):30–32.

Piedrahita, R.H. and P. Giovannini, 1991. Fertilized non-fed pond systems. Aquaculture Systems Engineering. Proceedings of WAS/ASAE sessions at World Aquaculture Society Meeting at San Juan, Puerto Rico, 16–20 June 1991. American Society of Agricultural Engineers, Saint Joseph, Michigan, pp. 1–14.

Piedrahita, R.H. and A. Seland, 1995. Calculation of pH in fresh and sea water aquaculture systems. Aquacultural Engineering, 14:331–346.

Piedrahita, R.H. and J.K. Wang, 1988. Engineering in aquaculture, an overview. Proceedings of the Joint U.S. India International Symposium on Aquaculture Research Needs for the Year 2000 at New Delhi, India.

Piedrahita, R.H., S.S. Nath, J. Bolte, S.D. Culberson, P. Giovannini, and D.H. Ernst, 1997. Computer applications in pond aquaculture—modeling and decision support systems. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 289–324.

Presentations

Batterson, T. and R.H. Piedrahita. Current trends, interests and concerns related to aquacultural wastes and their treatment in the United States. Proceedings of the European Inland Fisheries Advisory Commission (EIFAC)/Food and Agriculture Organization (FAO) Workshop on Economics of Waste Water Management at Stirling, Scotland, June 1994.

Brune, D.E., C.M. Drcho, and R.H. Piedrahita. Pond oxygen dynamics: design and management strategies. Presented to Aquaculture '92 International Conference at Orlando, Florida, 21–25 May 1992.

Culberson, S.D. and R.H. Piedrahita. Modification of stratified temperature and dissolved oxygen model to accommodate reduced data inputs: Identifying critical requirements. Presented to Aquaculture '92 International Conference at Orlando, Florida, 21–25 May 1992.

Jamu, D.M. and R.H. Piedrahita. A nitrogen and organic matter cycling model for an integrated aquaculture-crop system. Presented to WAS '97 at Seattle, Washington, February 1997.

Lu, Z. and R.H. Piedrahita. Modeling of temperature and dissolved oxygen in stratified aquaculture ponds using stochastic weather variables. Presented to WAS '97 at Seattle, Washington, February 1997.

Lu, Z. and R.H. Piedrahita. The probability distributions of temperature and dissolved oxygen in stratified fish ponds under stochastic input weather variables. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Piedrahita, R.H. Managing environmental impacts in aquaculture. Presented to the United States-Japan Natural Resources (UJRN) Aquaculture Panel at Kyoto, Japan, November 1992.

Piedrahita, R.H. and G. Grace. Removal of carbon dioxide and intensive aquaculture systems. Presented to the World Aquaculture Society Meeting at Halifax, Nova Scotia, June 1990.

Piedrahita, R.H. and G. Grace. Carbon dioxide removal for intensive aquaculture. Presented to the Workshop on Recirculating Aquaculture Systems at Baton Rouge, Louisiana, September 1991.

Piedrahita, R.H., Z. Lu, and D. Jamu. Dissolved oxygen modeling in tropical aquaculture ponds under the Pond Dynamics/Aquaculture Collaborative Research Support Program. Presented to the World Aquaculture Society Meeting, Bangkok, Thailand, January 1996.

Whitman, M.H. and R.H. Piedrahita. Water quality requirements of Pacific oysters (*Crassostrea gigas*) in holding systems. Presented to the World Aquaculture Society Meeting at Los Angeles, February 1989.

Other

Piedrahita, R.H. Aquacultural Engineering, a five-day course at the Universidad Autonoma de Baja California, Ensenada, Baja California, 23–28 November 1997.

University of Georgia

Presentation

Nath, S. Geographic Information System technologies for aquaculture decision support. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Nath, S.S., B.P. Verma, G. Rosenberg, and D. Nute. Integrated, multi-perspective approaches to decision support: Case study in Honduras. Presented to the 1998 Institute of Biological Engineering Meeting at Orlando, Florida, 10–12 July 1998.

University of Hawaii

Presentation

Szyper, J.P., R.H. Piedrahita, and P. Giovannini. Requirements for maximizing bloom stability and net oxygen production in earthen ponds. Poster presented to the World Aquaculture Society Meeting at Torremolinos, Spain, 26–28 May 1993.

University of Michigan

Publications

Diana, J.S., 1997. Feeding strategies. In: H. Egna and C. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 245–262.

Diana, J.S., J.P. Szyper, T.R. Batterson, C.E. Boyd, and R.H. Piedrahita, 1997. Water quality in ponds. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture, CRC Press, Boca Raton, pp. 53–71.

Lin, C.K., D. Teichert-Coddington, B. Green, and K. Veverica, 1997. Fertilization regimes. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, Boca Raton, pp. 73–108.

Springborn, R.R., A.L. Jensen, and W.Y.B. Chang, 1994. A variable growth rate modification of Von Bertalanffy's equation for aquaculture. Aquaculture and Fisheries Management, 25:259–267.

Springborn, R.R., A.L. Jensen, W.Y.B. Chang, and C. Engle, 1992. Optimum harvest time in aquaculture: An application of economic principles to a Nile tilapia, *Oreochromis niloticus* (L.), growth model. Aquaculture and Fisheries Management, 23:639–647.

University of Oklahoma

Publication

Rubinshtein, I., S. Rothbard, and W.L. Shelton, 1997. The relationship between the embryological age, cytokinesis-1 and the timing of ploidy manipulation in fish. Israeli Journal of Aquaculture/Bamidgeh, 49:99–110.

Presentation

Shelton, W. and R. Phelps. Sex manipulation in *Oreochromis niloticus*, presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

University of Texas

Publication

Ward, G.H., 1996. A strategic approach to carrying-capacity analysis for aquaculture on estuaries. In: United States/Japan Natural Resource Panel on Aquaculture, United States-Japan Cooperative Program in Natural Resources. Sea Grant, Texas A&M University, 24:71–84.

Other

Publications

Aguilar-Manjarrez, J. and S. Nath, 1998. A Strategic Reassessment of Fish Farming Potential in Africa. CIFA Technical Paper, No. 32. FAO, Rome, 170 pp.

Kapetsky, J.M. and S.S. Nath, 1997. A Strategic Assessment of the Potential for Freshwater Fish Farming in Latin America. COPESCAL Technical Paper, No. 10. FAO, Rome, 124 pp.

Nath, S.S. and J.P. Bolte, 1998. A water budget model for pond aquaculture. Aquacultural Engineering, 18(3):175–188.

Program Management Office Report Series

The following publications have been issued by the PD/A CRSP Program Management Office at Oregon State University, Corvallis, Oregon.

CRSP Research Reports

87-1 Hopkins, K.D., J.E. Lannan, and J.R. Bowman. A data base management system for research in pond dynamics. (10/87)

87-2 Nash, G., S. Chinabut, and C. Limsuwan. Idiopathic muscle necrosis in the freshwater prawn, *Macrobrachium rosenbergii* de Man, cultured in Thailand. (11/87)

87-3 Tavarutmaneegul, P. and C.K. Lin. Breeding and rearing of sand goby (*Oxyeleotris marmoratus*, Blk.) fry. (11/87)

88-4 Lin, C.K. Acidification and reclamation of acid sulfate soil fishponds in Thailand. (1/88)

88-5 Ver, L.M.B. and Y.N. Chiu. The effect of paddlewheel aerators on ammonia and carbon dioxide removal in intensive pond culture. (2/88)

88-6 Carpenter, K.E., A.W. Fast, V.L. Corre, J.W. Woessner, and R.L. Janeo. The effects of water depth and circulation on the water quality and production of *Penaeus monodon* in earthen ponds. (2/88)

88-7 Sanares, R.C., S.A. Katase, A.W. Fast, and K.E. Carpenter. Water quality dynamics in brackish water shrimp ponds with artificial aeration and circulation. (2/88)

88-8 Batterson, T.R., C.D. McNabb, C.F. Knud-Hansen, H.M. Eidman, and K. Sumatadinata. Effect of chicken

manure additions on fish production in ponds in West Java, Indonesia. (4/88)

88-9 Teichert-Coddington, D.R., N. Stone, and R.P. Phelps. Hydrology of fish culture ponds in Gualaca, Panama. (12/88)

88-10 Sikoki, F.D., R.A. Tubb, and L.R. Curtis. Elevation of sex steroids and inhibition of UDP-glucuronyltransferase are out of phase during gonadal maturation in the common carp. (12/88)

88-11 Minsalan, C.L.O. and Y.N. Chiu. Effects of teaseed cake on selective elimination of finfish in shrimp ponds. (12/88)

88-12 Fortes, R.D., V.L. Corre, Jr., and E. Pudadera. Effects of fertilizers and feeds as nutrient sources on *Oreochromis niloticus* production in Philippine brackish water ponds. (12/88)

89-13 Fast, A.W., K.E. Carpenter, V.J. Estilo, and H.J. Gonzales. Effects of water depth and artificial mixing on dynamics of Philippines brackish water shrimp ponds. (1/89)

89-14 Chang, W.Y.B. and H. Ouyang. Dynamics of dissolved oxygen and vertical circulation in fish ponds. (6/89)

89-15 Green, B.W., R.P. Phelps, and H.R. Alvarenga. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds. (4/89)

89-16 Lin, C.K. and M. Boonyaratpalin. An analysis of biological characteristics of *Macrobrachium rosenbergii* (de Man) in relation to pond production and marketing in Thailand. (2/89)

89-17 Chang, W.Y.B. Estimates of hypolimnetic oxygen deficits in ponds. (8/89)

89-18 Diana, J.S. and A.W. Fast. The effects of water exchange rate and density on yield of the walking catfish, *Clarias fuscus*. (9/89)

89-19 Diana, J.S., P.J. Schneeberger, and C.K. Lin. Relationships between primary production and yield of tilapia in ponds. (9/89)

89-20 Lin, C.K., V. Tansakul, and C. Apinhapath. Biological nitrogen fixation as a source of nitrogen input in fishponds. (11/89)

89-21 Teichert-Coddington, David R. and Ronald P. Phelps. Effects of seepage on water quality and productivity of inorganically fertilized tropical ponds. (12/89)

90-22 Chang, W.Y.B. Integrated lake farming for fish and environmental management in large shallow Chinese lakes: A review. (1/90)

90-23 Hopkins, K.D., M.L. Hopkins, and D. Pauley. A multivariate model of tilapia growth, applied to seawater tilapia culture in Kuwait. (1/90)

90-24 Hopkins, K.D. Reporting fishpond yields to farmers. (1/90)

90-25 Peralta., M. and D. Teichert-Coddington. Comparative production of *Colossoma macropomum* and *Tilapia nilotica* in Panama. (1/90)

90-26 Teichert-Coddington, D.R., B.W. Green, N. Matamoros, and R. Rodriguez. The substitution of chicken litter for feed in the commercial production of penaeid shrimp in Honduras. (5/90)

90-27 Green, B.W. and L.A. Lopez. Implementing the large-scale production of young males of *Tilapia nilotica* using hormonal sex inversion in Honduras. (5/90)

90-28 Hanson, B.J., J.F. Moehl, Jr., K.L. Veverica, F. Rwangano, and M. Van Speybroek. Pond culture of tilapia in Rwanda, a high altitude equatorial African country. (10/90)

90-29 Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. Hatchery techniques for egg and fry production of *Clarias batrachus* (Linnaeus). (10/90)

91-30 Green, B.W., D.R. Teichert-Coddington, and R.P. Phelps. Response of tilapia yield and economics to varying rates of organic fertilization and season in two Central American countries. (1/91)

91-31 Szyper, J.P. and C.K. Lin. Techniques for assessment of stratification and effects of mechanical mixing in tropical fish ponds. (5/91)

91-32 Knud-Hansen, C.F., T.R. Batterson, C.D. McNabb, I.S. Harahat, K. Sumantadinata, and H.M. Eidman. Nitrogen input, primary productivity and fish yield in fertilized freshwater ponds in Indonesia. (7/91)

91-33 Piedrahita, R.H. Calibration and validation of TAP, an aquaculture pond water quality model. (10/91)

91-34 Piedrahita, R.H. Modeling water quality in aquaculture ecosystems. (10/91)

91-35 Piedrahita, R.H. Engineering aspects of warmwater hatchery design. (10/91)

91-36 Piedrahita, R.H. and P. Giovannini. Fertilized non-fed pond systems. (10/91)

91-37 McNabb, C.D., T.R. Batterson, B.J. Premo, C.F. Knud-Hansen, H.M. Eidman, C.K. Lin, K. Jaiyen, J.E. Hanson, and R. Chuenpagdee. Managing fertilizers for fish yield in tropical ponds in Asia. (12/91)

91-38 Green, B.W. and H.R. Alvarenga. The effect of different application rates of chicken litter on tilapia production. (12/91)

91-39 Alvarenga, H.R. and B.W. Green. Production and economic aspects of tilapia cultivation in ponds fertilized with chicken litter. (12/91)

92-40 Szyper, J.P., K.D. Hopkins, and C.K. Lin. Production of *Oreochromis niloticus* (L.) and ecosystem dynamics in manured ponds of three depths. (3/92)

92-41 Piedrahita, R.H. Simulation of short-term management actions to prevent oxygen depletion in ponds. (3/92)

92-42 Teichert-Coddington, D.R., B.W. Green, and R.W. Parkman. Substitution of chicken litter for feed in production of penaeid shrimp in Honduras. (3/92)

92-43 Knud-Hansen, C.F., C.D. McNabb, and T.R. Batterson. Application of limnology for efficient nutrient utilization in tropical pond aquaculture. (4/92)

92-44 Hopkins, K. and A. Yakupitiyage. Bias in seine sampling of tilapia. (4/92)

92-45 Engle, C.R. and M. Skladany. The economic benefit of chicken manure utilization in fish production in Thailand. (5/92)

92-46 Green, B.W. Substitution of organic manure for pelleted feed in tilapia production. (5/92)

92-47 Green, B.W., and D.R. Teichert-Coddington. Comparison of two samplers used with an automated data acquisition system in whole-pond, community metabolism studies. (5/92)

92-48 Liu, K.M. and W.Y.B. Chang. Bioenergetic modeling of effects of fertilization, stocking density, and spawning on growth of the Nile tilapia, *Oreochromis niloticus* (L.). (9/92)

93-49 Teichert-Coddington, D.R., B.W. Green, and R.P. Phelps. Influence of site and season on water quality and tilapia production in Panama and Honduras. (4/93)

93-50 Suresh, A.V. and C.K. Lin. Tilapia culture in saline waters: A review. (4/93)

93-51 Knud-Hansen, C.F. Analyzing standard curves in the chemistry of waters used for aquaculture. (4/93)

93-52 Szyper, J.P., J.Z. Rosenfeld, R.H. Piedrahita, and P. Giovannini. Diel cycles of planktonic respiration rates in briefly incubated water samples from a fertile earthen pond. (4/93)

93-53 This report is a duplicate of an earlier number.

93-54 Lin, C.K., K. Jaiyen, and W. Muthuwana. Integration of intensive and semi-intensive aquaculture: Concept and example. (5/93)

93-55 Szyper, J.P. and J.M. Ebeling. Photosynthesis and community respiration at three depths during a period of stable phytoplankton stock in a eutrophic brackish water culture pond. (9/93)

93-56 Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L.). (10/93)

93-57 Boyd, C.E. and D. Teichert-Coddington. Relationship between wind speed and reaeration in small aquaculture ponds. (10/93)

93-58 Teichert-Coddington, D.R. and B.W. Green. Influence of daylight and incubation interval on water column respiration in tropical fish ponds. (10/93)

93-59 Knud-Hansen, C.F. and A.K. Pautong. On the role of urea in pond fertilization. (11/93)

94-60 Shrestha, M.K. and C.F. Knud-Hansen. Increasing attached microorganism biomass as a management strategy for Nile tilapia (*Oreochromis niloticus*) production. (5/94)

94-61 Springborn, R.R., A.L. Jensen, W.Y.B. Chang, and C. Engle. Optimum harvest time in aquaculture: An application of economic principles to a Nile tilapia, *Oreochromis niloticus* (L.), growth model. (2/94)

94-62 Hopkins, K.D. and D. Pauly. Instantaneous mortalities and multivariate models: Applications to tilapia culture in saline water. (2/94)

94-63 Green, B.W. and D.R. Teichert-Coddington. Production of *Oreochromis niloticus* fry for hormonal sex reversal in relation to water temperature. (2/94)

94-64 Engle, C.R., M. Brewster, and F. Hitayezu. An economic analysis of fish production in a subsistence agricultural economy: The case of Rwanda. (6/94)

94-65 Knud-Hansen, C.F. and T.R. Batterson. Effect of fertilization frequency on the production of Nile tilapia (*Oreochromis niloticus*). (9/94)

94-66 Teichert-Coddington, D.R., R. Rodriguez, and W. Toyofuku. Cause of cyclic variation in Honduran shrimp production. (11/94)

94-67 Springborn, R.R., A.L. Jensen, and W.Y.B. Chang. A variable growth rate modification of von Bertalanffy's equation for aquaculture. (12/94)

94-68 Diana, J.S., D.J. Dettweiler, and C.K. Lin. Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. (12/94)

94-69 Ayub, M., C.E. Boyd, and D. Teichert-Coddington. Effects of urea application, aeration, and drying on total carbon concentrations in pond bottom soils. (12/94)

94-70 Boyd, C.E. and D. Teichert-Coddington. Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds. (12/94)

94-71 Hopkins, K.D. Reporting fish growth: A review of the basics. (12/94)

94-72 Hopkins, K.D. and J.D. Bowman. A research methodology for integrated agriculture-aquaculture farming systems. (12/94)

94-73 Diana, J.S. and K. Jaiyen. Supplemental feeding of tilapia in fertilized ponds. (12/94)

94-74 Knud-Hansen, C.F. Pond history as a source of error in fish culture experiments: A quantitative assessment using covariate analysis. (12/94)

94-75 Green, B. and D. Teichert-Coddington. Growth of control and androgen-treated Nile tilapia, *Oreochromis niloticus* (L.), during treatment, nursery and growout phases in tropical fish ponds. (12/94)

94-76 Teichert-Coddington, D. and B. Green. Comparison of two techniques for determining community respiration in tropical fish ponds. (12/94)

94-77 Teichert-Coddington, D. and B. Green. Tilapia yield improvement through maintenance of minimal oxygen concentrations in experimental growout ponds in Honduras. (12/94)

94-78 Teichert-Coddington, D., M. Peralta, and R.P. Phelps. Seepage reduction in tropical fish ponds using chicken litter. (12/94)

95-79 Giovannini, P. and R.H. Piedrahita. Modeling photosynthetic production optimization for aquaculture ponds. (2/95)

95-80 Culberson, S.D. and R.H. Piedrahita. Model for predicting dissolved oxygen levels in stratified ponds using reduced data inputs. (2/95)

95-81 Culberson, S.D. and R.H. Piedrahita. Modification of stratified temperature model to accommodate reduced data inputs: Identifying critical requirements. (2/95)

95-82 Teichert-Coddington, D. Development of production technologies for semi-intensive fish farming during the past decade in Central America. (2/95)

95-83 Teichert-Coddington, D. Effects of protein diet and sowing density on the production of *Penaeus vannamei* in land tanks. (2/95)

95-84 Szyper, J.P., C.K. Lin, D. Little, S. Setboonsarng, A. Yakupitiyage, P. Edwards, and H. Demaine. Techniques for efficient and sustainable mass production of tilapia in Thailand. (7/95)

95-85 Egna, H.S. Psychological distress as a factor in environmental impact assessment: Some methods and ideas for quantifying this intangible intangible. (7/95)

95-86 Bowman, J.R. and J.E. Lannan. Evaluation of soil pH-percent base saturation relationships for use in estimating the lime requirements of earthen aquaculture ponds. (7/95)

95-91 Green, B.W., Z.E. Nagdy, H. Hebicha, I. Shaker, D.A.R. Kenawy, and A.R.E. Gamal. Evaluation of Nile tilapia production systems in Egypt. (10/95)

96-87 Green, B.W. and C.E. Boyd. Water budgets for fish ponds in the dry tropics. (1/96)

96-88 Green, B.W. and C.E. Boyd. Chemical budgets for organically fertilized fish ponds in the dry tropics. (1/96)

96-89 Teichert-Coddington, D.R. and R. Rodriguez. Semi-intensive commercial grow-out of *Penaeus vannamei* feed diets containing differing levels of crude protein during wet and dry seasons in Honduras. (1/96)

96-90 Boyd, C.E. and D. Teichert-Coddington. Dry matter, ash, and elemental composition of pond-cultured *Penaeus vannamei* and *P. stylirostris*. (1/96)

96-92 Egna, H.S. Monitoring water quality for tropical freshwater fisheries and aquaculture: A review of aircraft and satellite imagery applications. (1/96)

96-93 Lin, C.K. and J.S. Diana. Co-culture of catfish (*Clarias macrocephalus* × *C. gariepinus*) and tilapia (*Oreochromis niloticus*) in ponds. (2/96)

96-94 Lin, C.K. Clarias and tilapia interaction in polyculture. (4/96)

96-95 Abdalla, A.A.F. and C.D. McNabb. Ammonia dynamics in fertilized fish ponds stocked with Nile tilapia. (6/96)

96-96 Boyd, C.E. and P. Munsiri. Phosphorus adsorption capacity and availability of added phosphorus in soils from aquaculture areas in Thailand. (6/96)

96-97 Teichert-Coddington, D.R. Effect of stocking ratio on semi-intensive polyculture of *Colossoma macropomum* and *Oreochromis niloticus* in Honduras, Central America. (11/96)

96-98 Munsiri, P. and B.F. Hajek. Texture and chemical composition of soils from shrimp ponds near Choluteca, Honduras. (11/96)

97-99 Moehl, J.F. and J.J. Molnar. Institutional requirements for aquacultural development in Africa: Lessons from Rwanda. (1/97)

97-100 Hishamunda, N., C.M. Jolly, and C.R. Engle. Estimating *Oreochromis niloticus* production function for small-scale fish culture in Rwanda. (1/97)

97-101 Shrestha, M.K. and C.K Lin. Phosphorus fertilization strategy in fish ponds based on sediment phosphorus saturation level. (1/97)

97-102 Green, B.W. Polyculture of tilapia with marine shrimp. (1/97)

97-103 Diana, J.S., C.K. Lin, and Y. Yi. Timing of supplemental feeding for tilapia production. (4/97)

97-104 Engle, C.R. Optimal resource allocation by fish farmers in Rwanda. (4/97)

97-105 Szyper, J.P. Observations and model predictions of daily areal primary production in a eutrophic brackish water culture pond. (4/97)

97-106 Szyper, J.P. Comparison of three mixing devices in earthen culture ponds of four different surface areas. (4/97)

97-107 Green, B.W. Inclusion of tilapia as a diversification strategy for penaeid shrimp culture. (5/97)

97-108 Teichert-Coddington, D., J. Harvin, and D. Martinez. Semi-intensive shrimp pond management and quality of effluents. (5/97)
97-109 Veverica, K. The Pond Dynamics/Aquaculture CRSP-sponsored proceedings of the third conference on the culture of tilapias at high elevations in Africa. (6/97)
97-110 Yohe, J.M., P.B. McConnell, H.S. Egna, J. Rowntree, J. Oxley, R.G. Hanson, D. Cummins, and A. Kirksey. The CRSPs: International collaborative research support programs. (6/97)
97-111 Solubility of selected inorganic fertilizers in brackish water. (1/98)
97-112 Water quality in laboratory soil-water microcosms with soils from different areas of Thailand. (1/98)
97-113 Determination of phosphorus saturation level in relation to clay content in formulated pond muds. (1/98)
97-115 Influence of Nile tilapia (*Oreochromis niloticus*) stocking density in cages on their growth and yield in cages and in ponds containing the cages. (1/98)
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98-119 PD/A CRSP Central Database: A standardized information resource for pond aquaculture. (4/98)
98-120 Secchi disk visibility and chlorophyll *a* relationship in aquaculture ponds. (4/98)
98-121 Masculinization of Nile tilapia (*Oreochromis niloticus*) by single immersion in 17a-methyldihydrotestosterone and trenbolone acetate. (4/98)
98-122 A strategic assessment of the potential for freshwater fish farming in Latin America. (4/98)
98-123 Experimental and commercial culture of tilapia in Honduras. (4/98)
98-124 Small-scale fish farming in Rwanda: Economic characteristics. (7/98)
98-124a Small-scale fish farming in Rwanda: Data report. (7/98)
98-125 Acute and sublethal growth effects of un-ionized ammonia to Nile tilapia *Oreochromis niloticus* (10/98)
98-126 A water budget model for pond aquaculture (10/98)
98-127 A strategic reassessment of fish farming potential in Africa (10/98)
98-128 A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds (10/98)
99-129 Aquaculture extension in Rwanda (4/99)
99-130 Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*) (4/99)
99-131 The effects of fertilization and water management on growth and production of Nile tilapia in deep ponds during the dry season (4/99)
99-132 Relationship between Secchi disk visibility and chlorophyll *a* in aquaculture ponds (4/99)

DATA REPORTS BY PD/A CRSP RESEARCHERS

Batterson, T.R., C.D. McNabb, C.F. Knud-Hansen, H.M. Eidman, and K. Sumantadinata, 1989. Pond Dynamics Collaborative Research Data Reports, Volume 3, Number 3, Indonesia: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 135 pp.

Bowman, J. and D. Clair, 1996. Pond Dynamics Collaborative Research Data Reports, Volume 1, Second Edition, General Reference: PD/A CRSP Site Descriptions. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 74 pp.

Carpenter, K.E., A.W. Fast, J. Carreon, and R. Juliano, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 4, Number 3, Philippines: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 257 pp.

Carpenter, K.E., J. Woessner, R.D. Fortes, A. Fast, and P. Helfrich, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 4, Number 2, Philippines: Cycle II of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 501 pp.

Diana, J.S., C.K. Lin, T. Bhukaswan, and V. Sirsuwanatach, 1987. Pond Dynamics Collaborative Research Data Reports, Volume 2, Number 1, Thailand: Cycle I of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 47 pp.

Diana, J.S., C.K. Lin, T. Bhukaswan, V. Sirsuwanatach, and B.J. Buurma, 1990. Pond Dynamics Collaborative Research Data Reports, Volume 2, Number 2, Thailand: Cycle II of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 54 pp.

Diana, J.S., C.K. Lin, T. Bhukaswan, V. Sirsuwanatach, and B.J. Buurma, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 2, Number 3, Thailand: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 86 pp.

Egna, H.S., N. Brown, and M. Leslie (Editors), 1989. Pond Dynamics Collaborative Research Data Reports, Volume 1, General Reference: Site Descriptions, Materials and Methods for the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 84 pp.

Green, B.W., H.R. Alvarenga, R.P. Phelps, and J. Espinoza, 1989. Pond Dynamics Collaborative Research Data Reports, Volume 6, Number 3, Honduras: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 114 pp.

Green, B.W., H.R. Alvarenga, R.P. Phelps, and J. Espinoza, 1990. Pond Dynamics Collaborative Research Data Reports, Volume 6, Number 1, Honduras: Cycle I of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 94 pp.

Green, B.W., H.R. Alvarenga, R.P. Phelps, and J. Espinoza, 1990. Pond Dynamics Collaborative Research Data Reports, Volume 6, Number 2, Honduras: Cycle II of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 94 pp.

Hanson, B., V. Ndoreyaho, F. Rwangano, R. Tubb, and W.K. Seim, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 5, Number 2, Rwanda: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 102 pp.

Hanson, B., V. Ndoreyaho, R. Tubb, F. Rwangano, and W.K. Seim, 1989. Pond Dynamics Collaborative Research Data Reports, Volume 5, Number 1, Rwanda: Cycle I of The Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 62 pp.

Hughes, D., R.P. Phelps, and R.P. Malca, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 8, Number 2, Aguadulce, Panama: Cycle II of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 143 pp.

Hughes, D., R.P. Phelps, and R.P. Malca, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 8, Number 3. Aguadulce, Panama: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 230 pp.

Hughes, D., A.T. Diaz, R.P. Phelps, and R.P. Malca, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 8, Number 1, Aguadulce, Panama: Cycle I of The Global Experi-

ment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 122 pp.
McNabb, C.D., T.R. Batterson, B.J. Premo, H.M. Eidman, and K. Sumantadinata, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 3, Number 2, Indonesia: Cycle II of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 49 pp.
McNabb, C.D., T.R. Batterson, B.J. Premo, H.M. Eidman, and K. Sumantadinata, 1988. Pond Dynamics Collaborative Research Data Reports, Volume 3, Number 1, Indonesia: Cycle I of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 67 pp.
Teichert-Coddington, D.R., M. Peralta, R.P. Phelps, and R.P. Malca, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 7, Number 1, Gualaca, Panama: Cycle I of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 97 pp.
Teichert-Coddington, D.R., M. Peralta, R.P. Phelps, and R.P. Malca, 1991. Pond Dynamics Collaborative Research Data Reports, Volume 7, Number 2, Gualaca, Panama: Cycle III of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 56 pp.
Woessner, J., R.D. Fortes, and V. Corre, Jr., 1991. Pond Dynamics Collaborative Research Data Reports, Volume 4, Number 1, Philippines: Cycle I of the Global Experiment. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 141 pp.

CRSP WORK PLANS

Pond Dynamics/Aquaculture Collaborative Research Support Program, 1983. CRSP Work Plan: First Experimental Cycle. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 99 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1984. CRSP Work Plan: Second Experimental Cycle. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 143 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1985. CRSP Work Plan: Third Experimental Cycle. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 128 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1989. Revised CRSP Work Plan: Fourth Experimental Cycle. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 39 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1989. Fifth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 151 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1991. Sixth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 71 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1993. Revised Seventh Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 85 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1996. Interim Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 47 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1997. Eighth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 171 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1998. Addendum to the Eighth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 31 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1999. Second Addendum to the Eighth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 18 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1999. Ninth Work Plan. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 92 pp.

CRSP ADMINISTRATIVE REPORTS

Pond Dynamics/Aquaculture Collaborative Research Support Program, 1983. First Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 29 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1984. Second Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 35 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1985. Third Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 37 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1986. Fourth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 28 pp.
Pond Dynamics/Aquaculture Collaborative Research Support Program, 1988. Fifth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 49 pp.
Egna, H.S. and H. Horton. (Editors), 1989. Sixth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 91 pp.
Egna, H.S., J. Bowman, and M. McNamara (Editors), 1990. Seventh Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 114 pp.
Egna, H.S., J. Bowman, and M. McNamara (Editors), 1991. Eighth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 166 pp.
Egna, H.S., M. McNamara, and N. Weidner (Editors), 1992. Ninth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 172 pp.
Egna, H.S., M. McNamara, J. Bowman, and N. Astin (Editors), 1993. Tenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 275 pp.
Egna, H.S. and M. McNamara (Editors), 1994. Eleventh Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 80 pp.
Egna, H.S., J. Bowman, B. Goetze and N. Weidner (Editors), 1994. Eleventh Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 178 pp.
Egna, H.S., M. McNamara, and N. Weidner (Editors), 1995. Twelfth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 95 pp.
Egna, H.S., J. Bowman, B. Goetze, and N. Weidner (Editors), 1995. Twelfth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 209 pp.
Goetze, B., H. Berkman, and H. Egna (Editors), 1995. Egypt Project Final Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 30 pp.
McNamara, M., H. Egna, B. Goetze, B. Herbison, and D. Clair (Editors), 1996. Thirteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 96 pp.
Egna, H.S., B. Goetze, D. Burke, M. McNamara, and D. Clair (Editors), 1996. Thirteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 206 pp.
Clair, D., B. Goetze, D. Burke, M. McNamara, and H. Egna, (Editors), 1997. Fourteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 94 pp.

Burke, D., B. Goetze, D. Clair, and H. Egna (Editors), 1997. Fourteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 192 pp.
Clair, D., B. Goetze, D. Burke, J. Baker. and H. Egna (Editors), 1998. Fifteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 113 pp.
Burke, D., J. Baker, B. Goetze, D. Clair, and H. Egna (Editors), 1998. Fifteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 187 pp.
Clair, D., D. Burke, K. McElwee, M. Niles, and H. Egna, 1999. Sixteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 100 pp.
McElwee, K., D. Burke, M. Niles, and H. Egna (Editors), 1999. Sixteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 189 pp.

Other Published Work by CRSP Researchers

Publications

Boyd, C.E.. 1998. Mechanical aeration in pond aquaculture, In: Proceedings Second International Symposium on Aeration Technology, American Society of Mechanical Engineers, Washington, D.C., pp. 1–6.
Boyd, C.E. 1998. Pond water aeration systems. Aquacultural Engineering, 18:9–40.
Boyd, C.E., 1999. Aquaculture sustainability and environmental issues. World Aquaculture, 30(2):10–13 and 71–72.
Boyd, C.E., 1999. Codes of practice for responsible shrimp farming. Global Aquaculture Alliance, St. Louis, Missouri. 42 pp.
Boyd, C.E. and J.W. Clay. 1998. Shrimp aquaculture and the environment. Scientific American, June 1998, 278(6):42–49.
Boyd, C.E. and A. Gross. 1999. Biochemical oxygen demand in channel catfish pond waters. Journal of the World Aquaculture Society, 30:349–356.
Boyd, C.E. and H.R. Schmittou. 1999. Achievement of sustainable aquaculture through environmental management. International Journal of Aquaculture Economics and Management, 3:1–11.
Boyd, C.E. and C.S. Tucker, 1998. Pond Aquaculture Water Quality Management, Kluwer Academic Publishers, Boston, MA, 700 pp.
Brune, D.E. and R.H. Piedrahita, 1982. Operation of a retained biomass nitrification system for treating aquaculture water for reuse. Proceedings of the First International Conference on Fixed-Film Biological Processes, pp. 845–869.
Chang, W.Y.B., 1986. Aquaculture research in China. China Exchange News, CSCPRC, National Academy of Sciences, 14(2):13–16.
Chang, W.Y.B., 1986. Practical methods for treating fish during oxygen stress in ponds. Aquaculture Magazine, 13(4):20–22.
Chang, W.Y.B., 1986. Vertical oxygen dynamics of shallow tropical impoundments in the Pearl River Delta, China. Tran. Amer. Phys. Union, 66(51):13–1.
Chang, W.Y.B., 1987. A historical center of fish culture in China: Lake Tai/Yangtze River Delta. Aquaculture Magazine, 13:39–42.
Chang, W.Y.B., 1987. Fish culture in China. Fisheries, 12(3):11–15.
Chang, W.Y.B., 1987. Large lakes of China. J. Great Lakes Res., 13(3):235–249.
Chang, W.Y.B., 1989. Estimates of hypolimnetic oxygen deficits in ponds. Aquaculture and Fisheries Management, 20:167–172.
Chang, W.Y.B., 1989. Integrated lake farming for fish and environmental management in large shallow Chinese lakes: A review. Aquaculture and Fisheries Management, 20:441–452.
Chang, W.Y.B. and H. Ouyang, 1988. Dynamics of dissolved oxygen and vertical circulation in fish ponds. Aquaculture, 74:263–276.
Chang, W.Y.B. and R. Rossmann, 1988, Changes in the abundance of blue-green algae related to nutrient loadings in the nearshore of Lake Michigan. Hydrobiologia, 157:271–278.
Chang, W.Y.B., J. Diana, and W. Chapoehuk, 1983. Strengthening of Southeast Asian Aquaculture Institutions. Workshop Report to Agency for International Development.
Ebeling, J.M. and R.H. Piedrahita, 1985. Microcomputer-based data acquisition system for aquaculture use. American Society of Agriculture Engineers, 85-5014, 9 pp.
Fitzsimmons, K. 1999. Future trends for tilapia aquaculture in the Americas. In: B. Costa-Pierce (Editor), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society and American Tilapia Association, Baton Rouge, Louisiana. (in press)
Fitzsimmons, K. 1999. Tilapia aquaculture in Mexico In: B. Costa-Pierce (Editor), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society and American Tilapia Association, Baton Rouge, Louisiana. (in press)
Fridley, R.B., R.H. Piedrahita, and T.M. Losordo, 1988. Challenges in aquacultural engineering. Agricultural Engineering, 69(4):12–15.
Gross, A., C.E. Boyd, and J. Seo, 1999. Evaluation of the ultraviolet spectrophotometric method for the measurement of total nitrogen in water. Journal of the World Aquaculture Society, 30:388–393.
Gross, A., C.E. Boyd, and C.W. Wood, 1999. Ammonia volatilization from freshwater ponds. Journal of Environmental Quality, 28:793–797.
Hopkins, K.D., J.E. Lannan, and J.R. Bowman, 1988. Managing a data base for pond research data—the CRSP experience. Aquabyte, 1(1):3–4.
Liu, K.M. and W.Y.B. Chang, 1992. Bioenergetic modeling of effects of fertilization, stocking density, and spawning on growth of the Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture and Fisheries Management, 23:291–301.
Losordo, T.M. and R.H. Piedrahita, 1988. Modeling vertical water quality profiles in aquaculture ponds, review and evaluation. Proceedings of the Conference Aquacultural Engineering: Technologies for the Future at Stirling, Scotland. I. Cheme Symposium Series No. 111: EFCE Publications Series No. 66, Rubgy, United Kingdom, pp. 313–327.
Losordo, T.M. and R.H. Piedrahita, 1988. Simulating aquacultural pond thermal stratification with a spreadsheet model. American Society of Agricultural Engineers, 88-5003, 38 pp.
Losordo, T.M., J.M. Ebeling, and R.H. Piedrahita, 1986. Stratification measurement techniques in aquaculture ponds. American Society of Agricultural Engineers, 86-5047, 14 pp.
Losordo, T.M., R.H. Piedrahita, and J.M. Ebeling, 1988. An automated water quality acquisition system for use in aquaculture ponds. Aquacultural Engineering, 7:265–278.
Piedrahita, R.H., 1987. Sensitivity analysis for an aquaculture pond model. In: J.G. Balchen (Editor), Automation and Data Processing in Aquaculture. IFAC Proc. Ser. No. 9, Proceedings of the IFAC Symposium, Trondheim, Norway, 18–21 August 1986, pp. 119–123.
Piedrahita, R.H., 1988. Introduction to computer modeling of aquaculture pond ecosystems. Aquaculture and Fisheries Management, 19:1–12.
Piedrahita, R.H. and D.E. Brune, 1989. Aquacultural Engineering: Aquatic habitat commands innovative thrusts. Agricultural Engineering, 70(1):30–32.
Piedrahita, R.H. and G. Tchobanoglous, 1987. The use of human wastes and sewage in aquaculture. In: D.J.W. Moriarty and R.S.V. Pullin (Editors), Detritus and microbial ecology in aquaculture: ICLARM Conference Proceedings 14, Manila, Philippines, pp. 336–352.
Piedrahita, R.H., J.M. Ebeling, and T.M. Losordo, 1987. Use of data acquisition systems in aquaculture. In: J.G. Balchen (Editor), Automation and Data Processing in Aquaculture. IFAC Proc. Ser. No. 9, Proceedings of the IFAC Symposium, Trondheim, Norway, 18–21 August 1986, pp. 259–262.

Piedrahita, R.H., G. Tchobanoglous, and B. Moore, 1987. Effect of organic matter addition to fish culture systems. Transactions of American Society of Agricultural Engineers, 30(1):233–237.

Piedrahita, R.H., D.E. Brune, G. Tchobanoglous, and G.T. Orlob, 1984. A general model of the aquaculture pond ecosystem. Journal of the World Mariculture Society, 14:355–366.

Potts, A.C. and C.E. Boyd, 1998. Chlorination of channel catfish ponds. Journal of the World Aquaculture Society, 29:432–440.

Rodriquez, F. and T. Popma, 1999. Tilapia aquaculture in Colombia. In: B.A. Costa-Pierce and J.E. Rakocy, (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana. (in press)

Smith, D.W. and R.H. Piedrahita, 1988. The relation between phytoplankton and dissolved oxygen concentration in fish ponds. Aquaculture, 68:249–265.

Teichert-Coddington, D.R. and R.O. Smitherman, 1988. Lack of response by *Tilapia nilotica* to mass selection for rapid early growth. Transactions of the American Fisheries Society, 117:297–300.

Teichert-Coddington, D.R., L.L. Behrends, and R.O. Smitherman, 1990. Effects of manuring regime and stocking rate on primary production and yield of tilapia using liquid swine manure. Aquaculture, 88:61–68.

Yohe, J.M., P. Barnes-McConnell, H. Egna, J. Rowntree, J. Oxley, R.G. Hanson, D. Cummins, and A. Kirksey, 1991. The Collaborative Research Support Programs (CRSPs): 1978 to 1990. In: Toward Sustainability—A Plan for Collaborative Research on Agriculture and Natural Resource Management. National Academy Press, Washington, D.C., 36 pp.

Yohe, J.M., P. Barnes-McConnell, H. Egna, J. Rowntree, J. Oxley, R.G. Hanson, D. Cummins, and A. Kirksey, 1995. The CRSPs: International Collaborative Research Support Programs. In: J.F. Leslie and R.A. Frederiksen (Editors), Disease Analysis through Genetics and Biotechnology. Iowa State University Press, Ames, Iowa, 321 pp.

Presentations

Bowman, J. Soil pH and liming: A review of acidity/alkalinity management practices in aquaculture. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Boyd, C.E. Use of probiotics in aquaculture. Presented to Fifth Asian Aquaculture Conference, Chiang Mai, Thailand, 1998.

Boyd, C.E. Shrimp farming and the environment. Presented to the IV Ecuadorian Symposium on Aquaculture, Guayaquil, Ecuador, 22–27 October 1997.

Boyd, C. E. Soil and water quality management in shrimp farming. Presented to Aquaculture Brazil '98 at Recife, Brazil. 1998.

Boyd, C.E. Control of suspended solids in effluents from coastal aquaculture ponds. Presented to Aquaculture '99, World Aquaculture Society Annual Meeting, Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E. Promoting environmentally responsible aquaculture to meet world food needs. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E.. The Global Aquaculture Alliance Codes of Practice. Aquaculture '99, World Aquaculture Society Annual Meeting, Sydney, Australia, 26 April–2 May 1999.

Boyd, C.E. Water quality in channel catfish farming. Presented to Aquaculture '99, World Aquaculture Society Annual Meeting, Sydney, Australia, 26 April–2 May 1999.

Brown, C. Ontogeny of digestive enzymes in marine larvae: Dietary and hormone effects. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Brown, J.J., E.P. Glenn, and K.M. Fitzsimmons. Forage crop production on highly saline aquaculture effluent. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Chang, W.Y.B. Large lakes in China. Presented to 29th Conference of the International Association for Great Lakes Research, 26–29 May 1986.

Chang, W. China integrated aquaculture: An efficient ecological system. Presented to the Limnology & Oceanography 1987 Annual Meeting.

Chang, W. The world's highest lake: Tibetan Lakes. Presented to 30th Conference of the International Association for Great Lakes Research, 1987.

Couplets, I.I. I dream of a pond with 5Y3/2 soil/With runoff well managed so as not to spoil/A countryside verdant where farmers work smarter/For more fish to eat and more fish to barter. (in verse)

Fitzsimmons, K. High school students and aquaculture projects. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 January 1999.

Fitzsimmons, K. and B.C. Posadas. Consumer demand for tilapia products in the U.S. and the effects on local markets in exporting countries. Presented to the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9–12 November 1997.

Lin, C.K. Inland marine shrimp culture and its legislative, environmental and socio-economic implications in Thailand. Presented to Aquaculture '99, WAS Annual Meeting at Sydney, Australia, 26 April–2 May 1999.

Lin, C.K. and C. Limsuwan. Management strategies and approaches for water quality improvement in shrimp farming. Presented to the American Association for the Advancement of Science at Philadelphia, Pennsylvania, 12–17 February 1998.

Lin, C.K., J.B. Hambrey, and J. Szyper. Environmental impact assessment for a shrimp farm project in Tanzania: a case study. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Lin, C.K., W. Ruttanagosrigit, D. Thakur, and P. Wanuchsoontorn. Organic matter and nutrients in sludge of closed ponds for intensive shrimp culture. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15–19 February 1998.

Muthuwan, V. and C.K. Lin. Green water recirculating system for intensive culture of marine shrimp (*Penaeus monodon*). Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 November 1998.

Phelps, R.P., K.L. Veverica, R.S. Weyers, and J.J. Duffy. Induced spawning of the red snapper, *Lutjanus campechanus*, using three different hormone treatments. Poster presented to the World Aquaculture Society Meeting at Bangkok, Thailand, January 1996.

APPENDIX 8. ACRONYMS

AAAS	American Association for the Advancement of Science
AARM	Aquaculture and Aquatic Resources Management
AIARD	Association of International Agriculture and Rural Development
AIT	Asian Institute of Technology
AID	Agency for International Development
ALCOM	Aquaculture for Local Community Development Programme
ANDAH	Asociación Nacional de Acuicultores de Honduras (Honduran National Association of Aquaculturists)
AU	Auburn University
BASIS CRSP	Broadening Access and Strengthening Input Market Systems CRSP
BFAR	Bureau for Fisheries and Aquaculture Research
BIFAD	Board for International Food and Agricultural Development
BOD	Biochemical Oxygen Demand
BOD	Board of Directors
CAMEL	Collection and Management of Electronic Links
CARE	Cooperative for Assistance and Relief Everywhere
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture)
CIDA	Canadian International Development Agency
CIESIN	Consortium of International Earth Science Information Networks
CIFAD	Consortium for International Fisheries and Aquaculture Development
CLAR	Central Laboratory for Aquaculture Research
CLSU	Central Luzon State University
CODDEFFAGOLF	Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (Committee for the Protection and Development of the Flora and Fauna of the Gulf of Fonseca)
CRI	Centro Regional de Investigaciones (Regional Research Center)
CRSP	Collaborative Research Support Program
DANIDA	Danish International Development Agency
DAP	Diammonium Phosphate
DAST	Data Analysis and Synthesis Team
DIGEPESCA	Dirección General de Pesca y Acuicultura (General Directorate for Fisheries and Aquaculture)
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DSS	Decision Support System
EAEN	East African Environmental Network
EARTH	Escuela de Agricultura de la Region Tropical Humeda (Agriculture School of the Tropical Humid Region)
EDC	Education Development Component
EdOp Net	Educational Opportunities Network
EEP	External Evaluation Panel
EIFAC	European Inland Fisheries Advisory Commission
ESPOL/CENAIM	Escuela Superior Politécnica del Litoral/Centro Nacional de Acuicultura e Investigaciones Marinas (Coastal Polytechnical University/National Center for Aquaculture and Marine Research)
FAC	Freshwater Aquaculture Center
FAO	Food and Agriculture Organization
FARMESA	Farm-level Applied Research Methods for East and Southern Africa
FCR	Feed Conversion Ratio
FDA	United States Food and Drug Administration
FIRI	Inland Water Resources and Aquaculture Service of the FAO
FISA	Fisheries Society of Africa
FPX	Federación de Agroexportadores de Honduras (Federation of Export Producers)
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GMT	Genetically Male Tilapia
GOH	Government of Honduras
GRE	Graduate Record Examination
HACCP	Hazard Analysis Critical Control Point
HBOI	Harbor Branch Oceanographic Institute

HIMB	Hawaii Institute of Marine Biology
HTML	Hypertext Markup Language
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Center for Research in Agroforestry
IDRC	International Development Research Centre
IFS	International Foundation for Science
IIAP	Instituto de Investigaciones de la Amazonia Peruana (Research Institute of the Peruvian Amazon)
IMNC	Information Management and Networking Component
INTSORMIL CRSP	International Sorghum and Millet Collaborative Research Support Program
IPB	Institut Pertanian Bogor
ISTA IV	Fourth International Symposium on Tilapia in Aquaculture
IUCN	World Conservation Union
IQC	Indefinite Quantity Contract
JCARD	Joint Committee on Agricultural Research and Development
JICA	Japan International Cooperation Agency
KEMRI	Kenya Medical Research Institute
KFFA	Mt. Kenya Fish Farmers Association
KUL	Katholieke Universiteit Leuven (Catholic University of Leuven)
LUPE	Land Use Productivity Enhancement (Proyecto Mejoramiento del Uso y Productividad de la Tierra)
MDHT	17α-methyldihydrotestosterone
ME	Management Entity
MOU	Memorandum of Understanding
MT	17α-methyltestosterone
NAC	National Aquaculture Centre
NACA	Network of Aquaculture Centres in Asia-Pacific
NARP	National Agricultural Research Project
NCRAC	North Central Regional Aquaculture Center
NGO	Nongovernmental organization
NIFI	National Inland Fisheries Institute
NPH	Nuestros Pequeños Hermanos (Our Little Brothers)
NTIS	National Technical Information Services
OAU/STRC	Organization of African Unity's Scientific, Technical, and Research Commission
OSU	Oregon State University
PAR	Photosynthetically Active Radiation
PARADI	Poissons Africains: Rôle et Applications de la Diversité (African Fish: Role and Applications of Diversity)
PD/A CRSP	Pond Dynamics/Aquaculture Collaborative Research Support Program
PDA-CRSP-L	PD/A CRSP Electronic Mailing List
PDF	Portable Document Format
PI	Principal Investigator
PL	Post-Larval
PMO	Program Management Office
PRADEPESCA	Programa Regional de Apoyo al Desarollo de la Pesca en el Istmo Centroamericano (Regional Development Support Program for Fisheries in the Central American Isthmus)
PROARCA	Programa Ambiental Regional para Centroamerica (Central American Regional Environmental Program)
RAISE	Rural Agriculture Incomes in a Sustainable Environment
RFP	Request for Proposals
RSA	Republic of South Africa
SACRED	Sustainable Agricultural Centre for Research and Development in Africa
SADC	Southern African Development Community
SANREM CRSP	Sustainable Agriculture and Natural Resources Management CRSP
SARDev	Sustainable Aquaculture for Rural Development
SEAFDEC	Southeast Asian Fisheries Development Center
SEAPOL	Southeast Asian Programme in Ocean Law, Policy, and Management
SEDEC	Socio-Economic Development Centre
SIDA	Swedish International Development Cooperation Agency
SIUC	Southern Illinois University at Carbondale
SPAAR	Special Program for African Agricultural Research
TA	Trenbolone Acetate
TAFE	Technical and Further Education
TC	Technical Committee
TOEFL	Test of English as a Foreign Language
TPS	Technical Progress Subcommittee

TSP	Triple Superphosphate
UA	University of Arizona
UAM	Universidad Autónoma Metropolitana (Metropolitan University)
UAPB	University of Arkansas at Pine Bluff
UCD	University of California, Davis
UG	University of Georgia
UH	University of Hawaii
UJAT	Universidad Juárez Autónoma de Tabasco (University of Tabasco)
UM	The University of Michigan
UNAP	Universidad Nacional de la Amazonia Peruana (National University of the Peruvian Amazon)
UNR	Université Nationale du Rwanda (Rwandan National University)
UO	University of Oklahoma
US	United States
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
UV	Ultraviolet
WARDA	West African Rice Development Association
WAS	World Aquaculture Society
WRAC	Western Regional Aquaculture Consortium
YEDC	Yukon Development Education Centre

Appendix 9. Seventeenth Annual Technical Report Contents

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