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 1997 to 31 July 1998.

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-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 decisions and accomplishments by the Program Management Office, Board of Directors, External Evaluation Panel, and Technical Committee in the reporting period are noted below.

- In October 1997, program Director Hillary Egna was presented with the first "Women in Leadership" award by the Pacific Northwest Chapter of UNIFEM (The United Nations Development Fund for Women). UNIFEM supports the development initiatives of women worldwide. The Pacific Northwest Chapter of UNIFEM instituted this award to recognize and honor women and organizations who have made outstanding contributions to the advancement of the status of women, families, and communities.

- The PD/A CRSP co-sponsored the Fourth International Symposium on Tilapia in Aquaculture held in Orlando, Florida, 9-12 November 1997. Director Hillary Egna was among the speakers at the opening address, where she had the opportunity to introduce the PD/A CRSP to the attendees. In addition, the PD/A CRSP presented its research work at the conference both through a display booth and through the presentations of CRSP-funded research.

- The Ninth Work Plan Restricted Request for Proposals (RFP) for CRSP research to be carried out in the period 1 July 1998 to 30 June 2000 was developed with input from the CRSPs three advisory groups and solicited proposals for regional work plans, cross-cutting research work plans, and work plans for specific research support activities. The deadline for submissions was 1 October 1997. The PMO coordinated a peer review of proposals received and a review by advisory committees (BOD and EEP).

  The peer review was conducted in two phases—a review inclusive of all proposals (involving more than 100 scientists external to the TC) and subsequently a TC review for revised proposals. (Authors of proposals which received a "Fund after Major Revision" recommendation in the external review were given the opportunity for revision.)

- The EEP submitted its final 1996 report to the PMO in December 1997. The report was distributed to program participants for comment, and these comments were incorporated into the MEs response. The *Annual External Evaluation Panel Review Report of the PD/A CRSP for the Period January 1996 - January 1997*, containing the EEPs report and the responses of the ME, was published in January 1998. The PMO has subsequently followed up on the report and begun implementing many of the EEPs recommendations.

- The PMO organized and coordinated attendance at the program's Annual Meeting, which was held in conjunction with the World Aquaculture Society meeting in Las Vegas, Nevada, in February 1998.

- The PMO designed and distributed Project Profiles to the EEP and the BOD at the Annual Meeting, and to program participants thereafter. These Profiles were developed at the request of EEP members, who expressed an interest in receiving information related to projects in a summarized format. The Profiles are intended to serve as management and fiscal tracking tools and to provide background information to assist the ME in decision-making and the BOD and EEP in their advisory roles.

- The TC revised its bylaws during the program's Annual Meeting. Also at the Annual Meeting, Doug Ernst, Kevin Fitzsimmons, and Marion McNamara were elected, and Shree Nath and Bill Shelton were re-elected to the TC. John Bolte and Jim Szyper stepped down after completion of their terms of office on the *Work Plan and Budgets* and the *Materials and Methods Subcommittees*, respectively. (Since the Annual Meeting, Peter Edwards has resigned from his seat on the *Technical Progress Subcommittee* due to conflicting time commitments; researcher Yang Yi was appointed by the Co-chairs to fill the vacant seat.) A complete listing of Technical Committee and Subcommittee members appears in Appendix 2.

- The PMO initiated a new subcontract with Auburn University scientists for research in adoption and diffusion of technologies to be carried out in conjunction with collaborators in Guatemala and Panama, and from the University of Delaware.

- The PMO produced the *Addendum to the Eighth Work Plan*. Researchers may in the course of their work find that a change in experimental design or schedule is needed to their approved work plan. Any such change request is made to the Co-chairs of the TC for their review and approval on technical considerations. If approved, the change request is forwarded to the PMO for final approval by the Director on programmatic considerations. Change requests that received the approval of the TC and the Director were collected and published in the first *Addendum*. Changes that have occurred since the *Addendum* was compiled will appear in a forthcoming *Second Addendum to the Eighth Work Plan.*

- The PMO commissioned a review of project impact indicators to determine whether they adequately reflect and record project impact. Having worked personally with almost every CRSP researcher, Dr. Candace Buzzard, a specialist in project monitoring and performance measures, addressed attendees of the program's Annual Meeting. In addition, *A Review of Impact Assessment and Performance Indicators for the PD/A CRSP*, which summarizes the process, was disseminated to program participants in May 1998. The review found that "the PD/A CRSP has taken steps to institute an effective system for monitoring of progress toward achieving its objectives and documenting the apparent impact of individual project activities on an on-going basis."

- The CRSP welcomed Dr. Edna McBreen, Associate Vice Chancellor of the Institute of Agriculture and Natural Resources at the University of Nebraska, Lincoln, as a new member of the EEP. (A listing of panel members appears in Appendix 2.)

- Under previous grants, the Philippines served as a companion site to the prime Southeast Asia site in Thailand. The *Continuation Plan 1996-2001* identified the Philippines as a potential prime site. The Management Entity issued a restricted Request for Proposals (RFP) for a lead institution for a Philippines prime site with a deadline of 5 May 1997. Two proposals were received, but the RFP was reopened until 1 October 1997 owing to an inconclusive external peer review and evaluations by the BOD and EEP. In response to the re-issued RFP, three proposals were received. The ME, in concert with the BOD and EEP, recommended that the University of Hawaii receive the award for Lead Institution of the PD/A CRSP Philippines Project. A new subcontract with the University of Hawaii was initiated and is in place as of July 1998.

- The Director participated in CRSP Council meetings (both by teleconference and in person) throughout the reporting period and contributed to the Council's input on revised guidelines for CRSPs that are being developed by the Board for International Food and Agriculture Development. In addition, the Director attended the 1997 International Center's Week in Washington, DC. Also in the reporting period, networking was stepped up between the PMO and various professional associations (NASULGC, AIARD, World Aquaculture Society, American Tilapia Association, etc.) and organizations (UN-FAO, ICLARM, etc.).

- The Director and PMO and Information Management staff also contributed to the planning and development of two other CRSP Council activities: the CRSP Symposium to be held in conjunction with the annual meeting of the American Society of Agronomy in Baltimore, Maryland, in October 1998, and the USAID-CRSP Exhibit "Mutual Benefits for Developing Countries and the United States" on display from September through December 1998 at the Ronald Reagan Building in Washington, DC.

- Over the course of the reporting period, two meetings of the BOD were held during the Program's Annual Meeting in Las Vegas, Nevada, on 12 and 13 February 1998, and two teleconferences were held on 7 October 1997 and 12 May 1998. In addition, a letter vote was conducted in June 1998. The ME also participated in meetings with the EEP at the Fourth International Society for Tilapia in Aquaculture (ISTA) Conference in Florida (November 1997) and at the Annual Meeting (February 1998) and by teleconference in December 1997 and in July 1998.

- The PMO collaborated with The University of Michigan, the Asian Institute of Technology, and lead university Virginia Polytechnic Institute to develop a proposal in response to a USAID Request For Application (Management of Aquatic Ecosystems through Community Husbandry [MACH] project, targeted to address problems of floodplain ecosystems in Bangladesh).

- In April 1998 the PD/A CRSP was informed of a $1.2 million budget cut as compared to the amount authorized in the program's current grant (1996-2001) for the third year of operations. After discussions with the Agency, the Director was able to obtain an additional $200,000 for special projects. Substantial efforts were made in public relations, educational awareness, and federal relations throughout the remainder of the reporting period.

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 represents a wide range of US and international aquacultural experience. During the reporting period, participating US institutions included:

- Auburn University;
- Oregon State University;
- Southern Illinois University at Carbondale;
- The University of Michigan;
- University of Arizona;
- University of Arkansas at Pine Bluff;
- University of California at Davis;
- University of Delaware;
- University of Hawaii;
- University of Georgia;
- University of Oklahoma; and
- 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 a formal tie between a US and host country institution, which were in place during the reporting period include those between:

- International Center for Aquaculture and Aquatic Environments, Auburn University, and the Secretaría de Agricultura y Ganadería, Republic of Honduras;
- Southern Illinois University, Carbondale, and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana;
- Oregon State University Fisheries and Wildlife Department and the Department of Fisheries, Kenya; and
- The University of Michigan and the Asian Institute of Technology, Thailand.

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

EIGHTH WORK PLAN

The CRSPs *Eighth Work Plan*, describing activities to be conducted by the CRSP during the period 1 August 1996 to 31 July 1998, was developed by the TC and is the first work plan designed within the framework of the *Continuation Plan 1996-2001*. The *Addendum to the Eighth Work Plan*, containing approved methods and schedules changes to work first described in the *Eighth Work Plan*, was printed in Spring 1998. Changes approved since the *Addendum* was published will be collected and published in a forthcoming *Second Addendum to the Eighth Work Plan*.

Previous activities were described in the *Interim Work Plan* which covered the period from 1 September 1995 to 31 August 1996. The Interim Work Plan was necessitated by a cost-extension to the preceding grant which was scheduled to end with the Seventh Work Plan.

The first three CRSP work plans 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.

In comparison with previous work plans, the investigations contained in the *Eighth Work Plan* reflect the broadening of research which was proposed in the *Continuation Plan 1996-2001* as well as increased integration among sites. In addition to specific research activities implemented at prime sites in Africa, Asia, and Latin America, the *Eighth Work Plan* includes, for the first time, work plans for cross-cutting research. Cross-cutting research is research 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. This research builds upon and expands results obtained through earlier PD/A CRSP efforts.

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 socio-economic 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 P. Bolte	US Principal Investigator, Project Leader
Douglas H. Ernst	Database Manager

Networking Activities

Database Manager Doug Ernst served as president of the American Fisheries Society Bioengineering Section. He was also in contact with the Consortium for International Earth Science Information Network (CIESIN) regarding Internet GIS-based access to data in the PD/A CRSP Central Database. During the reporting period, Ernst continued collaborative work with the International Center for Living Aquatic Resources Management (ICLARM) and the Network of Aquaculture Centers in Asia Pacific (NACA).

Publication

Ernst, D.H., J.P. Bolte, D. Lowes, and S. Nath, 1998. PD/A CRSP Central Database: A standardized information resource for pond aquaculture. In: K. Fitzsimmons (Editor), Tilapia Aquaculture: Proceedings from the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 683-700.

Conferences

Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997. (Ernst)
PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Ernst)
Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Ernst)
Annual Governing Board Meeting of the American Fisheries Society, March 1998. (Ernst)

REPORT: PD/A CRSP CENTRAL DATABASE MANAGEMENT AND DEVELOPMENT

Eighth Work Plan, Database Management 1 (DM1)

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BACKGROUND

The PD/A CRSP Aquaculture Central Database is a centralized data storage and public query-retrieval system for CRSP-sponsored research in aquaculture food-fish production (Hopkins et al., 1987; Batterson et al., 1991; Bolte et al., 1997; Ernst et al., 1997). The Database is open for data submission from all PD/A CRSP-funded aquaculture research projects, as well as other aquaculture research efforts with compatible objectives and compliance with standardized methodology (Egna, 1996; Ernst and Bolte, 1997). For data use, the Database is available cost-free and is of interest to researchers, educators, outreach and extension agents, and producers in pond-based aquaculture.

Datasets may be searched and extracted from the Database based on fish culture location, calendar year, fish species, and desired data types. A comprehensive interface to the data and related information in the Database is provided at its designated Internet website (http://biosys.bre.orst.edu/crspDB). This publication mechanism provides immediate and comprehensive access to the Database worldwide. Since its inception in January 1997, the Database website has received 1,400 visitors. While it is not known how these visitors utilized the site, this level of use compares well to the 30 documented cases of Database use from 1983 (inception) through 1996. For intensive users of the Database, the entire Database is also available on electronic media (100 MB Zip disk).

The Database currently contains over 80 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 USA.

Two fundamental rationales for developing the Database were to:

1) Create a mechanism for analysis of variance among geographically dispersed aquaculture research sites, in addition to analyses within single ponds and among ponds at a single location; and
2) Support development of predictive models for aquaculture pond processes (Egna et al., 1987).

Prein et al. (1993) also present a strong argument for the development of standardized aquaculture databases. They show that when individual, standardized studies are combined into a single dataset, a continuum of data is created that spans the fish culture methods used and fish production levels achieved. This provides an opportunity for application of statistical, multivariate analyses and elucidation of multiple factor, synergistic relationships that would otherwise be not possible or possible only with additional research.

In addition, regional-scale and facility-scale computer tools are increasingly being used to locate, plan, design, and manage aquaculture facilities (Ernst and Nath, 1997). These computer tools require standardized datasets for their development and calibration and often utilize predictive models developed through aquaculture research. Finally, the Database may be applied directly to practical problems in aquaculture design and management. For this purpose, the Database provides comprehensive results of rigorous applied studies that may be used as sources of benchmark and comparative fish production data for specific fish culture sites, methods, and species.

OBJECTIVES

Objectives of the work completed under the Eighth Work Plan were to advance the management of the Database by carrying forward work in progress and opening new areas of development. These objectives fall into two major areas consisting of:

1) *Research data acquisition* for the Database from CRSP principal investigators and
2) *Research support and outreach* functions provided by the Database for the CRSP.

Regarding data acquisition, objectives include improved capacity, efficiency, standards, and incentives for data submission to the Database. Regarding research support and outreach, objectives include improved access, reporting, and usefulness of the Database to researchers and the greater aquaculture community.

These objectives are represented by a number of specific tasks, and the remainder of this discussion is organized according to these tasks. For each task, background information and accomplishments are given as well as directions of continued work to provide continuity between work plans. References to *menu items* in this discussion refer to menu items on the home page of the Database website where additional documentation of the given subject area can be found. The reporting period of this report is 1 August 1997 to 31 July 1998.

TASKS AND ACCOMPLISHMENTS

Data Submission

Tasks

Track status of datasets due to the Database from CRSP studies and add submitted data to the Database when forthcoming.

Background

As of 31 July 1998, the Database contained data from 82 studies performed under the First through Eighth CRSP Work Plans (Table 1; menu item Experiment List). This represents approximately two-thirds, by rough estimation, of the total studies performed under the CRSP for this period. For studies prior to the Eighth Work Plan, data submission from CRSP principal investigators to the Database was not contractually enforced. For the Eighth and later Work Plans, data submission from CRSP principal investigators to the Database will be contractually enforced. Based on these differing policies, follow-up procedures on past-due data submissions from these two management periods require different mechanisms. A critical requirement common to all data submission tracking is the availability of summary tables that provide listings of studies performed in each work plan. Data for each study should include: 1) study title and identification number; 2) study theme; 3) site name; 4) start and end dates of study period; 5) data types collected; 6) responsible principal investigators; and 7) data and report submission status.

Completed

For the Eighth Work Plan, a summary table was developed in collaboration with the PMO, where data formats, housing, and interfaces are provided at the Database website and table content is the responsibility of the PMO (except data-submission status). This table facilitates project tracking by providing a single, current source of concurrently available information. Methods used in the Database and its web interface to support this table can be easily duplicated; thus tables and interfaces for future work plans can be implemented with little additional work. Write capabilities (data entry and editing) for these tables are restricted to the PMO and Database Manager. Read capabilities (data review) are not restricted and provide summary information for project management as well as a listing of current research areas for website users (menu item Projects).

For Work Plans prior to the Eighth (i.e., in the period ending 31 July 1996), the CRSP Technical Progress Subcommittee (TPSC) was assigned the responsibility of developing Work Plan summary tables (1997 PD / A CRSP Annual Meeting). This table was meant to provide a basis for both the Database Manager and the TPSC to contact responsible parties regarding the status of past-due data submissions and intended submission timelines. Given that the submission of this data relies on the goodwill of the responsible parties, incentives to researchers for data submission have been addressed in completed or ongoing work. These include author citations for datasets extracted by data users, linkage to related author

Table 1. Total aquaculture experiments reported in the PD / A CRSP Central Database as of 31 July 1998, by site and work plan.

Site Name	Work Plan									Total
	1	2	3	4	5	6	7	Interim	8	
Choluteca, Honduras								1		1
Comayagua, Honduras	1	2	2	2	4	1				12
Aguadulce, Panama	2	2	2							6
Gualaca, Panama	2		2							4
UNAP, Peru										0
Abbassa, Egypt							1			1
Sagana, Kenya										0
Rwasave, Rwanda	2		2	4	3					11
Bogor, Indonesia	2	1	2							5
FAC, Philippines						3	3			6
Iloilo, Philippines	2	2	2							6
AIT, Thailand				3	3	3	3			12
Ayutthaya, Thailand	1	2	2	3	4	4	1			17
Huay Luang, Thailand										0
Nong Sua, Thailand	1									1
TOTAL	13	9	14	12	14	11	8	1	0	82

Data submitted[1]	Data owed [2]	No experiments conducted

[1] Numbers in white cells indicate number of studies submitted and do not necessarily include all studies conducted. Total number of studies with data owed is under study by Technical Progress Subcommittee.
[2] "Data owed" status is under study by Technical Progress Subcommittee.

publications, statistical and reporting procedures for datasets, and expanded visibility and potential for use of study data as made possible by its publication on the World Wide Web. The position espoused by the Database Manager is that publication of data in the Database should be viewed as an opportunity for additional research outreach, impact, and recognition.

Continued
As of August 1998, the Database Manager has not received any materials from the TPSC regarding the generation of summary tables for the First through Interim Work Plans. When this information is forthcoming, the Database Manager and the TPSC will be able to take a more active role in pursuing past-due datasets from CRSP-sponsored research.

Training Workshops

Tasks
Provide training for CRSP principal investigators on procedures for submitting data to the Database and use of the Database for research purposes.

Background
Database training budgets for personnel travel and lodging are outside the scope of the Database Manager. However, budgetary and organizational support may be provided by the Education Development Component of the CRSP. This practical training promotes efficient data management practices by researchers, from the format of record spreadsheets used at research sites to the submission of data to the Database. This training also serves to familiarize participants with research applications available to them at the Database website and the benefits of Database publication of their work.

Completed
In August 1997, a one-day training workshop on the Database and use of the World Wide Web was organized by Marion McNamara of the CRSP Education Development Component. Participants included Eneida Ramírez (Honduras), Antonio Circa (Philippines), Fernando Alcántara-Bocanegra (Peru), and Bethuel Omolo (Kenya). Participant feedback showed that the training was beneficial to their research efforts and their collaboration with the CRSP Database. A similar training scheduled for the Thailand CRSP site in the Fall of 1998 has been canceled due to lack of funding.

Continued
Future Database training workshops depend on the availability of external funding.

Supported Data Types

Tasks
Complete additional data tables and associated data submission protocols for data types generated by CRSP studies that are not currently supported by the Database.

Background
Consideration of new data types for the Database is an ongoing process performed in response to the development of new research areas and based on discussions with CRSP principal investigators. Conditions for addition of new data types to the Database are that the data represent a sufficient level of subject and content development and that the data have thematic relevance to the greater aquaculture community. Potential data types that were considered in the current reporting period included: 1) fish reproduction; 2) socio-economic; and 3) economic data types.

Completed
For fish reproduction, discussions with Martin Fitzpatrick (OSU) showed that this subject area was not yet sufficiently developed for inclusion in the Database but likely would be within a few years. For socioeconomic data, a standardized questionnaire was provided by Joe Molnar (AU) for impact

assessment regarding adoption of specific aquaculture technologies. For economic data, Database capabilities for partial budget analyses were developed in cooperation with Carole Engle (UAPB). 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. Data type and formatting requirements for submission of socioeconomic and economic data have been added to the Data Submission Manual (Ernst and Bolte, 1997; menu item Data Submission). Data types currently supported by the Database now include the following: 1) weather; 2) pond soil analyses; 3) pond applications; 4) water quantity variables and management; 5) water quality variables and natural productivity; 6) fish productivity; 7) socioeconomic; and 8) economic.

Continued

Opportunities for adding new data structures to the Database will continue to be assessed, based on subject development and thematic relevance.

Handbook of Analytical Methods

Tasks

Add the PD/A CRSP Handbook of Analytical Methods (Piedrahita et al., 1991) to the Database, establish one-to-one linkages between Handbook variable names and Database data-field names, and provide a review interface for the Handbook at the Database website for use by research personnel and data users.

Background

Considering that standard research methods provide the basis for the existence of the Database, and that the Database provides a permanent storage medium for the PD/A CRSP, incorporation of the Handbook into the Database helps support both research personnel and data users. Standardized methods are an essential requirement of the Database, where replicate data from multiple temporally and spatially distributed aquaculture studies are combined under a common data organization and access structure. In addition, at the PD/A CRSP 1997 Annual Meeting, the Materials and Methods Subcommittee delegated responsibilities for Handbook revisions and additions. The Database Manager was charged with receiving and collating these updated methods, using the existing version of the Handbook as a starting point.

Completed

An electronic form of the Handbook was added to the Database, data field names for each variable covered in the Handbook were established under individual methods, and the Handbook was provided with a review interface (menu item Research Methods). The original, printed Handbook contains copyrighted materials, which are made available to CRSP researchers only. For public domain publication of the Handbook at the Database website, copyrighted sections are replaced with references. This public domain version is useful to data users as contextual information for specific studies (materials and methods) and to aquaculture research projects outside of the CRSP that are required to submit data developed under standardized methodology.

Continued

As inputs from the Materials and Methods Subcommittee come forward, methods in the Handbook will be updated.

Experiment-Treatment Specifications

Tasks

Add experiment-treatment specifications to the Database that define the materials and methods used for each treatment dataset regarding fish production methods. Include fish production methods in Database search criteria.

Background

Database search criteria of fish production site, dates, fish species, and desired data types may be used to refine and limit data searches to a large degree. However, additional search criteria of fish production methods would be useful to Database users. These production methods are defined by experiment-treatment specifications and include the following:

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

This approach requires that each set of treatment data in the Database, comprised of three or four sets of replicate data, is supported with complete treatment specifications. Unfortunately, treatment specifications for data submitted to the Database prior to January 1997 were not required. Experiment protocols and treatment specifications are now required at the time of data submission.

Completed

To generate experiment-treatment specifications for data submitted to the Database prior to January 1997, CRSP literature was initially consulted. However, CRSP Work Plans, Technical Reports, and Annual Reports were of limited use for defining treatment specifications in the Database, especially after the Third Work Plan, given their superset relationship to the subset of data in the Database, the apparent re-mixing of experiment treatments between proposals and reports, and lack of linking references in the reports and Database. Next, procedures were used to compile fish stocking, pond application, and water management data in the Database and summarize these data as replicate mean values. Results from this analysis were unable to provide complete treatment specifications and raised a number of questions. First, given that this procedure was performed for each experimental replicate (pond), it was not always clear how to group these replicates into treatments given the variability between replicates. Secondly, significant numbers of replicates showed no fish stocking (17%) and/or material applications (27%). With no corroborative information, it was not known if these replicates had missing data. Also, for derived replicate groupings, there was no mechanism to check the accuracy of derived treatment specifications.

Continued

Summary tables for the First through Interim Work Plans, to be developed by the TPSC (see Data Submission and Status Tracking), would be very helpful to the completion of this task. These summary tables would provide a basis for tracking datasets back to work plan and report literature where experiment objectives, protocols, and treatment specifications can be found. These summary tables would also help identify responsible principal investigators and determine the completeness of submitted datasets. If the TPSC provides no materials to the Database Manager by the 1999 PD/A CRSP

Annual Meeting, then treatment specifications derived from reported study data will be used. By either mechanism, treatment specifications will be reviewed by associated principal investigators where possible.

Contextual Linkage

Tasks
Provide context-sensitive linkage to supporting information for user-extracted datasets, including research site and facility descriptions, research author citation and contact information, and related publications.

Background
The value of extracted datasets to Database users is considerably enhanced by provision of related information, analogous to those provided in traditional printed publications of research studies. This information includes the following:

1) Principal investigator information to support data citations and referrals;
2) Site and facility descriptions to support fuller accounting of materials and methods; and
3) Associated publications that provide research objectives, experimental protocols, and discussions of results.

The Program Management Office already maintains much of this information as individual web documents, and thus the major remaining task was to develop procedures to dynamically link this information to user-extracted datasets based on dataset characteristics. Two major characteristics of datasets and related information that support this linkage procedure are study location(s) and time period(s).

Completed
Manual linkage to research site, author, and publication information is available at the Database website via hyperlinks to web documents maintained by the Program Management Office (PMO). Linkage to publications required the development of publication data tables and interfaces, used to locate and access specific publications (abstract or full text) maintained as individual web documents. Publication data tables consist of publication titles, authors, abstracts, keywords, and descriptions. These data may be searched based on keywords, subjects, and authors. Write capabilities (data entry and editing) for these publication tables are restricted to the PMO and Database Manager. Read capabilities (data review) are not restricted (menu item Publications). Content of the publications data table is the responsibility of the PMO, and there are currently 220 publications in the publications table.

Continued
Automated linkage to research site, author, and publication information will be developed when possible. This will consist of dynamically created sets of hyperlinks, presented to the Database user based on extracted datasets. Linkage to author information is currently hindered by the lack of summary tables for the First through Interim Work Plans (see Data Submission and Status Tracking). These tables would provide author-date-site linkage for past and current principal investigators of the CRSP.

Technical Support

Tasks
Provide a data dictionary, technical glossary, and users manual for Database users, available at the Database website.

Background
Definitions of data types (description and units) and technical terms used at the Database website, in conjunction with material contained in the Database Submission Manual and Handbook of Analytical Methods, are necessary for users to fully utilize the Database. A users manual is also necessary for users at all knowledge levels, given the relatively new type of information resource represented by the Database website. This manual should provide examples of typical Database search strategies and describe applications of extracted information to aquaculture design and management.

Completed
The data dictionary and technical glossary have been completed (see menu item Glossary).

Continued
The users manual will be completed following completion of statistical support procedures (see Reporting of Extracted Datasets).

Dataset Reporting

Tasks
Enhance the ability of Database users to utilize extracted datasets by providing graphical data presentation in addition to tabular summaries. A closely related task, beyond the scope of the current reporting period, is to provide statistical summaries of datasets to users.

Background
All tasks discussed in this report lead to better user support, but data reporting methods and applications are primary considerations. Availability of raw, replicate, sample data is of most use to people working in aquaculture research and model development. Users such as extension agents and producers are best supported by statistically distilled and graphical presentations of these data and design and management tools calibrated with these data.

Completed
Extracted datasets are currently available at the Database website as raw, replicate-level sampling data in tabular and graphical formats (e.g., water temperature and fish weight time-series data). Tabular data may be viewed at the Database website or downloaded to local computers, as comma-delimited ASCII files readable by spreadsheet programs. Graphical data presentation is also available at the Database website. This consists of combined XY line graphs for all replicates in the extracted dataset based on the selected variable as a function of time or water depth. Graph lines are color-coded and labeled by replicate (pond) name. Mechanisms to support graphical web presentation utilize a server application (Allaire Cold Fusion) to support client-server database access and database publication via the Internet. This application is used in conjunction with the database software (Microsoft Access). A programming language (Java, Sun Microsystems) is used to embed plots in web pages for graphical data retrieval.

Continued
Statistical summary procedures for extracted datasets are under development. Summary statistics will include time-series data for treatment means and variances (standard errors), analysis of variance, and fitted model parameters

(e.g., fish growth models). These statistics can be applied to graphical dataset presentation, for example, graphing of treatment means with standard error bars to show replicate variability. Summary data will also include variables calculated by combining data, for example, fish growth and feeding rates, feed conversion efficiency, and biomass density and productivity. Generation of summary calculations and statistics is also critical to the sharing of data from the CRSP Database to other information resources applicable to aquaculture (see Database Promotion).

Database Promotion

Tasks

Actively promote the Database to the greater aquaculture community through aquaculture conferences and publications, linkages to related websites and databases, and direct marketing to target audiences.

Background

The considerable effort that has gone into the development and publication of the CRSP Database must be supported through its promotion to researchers, educators, outreach and extension agents, and producers in pond-based aquaculture. Critical issues are user awareness of the Database availability, content, and applications. In addition, sharing of Database data with other aquaculture-related databases provides additional opportunity for users to be exposed to CRSP studies.

Completed

For the period of this report, the Database was presented at the Fourth International Symposium on Tilapia in Aquaculture (ISTA IV) (Ernst et al., 1997) and included in a session on aquaculture computer tools held at the 1998 Annual World Aquaculture Society Conference. Related databases and/or access sites currently in collaboration with the Database Manager for access to or containment of data in the CRSP Database include the ICLARM FishBase (Froese and Pauly, 1996), NACA (Bangkok, Thailand), and CIESIN. Simple site-to-site linkages with related aquaculture websites have also been established.

Continued

For data linkage with ICLARM, NACA, and CIESIN, data content and format requirements have been established, but transfer of or access to data in the Database will follow completion of statistical summary procedures (see Reporting of Extracted Datasets). These statistical summary procedures will be performed on the entire Database, and associated publication resources will be provided with summary treatment data rather than raw replicate data. Similarly, direct marketing of the Database beyond the research community (education, extension, and production) will follow completion of statistical summary capabilities and addition of data query constraints based on fish culture methods. Data submission from outside the PD/A CRSP has shown no success, but the potential for this type of collaboration will likely increase as the analysis capacity available at the Database website is further developed and made known.

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EDUCATION DEVELOPMENT

MOU No. RD009E

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Amy Heller	Student Worker (through July 1998)
Gabriela Montaño	Student Worker (Mexico)

Conference

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (McNamara)

REPORT: ANNUAL ACTIVITIES OF THE EDUCATION DEVELOPMENT COMPONENT

Eighth Work Plan, Human Capacity Development 1 (HCD1)

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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. The EDCs second year of operation is reported on during this period.

The EDC works with CRSP projects to design and implement appropriate training and education activities that support the research at each site. In addition to supporting site-specific activities, the EDC maintains a centralized clearinghouse for training and education opportunities in the fields of aquaculture, aquaculture development, aquatic ecology, fisheries, and natural resource management.

GLOBAL ACTIVITIES

Training Program for PD/A CRSP Research Associates
The EDC sponsored a three-week training program from 20 October to 8 November 1997 for Host Country Research Associates from Kenya, Honduras, Peru, and the Philippines. The training was designed to orient new collaborators to the CRSP and included sessions on gender considerations, experimental design, use of computer resources, and CRSP water quality and fish sampling techniques. Workshop participants began their program at Oregon State University, where they were welcomed by CRSP Board member Kelvin Koong, OSUs Dean of International Programs Jack Van de Water, CRSP Director Hillary Egna, and Deputy Director Brigitte Goetze. CRSP researchers Jim Bowman, Wilfrido Contreras, Martin Fitzpatrick, John Bolte, and Doug Ernst taught seminars, as did Ingvar Elle of the Information Management and Networking Component. Training participants continued on to Auburn University where they were welcomed by Bryan Duncan, chair of the CRSP Board of Directors, toured catfish aquaculture facilities, and attended workshops presented by CRSP researchers Tom Popma and David Teichert-Coddington on water quality and fish sampling techniques. The participants completed their program in Florida, where they attended the Fourth International Symposium on Tilapia in Aquaculture. At all three sites, participants attended seminars, lectures, and workshops, and gained first-hand knowledge of how university research and extension create partnerships with other governmental agencies and with the private sector.

Educational Opportunities Network (EdOp Net)
In addition to supporting activities that address specific needs in CRSP host countries, the EDC works to facilitate communication about educational opportunities worldwide in aquaculture and related fields. During this reporting period, the EDC continued publishing EdOp Net, a free monthly newsletter that summarizes educational and employment opportunities available in the fields of aquaculture, aquatic ecology, fisheries, fisheries biology, and natural resource management. EdOp Net is disseminated through the mail and through the Internet by email and the World Wide Web. Readership includes over 200 subscribers and over 1,600 hits on the web site each month. Toward the end of this reporting period, the Information Management Component assumed the responsibility for this publication.

International Conferences
The PD/A CRSP, through the EDC, was one of the sponsors of ISTA IV, the Fourth International Symposium on Tilapia in Aquaculture, held 9-12 November 1997 in Orlando, Florida. The EDC served as the CRSP link to the ISTA IV Planning Committee, providing assistance in organizing and publicizing the meeting.

Training Records
The EDC maintains records of formal and informal training efforts conducted by CRSP researchers, and makes this information available to CRSP researchers when requested. CRSP researchers have long recognized that education and training help to address the constraints to sustainable aquaculture development, and take advantage of opportunities to conduct formal and informal training activities. They conduct short courses and workshops, teach courses at host country institutions, and advise and mentor graduate students.

Even without formal financial support in the past, CRSP researchers have made significant contributions in the area of education and training.

Since the inception of the PD / A CRSP, over 500 individuals have participated in some form of CRSP education and training activities. Figure 1 shows the distribution of degree and non-degree training among those officially registered as CRSP participants. This figure does not include students of CRSP researchers who teach post-secondary courses in aquaculture at their home institutions. Figure 2 shows the gender distribution of CRSP training participants since the inception of the program.

Most participants in CRSP education and training activities are from current or past CRSP host countries—Egypt, Honduras, Indonesia, Panama, the Philippines, Rwanda, Thailand, and the US; however, the benefits of CRSP training activities extend well beyond the borders of these countries. Participants have been drawn from 33 countries over the course of the program, representing every region of the world (Figure 3).

Even without dedicated education and training funds, CRSP researchers have found ways to support students who are pursuing higher education degrees in aquaculture and related

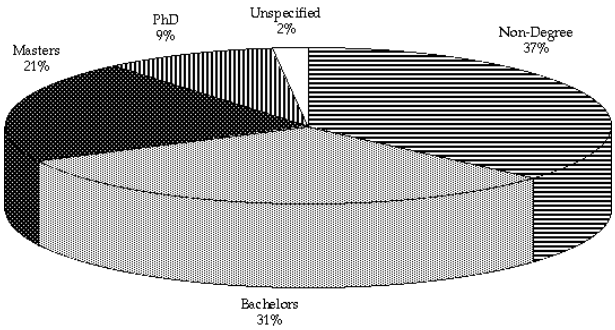

Figure 1. Distribution of PD / A CRSP degree and non-degree training, 1984-1998.

fields. Support has included providing graduate research assistantships for Ph.D. students, hiring undergraduate work-study students, providing research materials, and advising students working on research projects. During this reporting period, 10 formal degree programs were completed. Since 1990, over 50 theses have been completed, including 8 senior theses, 36 Masters theses, and 7 Ph.D. dissertations. The

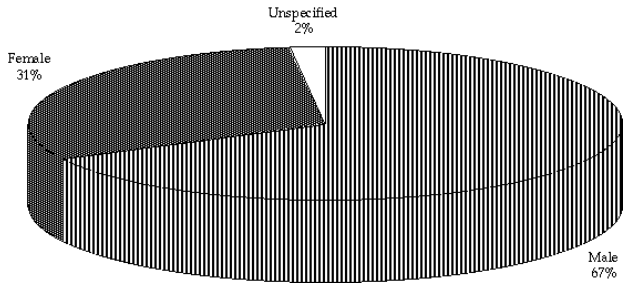

Figure 2. Gender distribution of PD / A CRSP training participants, 1984-1998.

following theses were completed this year with assistance from CRSP researchers:

Chan, R. 1997. Interactive effect of feeding frequency and time of feeding for tilapia. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.

De Jesus, M.J. 1998. An analysis of the commercial fishery of the Peruvian Amazon. M.S. thesis, Southern Illinois University, Carbondale, Illinois.

Jatuporn, B. 1997. Effect of aeration on water quality and fish production in fertilized ponds. M.Sc. thesis, Asian Institute of Technology, Bangkok, Thailand.

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, Auburn, Alabama.

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Rai, S. 1997. Co-culture of walking catfish with Indian major carps. 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.

Rwangano, F. 1998. Effects of water temperature regimes on the productive capacity of ponds for tilapia production. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

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.

HONDURAS

The five-year plan for the EDC training program calls for concentration on one CRSP host country during each year. Organizational work done in Honduras during 1997 resulted in the formation of an advisory panel and the development of a scope of work for training activities in Honduras. During this reporting period, the following activities have been implemented:

Scholarship for Masters-Level Graduate Student

The first priority of the Education Advisory Panel was to improve the long-term capacity of Hondurans to initiate and manage aquaculture research projects. To this end, a significant portion of the Honduras training funds are dedicated to the support of an appropriate candidate in a Masters program at Auburn University. Over 40 application packets have been sent to Honduran students, and placement in the program at Auburn is anticipated for March 1999.

Short-Term Training Activities

A second priority identified by the Education Advisory Panel was the need to provide short courses for producers on technical and managerial topics. The EDC, in cooperation with members of the Honduras Advisory Panel and Principal Investigators Bartholomew Green and Carole Engle, presented two workshops in October 1997. Thirty-two participants registered for the workshops, which focused on business planning for aquaculture operations

and which were modified to address the needs of tilapia farmers in the San Pedro Sula area and the concerns of shrimp farmers in the Choluteca area. As suggested by the Advisory Panel members, private producers paid fees to cover the costs of the two-day workshops, and the EDC supported the attendance of participants from government and educational institutions.

Support for Regional Conference
The EDC is the focal point for the PD / A CRSPs co-sponsorship of the Fifth Central American Symposium on Aquaculture to be held in San Pedro Sula, Honduras, from 3 to 5 March 1999. The EDC worked with the organizing committee to create the Call for Papers and various announcements about the program. The EDC is in charge of producing the proceedings for the symposium, although the final printing will be done in Honduras.

Members of the Honduras Education Advisory Committee are:
Francisco Avalos, Executive Director, Asociación Nacional de Acuicultores de Honduras (ANDAH)
Marco Polo Micheletti Bain, Vice-Minister, Secretaría de Agricultura y Ganadería
Medardo Galindo, Gerente General of the Federación de Agroexportadores de Honduras (FPX)
Rosa Garcia, Director, Dirección General de Pesca y Acuicultura (DIGEPESCA)
Daniel Meyer, Head, Animal Sciences Department of Escuela Agricola Panamericana (EAP)
Marco Tulio Sarmiento, Chief, Aquaculture Department, DIGEPESCA
Luis Morales, Chief, Research Department, DIGEPESCA
Bartholomew Green, Co-Principal Investigator, PD / A CRSP Honduras project
Alberto Zelaya, Gerente General, ANDAH

PHILIPPINES

During this period, an Education Advisory Panel was organized in the Philippines, with representatives from the institutions most involved in aquaculture development in the region, including representatives of the College of Fisheries and the Freshwater Aquaculture Center (FAC) at Central Luzon State University (CLSU), the Bureau of Fisheries and Aquatic Resources (BFAR) station at CLSU, the GIFT (Genetically Improved Farmed Tilapia) Foundation, and the US and Host Country principal investigators.

Planning for activities to take place under the Ninth Work Plan was the focus of this meeting. Funding cuts will curtail some of the efforts planned for the future under the Ninth Work Plan.

Increased Capacity for Training Activities
The EDC will collaborate with the FAC in seeking grants to increase the capacity of the center to serve as a training facility, and with BFAR to help develop a system to evaluate the effectiveness of training provided to producers who purchase fingerlings at the station.

Support for Graduate Level Thesis
The Advisory Panel recommended that small stipends to support graduate students would be the most productive way to encourage continued research related to the goals of the PD / A CRSP.

Members of the Philippines Education Advisory Committee are:
Terry Abella, Dean of the College of Fisheries
Tony Circa, Host Country Principal Investigator
Kevin Fitzsimmons, US Principal Investigator
Rueben Reyes, Manager of BFAR station
Ruben Sevilleja, Director of the Freshwater Aquaculture Center

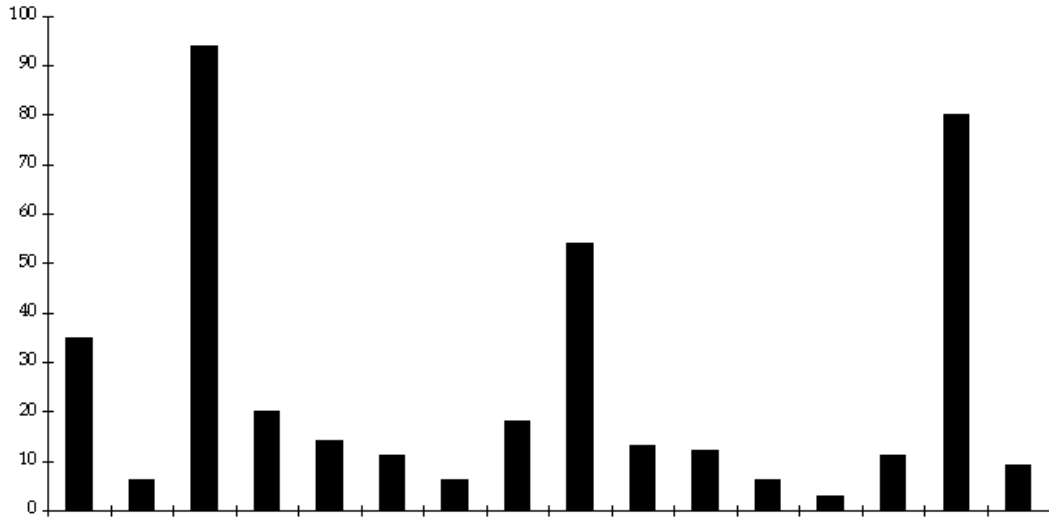

Figure 3. Home countries of PD / A CRSP training participants, 1984-1998.

INFORMATION MANAGEMENT AND NETWORKING

MOU No. RD009D

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Matt Niles	Graduate Research Assistant (from November 1997)
Kris McElwee	Graduate Research Assistant (from December 1997)
Sayea Jenabzadeh	Office Support / Research Assistant
Danielle Crop	Editorial Assistant (from January 1998)

* All IMNC staff are employed at less than full-time.

Conferences

Scholarly Publishing in the Electronic Era at Toronto, Canada, September 1997. (Clair)
PD / A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Burke, Clair, Goetze, Jenabzadeh)
Second International Conference of Women in Agriculture at Washington, DC, 28 June-2 July 1998. (Goetze)

REPORT: ANNUAL ACTIVITIES OF INFORMATION MANAGEMENT AND NETWORKING COMPONENT

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The Information Management and Networking Component (IMNC), the research support component that works most closely with the Program Management Office (PMO), performs critical organizational roles related to information. IMNC is charged not only with the dissemination of technical and programmatic information, but also with the collection and analysis of impact information. This component also facilitates electronic and face-to-face networking. In the reporting period IMNC activities have focused on publication production and distribution, Internet activities, impact monitoring, and program promotion and networking.

The mission of 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 impact, and to foster networking among persons involved in aquaculture.

Objectives are to:

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

During the reporting year, IMNC staff conducted a thorough overhaul of the program's mailing list database, which now numbers over 925 entries from 60 countries.

In addition to maintaining a detailed inventory of PD / A CRSP publications, IMNC staff also began tracking publication circulation and distribution during this reporting period in an effort to better gauge what areas of research attract the highest amount of public interest. Since this tracking system is new, no significant trends are yet apparent.

WORLD WIDE WEB

IMNC is responsible for the development and maintenance of the PD / A CRSP website, which was brought online in 1995. In a test initiated by INTSORMIL, a sister CRSP, and conducted by an independent online website analysis service, the PD / A CRSP home page received the highest technical ratings for any CRSP home page.

Web-related activities in the reporting period include: translation of PD / A CRSP publications into web-available formats; periodic update of website sections geared toward improving document accessibility; improvement of website presence on the Internet; and regular tracking of website hits to gauge user preference and help to formulate website policies.

Translating CRSP Publications
The publications page of the PD / A CRSP Website <http: / / www.orst.edu / Dept / crsp / pubs / publications.html> is a valuable source of CRSP programmatic and research material. Publications available include the quarterly program newsletter *Aquanews*, Annual Administrative and Technical Reports, the PD / A CRSP Research Report Series, and Global Experiment literature. The IMNC placed the following publications on the website during the reporting period:

- *Fourteenth Annual Technical Report* (Acrobat) (HTML)
- *Fourteenth Annual Administrative Report* (Acrobat) (HTML)
- *Fifteenth Annual Technical Report* (Acrobat)
- *Fifteenth Annual Administrative Report* (Acrobat)
- *Eighth Work Plan* (HTML)
- CRSP Research Reports 97-103 to 98-123 (HTML)
- *Aquanews* Newsletter—All issues published in the reporting period (Acrobat)
- *Educational Opportunities Network* Newsletter—All issues published in the reporting period (HTML)
- PD / A CRSP Publications in Context

Improving Document Accessibility
In order to make web content more accessible, IMNC performed several site section updates, including: further development of the publications database; improvement of the publications page to accommodate the increased number of publications now offered; steps to enhance browsing between documents and provide more rapid document downloading; better browser compatibility; and facilitation of hard copy publication orders. IMNC also developed and placed on the site literature to help put into context the large number of CRSP publications.

The online publications database is a cooperative project between IMNC and CRSP Central Database staff. References to publications are added to the database via a password-protected, online form. The database now contains over 220 references to documents. A matching query on the database delivers the publication abstract and links to the full article. References have been set to all documents and abstracts in the Research Report Series and technical and administrative reports.

The overall layout of the publications page was improved to more clearly represent the array of articles and data available from the site. Changes include a more readable layout, more thorough document descriptions, and links to Central Database data.

Because the site is regularly accessed by international as well as domestic visitors, rapid document loading is critical. To help reduce document download times, the abstracts of CRSP Research Reports have been divided into smaller sections. Also, technical figures, when appearing with HTML-formatted publications, have been placed separately from the articles they relate to, so that users have the option of downloading the figures via a hypertext link if they wish to view them. Furthermore, all tables which appear with HTML-formatted articles, whenever possible, are placed in HTML format, which makes them load significantly faster than if they appeared as images.

Because so many publications are offered from the website, the webmaster developed a "Publications in Context" page (http://www.orst.edu/Dept/crsp/pubs/pubs_in_context.html) to explain the publication cycle and how the publications relate to each other and to the Central Database.

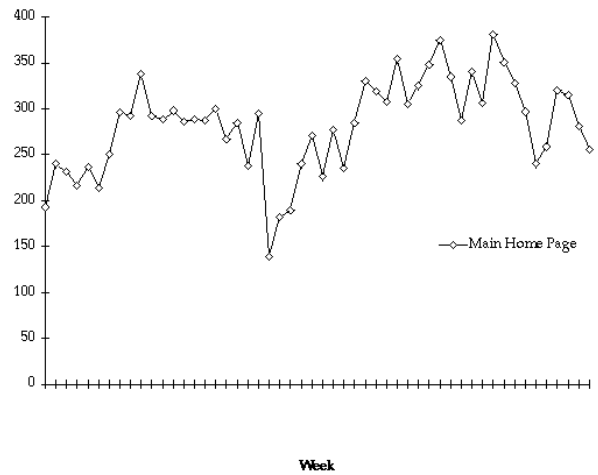

Figure 1. Weekly hits to the main page of the PD/A CRSP website (http://www.orst.edu/Dept/crsp/homepage.html).

An unfortunate fact of the Internet is that web browsers will display content differently depending on the brand and version of browser and the operating system on which content is being displayed. Therefore, before documents are loaded onto the website, they are tested on versions of Netscape and Microsoft browsers and viewed on Windows and Macintosh operating systems.

While the primary purpose of the CRSP website's publication section is to make documents available for direct downloading, visitors often wish to obtain publications in hard copy format. Updates to the hard copy order page included the addition of links from each publication list to the order form, and the addition of a short Javascript to help ensure that users successfully filled out the order form. The page was subjected to testing by members of the Program Management Office.

Improving Internet Presence
In order for the website content to benefit the largest number of people, it should be easily located using website search engines. Toward this end, special care is now taken in developing document titles and metatag descriptions that will insure accurate indexing of individual articles as well as main sections on website search engines. In this way it is hoped that users may find specific articles directly from search engines without first having to go through the main home page.

In addition to search engines, many will arrive at the website from other websites. The webmaster has submitted the URL of the website to the major aquaculture sites on the Internet. A recent web search has indicated that the CRSP website is linked from 68 other websites.

Tracking Site Usage
The IMNC monitors hits to the CRSP website (Figures 1 through 4). This allows us to gauge the relative popularity of various sections and generate website policy. In capturing statistics, hits to the building in which the Program Management Office is located are not counted. Statistics indicate that the most popular section on our site is the education and job opportunities section (Figure 2). The publications page also enjoys a high degree of popularity (Figure 3). However, statistics showed that users were not utilizing the annual reports to a great degree. Therefore it was decided that the reports would no longer be translated into HTML format but would instead be put online in Acrobat format.

CRSP PUBLICATIONS

The CRSP has produced a variety of documents during the reporting period. After publication, each document is made available on the World Wide Web. In addition, the IMNC collaborates with the Central Database on maintaining a web page which contains information on the most recent work plan changes. Once a year the IMNC publishes an addendum to the current work plan which details the work plan changes that were necessitated by the vagaries of research during the past year.

From time to time, the CRSP publishes collections of reports. Two such collections were produced in the past year: *Lessons Learned from On-Farm Trials* contains five case studies of

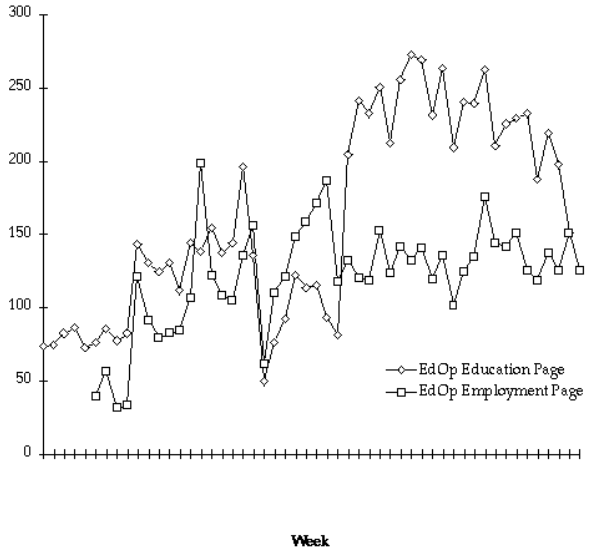

Figure 2. Weekly hits to the PD/A CRSP EdOp main pages. The EdOp pages contain monthly updated announcements of educational and employment opportunities in aquaculture and related fields.

PD/A CRSP farm trials in Honduras, Thailand, the Philippines, and Rwanda; *The Collected Abstracts in English, French, and Spanish* increases the accessibility of the CRSP Research Report Series by compiling the abstracts of 88 CRSP-sponsored research reports, together with their translations for non-English speaking audiences.

The CRSP commissioned Dr. Christopher Knud-Hansen (a former long-time CRSP researcher from Michigan State University) to write a pond fertilization guide entitled *Pond Fertilization: Ecological Approach and Practical Application*. The booklet was 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 is scheduled for publication in late 1998.

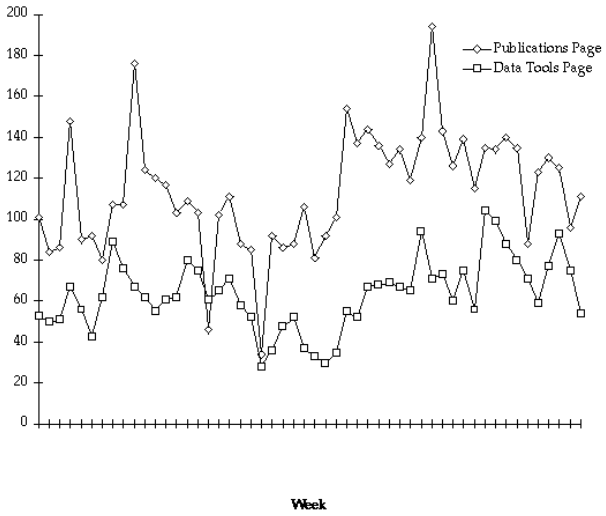

Figure 3. Weekly hits to the Publications and Data Tools pages of the PD/A CRSP website. The Publications page contains descriptions of and links to most major PD/A CRSP publications. The Data Tools page contains brief descriptions of and links to the PD/A CRSP Central Database and POND© decision support software.

A 10-year bibliography of CRSP researcher publications appears in Appendix 6 of this report.

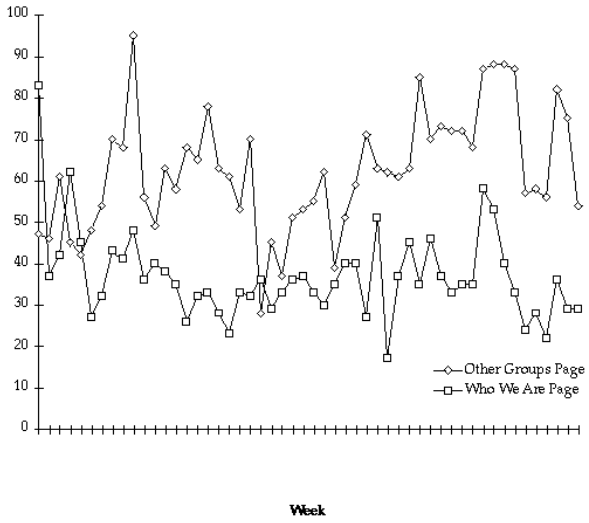

Figure 4. Weekly hits to the Who We Are and Other Groups pages of the PD/A CRSP web site. The Who We Are section contains links to PD/A CRSP introductory material, contact information, and study site descriptions. The Other Groups page contains links to websites related to aquaculture and international development.

During the reporting period, IMNC produced and distributed the publications noted below.

Fifteenth Annual Administrative Report
Clair, D., B. Goetze, D. Burke, J. Baker, and H. Egna (Editors), 1997. PD/A CRSP. Office of International Research and Development, Oregon State University, Corvallis, Oregon, 114 pp.

Fifteenth Annual Technical Report
Burke, D., J. Baker, B. Goetze, D. Clair, and H. Egna (Editors), 1997. PD/A CRSP. Office of International Research and Development, Oregon State University, Corvallis, Oregon, 188 pp.

Addendum to the Eighth Work Plan
Printed Spring 1998, 32 pp.

Lessons Learned from On-Farm Trials: The PD/A CRSP Experience
Printed Fall 1997, 84 pp.

The Collected Abstracts from the PD/A CRSP Research Report Series in English, French, and Spanish, 1987-1995. Printed Summer 1998, 188 pp.

CRSP Participant Directory, published December 1997 and July 1998.

CRSP List of Publications and Order Form, published December 1997 and July 1998.

CRSP Research Reports
This is an in-house publication series which includes Notices of Publication. The following Research Reports were issued in the last year:

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)
97-116 Chemical and physical characteristics of bottom soil profiles in ponds on haplaquents in an arid climate at Abbassa, Egypt. (1/98)
97-117 Water effluent and quality, with special emphasis on finfish and shrimp aquaculture. (1/98)
97-118 A collaborative project to monitor the water quality of estuaries in the shrimp producing regions of Honduras. (1/98)
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 17α-methyldihydro-testosterone 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)

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. The method of using indicators to monitor impact was still new when the CRSP collated its Eighth Work Plan and consequently continued to experience rapid change and development. In order to benefit from the newest insights, the IMNC commissioned an impact indicator review by Dr. Candace Buzzard (now at USAID/Botswana) who has several years of expertise in the field. Dr. Buzzard explained the concept of impact measurement during a presentation at the Sixteenth Annual Meeting. She assisted each principal investigator individually by reviewing the current impact indicators for his/her research. Her findings are summarized in a report entitled *A Review of Impact Assessment and Performance Indicators for the PD/A CRSP* (May 1998) which also contained several recommendations and which was distributed to program participants.

In addition to these formal impact indicators, IMNC staff collect project specific impact information via quarterly impact reports which are designed to capture researcher activities related to items such as:

- 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 (i.e., pond renovation)
- Linkage development (with USAID missions, regional institutions, etc.)
- Conferences attended
- Seminars, presentations, and or workshops given
- Electronic linkages
- Publications
- Theses
- Informational material developed

These forms are requested on a quarterly basis and allow the IMNC to monitor and track progress in the areas of outreach, public service, and professional development. The assembled information is shared with the Board of Directors and External Evaluation Panel to assist them in their periodic assessments of program and project progress.

PROGRAM PROMOTION AND NETWORKING

In an effort to increase the visibility of the program, the IMNC was represented at a PD/A CRSP display booth at the Fourth International Symposium on Tilapia in Aquaculture in Orlando, Florida, in November 1997. Over 50 visitors to the booth requested to be added to the CRSP mailing list. In addition to requesting the newest CRSP research results, visitors were also highly interested in the CRSPs Education Development Component and its services.

The IMNC also hosted information booths and poster displays at three local events at Oregon State University: University Days, Earth Week, and DaVinci Days. The DaVinci Days Festival in Corvallis, Oregon, is a widely publicized and well-attended event that draws visitors from across Oregon.

Informal networks are also established via CRSP Mail. The CRSP email address posted on the website elicits frequent questions from the public; questions are either answered by IMNC staff or routed to CRSP researchers with specific expertise in the query area. CRSP researchers have connected via this medium with producers in the CRSP host countries who were previously not aware of the CRSPs existence. During the reporting period, IMNC staff responded to requests for information from researchers, NGOs, and students in eleven countries (US, Spain, Suriname, India, Canada, Guyana, Ivory Coast, Philippines, Lebanon, Israel, and Pakistan). The following is a sample of the queries received via CRSP Mail: technologies used by aquaculture industry and other related industries for the removal of suspended solids and phosphorus from effluent discharge, appropriate species for brackishwater shrimp culture, and aquaculture projects in the Amazon.

RESEARCH SUMMARY

Research conducted under the *Eighth Work Plan* includes nine of the fifteen themes outlined in the *Continuation Plan 1996-2001* (see also Tables 1-4 on pp. 4-7 of the present report). In the reporting period (1 August 1997 through 31 July 1998), 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 4 for a tabular overview of reports received, themes addressed, and study completion dates (where these differ from completion dates listed in the *Eighth Work Plan*, it is owing to schedule changes requested and approved in the reporting period).

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **POND DYNAMICS**
PDR1/Pond soil characteristics and dynamics of soil organic matter and nutrients/Boyd [Progress report]

To provide baseline data regarding the pond ecosystems of PD/A CRSP sites and generate theory regarding the development of pond soils and a systematic method of pond soil classification, researchers continued to direct their efforts toward identifying pond soil characteristics and understanding the dynamics of soil organic matter and nutrients. This study examined soil cores extracted from newly renovated ponds in Sagana, Kenya, and contains data pertaining to basic soil characteristics, results of ammonia and carbon dioxide dynamics in soils incubated under aerobic conditions, ammonia dynamics of soil incubated under anaerobic conditions, and phosphorus equilibrium concentrations in laboratory soil-water mesocosms. Soil data collected in Kenya were then compared with data collected from other CRSP sites in the US, Honduras, Thailand, and Egypt. The profile of Kenya soils was not as developed as other CRSP sites, possibly due to recent pond renovations—the S horizon was well-developed and extended to 6 cm, but M, T, and P horizons were poorly developed. Soil pH was near neutral, with carbon concentrations between 2 and 5%. Carbon:nitrogen ratios were between 10 and 20, sulfur concentrations were 0.5%, and phosphorus concentrations were low. Incubation rates for pond soils from Kenya, Thailand, and Honduras revealed relatively low microbial respiration rates in comparison with terrestrial soils and net negative nitrogen mineralization had occurred. Phosphorus equilibrium concentrations of soil water mesocosms from freshwater ponds in Thailand and Kenya and from fresh and brackishwater ponds in Honduras indicated that ponds at each of these sites would be sinks for phosphorus added in fertilizer. Additionally, it appears that pond soil profiles become more distinct in a shorter period of time than terrestrial soil profiles.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **POND DYNAMICS**
PR2/New site development and characterization/Kohler [Final report]

Researchers provided a descriptive overview of the PD/A CRSP site located in Iquitos, Peru. Physical, meteorological, and hydrological characteristics of the site are presented in addition to a description of the hatchery facility and ponds. [This study was carried out in lieu of the Global Experiment (FFR1), as work with tilapia in Peru is prohibited by the Peruvian government.]

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **POND DYNAMICS**
KR1/New site development and characterization/Bowman [Abstract]

In late March of 1997, the CRSP initiated research at Sagana Fish Farm, Kenya, a recently established prime site in Africa. (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 are summarized in this abstract. Data were collected pertaining to solar radiation, photosynthetic active radiation, precipitation, relative humidity, wind speed, and air temperature. Preliminary soil analyses are also presented.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **POND DYNAMICS**
TR1/Effect of mud turbidity on fertilization, and an analysis of techniques to mitigate turbidity problems/Diana [Final report]

For aquaculture ponds with heavy clay dikes and bottoms, mud turbidity is a significant concern. High mud turbidity may inhibit plankton growth, cause acidity, limit light penetration for photosynthesis, and lead to a decline in nutrients. Additionally, turbidity problems prevail in countries such as Thailand, Cambodia, and Laos where there are many rain-fed ponds. Thus, a study was designed to assess the effects of different mitigation techniques on fish growth and identify suitable approaches for the mitigation of turbidity. Five different turbidity mitigation techniques were tested during the dry season: a control; a black plastic covering placed at the top of the dike and extending 50 cm down the pond edge; green manure (terrestrial weeds) to cover pond bottoms and alter texture; netting to cover pond bottoms; and lime applied biweekly at a rate of 200 kg ha^{-1}. Ponds that were limed had the best growth performance, except for survival, and the green manure treatment ponds had the lowest survival and the lowest fish yields. This may have been attributable to low dissolved oxygen concentrations caused by the decomposition of weeds during the first month of the experiment. The treatment that used netting to cover pond bottoms was successful at preventing turbidity due to fish

disturbance, which resulted in reduced phosphorus regeneration but not reduced fish production. The treatment that covered pond edges was not significantly different from the control in terms of fish growth performance; however, this treatment may be more effective during the wet season. Further research is advised to elucidate the relationship between pond bottom soil characteristics and water quality management in semi-intensive fish ponds.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: POND DYNAMICS
TR2/Management of organic matter and nutrient regeneration in pond bottoms/Diana [Final report]

During grow-out the accumulation of organic matter in pond bottom soils can lead to severe oxygen depletion at the sediment-water interface. A small amount of organic matter is beneficial; however, an abundance of organic matter in pond soils can cause anaerobic conditions. Throughout Asia polyculture and pond drying are practiced to mitigate the accumulation of organic matter on pond bottoms; however, very little research has been done in this area. A study was therefore initiated to assess the effect of polyculture and pond drying on organic matter accumulation and to develop a better understanding of the link between bottom soil characteristics and management. Two experiments were conducted. The first experiment assessed the effects of aerobic and anaerobic conditions of pond bottoms on organic matter decomposition and nutrient release and the effectiveness of common carp in removing organic matter from pond sediments and recycling nutrients for tilapia. The second experiment was designed to assess the physical and chemical conditions during microbial decomposition of organic matter and the resultant release of nutrients during pond drying. Results of these two experiments indicated that the polyculture of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) was effective in recycling nutrients and may be potentially effective in removing organic matter if common carp are stocked at higher densities. Also, although prior research has indicated that pond drying can retard the rate of organic matter accumulation due to the enhanced availability of oxygen that allows for greater rates of microbial decomposition of organic matter, it was found that pond drying did not result in significant oxidation of organic matter and releases of nutrients. This may have been because ponds were not completely dried and deep cracks had not completely developed to allow for enhanced oxygen availability.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS
HR1/Intensification of tilapia production: Effects of feeding at different stocking rate on pond water/Green [No report submitted; please see Editor's Note, p. 49.]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS
FFR1H/Global Experiment: Optimization of nitrogen fertilization rates in freshwater tilapia production ponds/Green [Final report]

Nile tilapia (*Oreochromis niloticus*) are often semi-intensively cultured using fertilizers to increase primary productivity, thereby increasing fish food availability. PD/A CRSP research over the years has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers; however, findings pertaining to optimal nitrogen, phosphorus, and carbon inputs necessary for increased production are inconsistent. Thus researchers undertook a study—the Global Experiment—to be carried out at all PD/A CRSP sites, 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 rates; and 3) develop a full-cost enterprise for the most profitable nitrogen fertilization rate identified. At the El Carao National Fish Culture Research Center in Honduras a dry- and wet-season study was conducted in which 8 kg P ha^{-1} wk^{-1} plus 0, 10, 20, or 30 kg N ha^{-1} wk^{-1} were added to 0.1-ha earthen ponds. During the wet-season study, tilapia yields varied curvilinearly in response to increased nitrogen inputs. Significant differences in tilapia yields were not detected for the dry-season study. The treatment receiving 20 kg N ha^{-1} wk^{-1} had the highest total revenues during both the dry- and wet-season studies, and partial budget analysis demonstrated that this treatment was the most economically optimal given the current economic situation of Honduras. Additionally, the full-cost enterprise budget for this treatment showed that income above variable costs was \$991 ha^{-1} per five-month production cycle.

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

To characterize the productive capacity of ponds, evaluate the relative contributions of inorganic fertilizers and supplemental feeds to fish production, 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: 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. 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.

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

In an effort to develop economical feed and fertilizer practices that maximize fish production, a study involving stable carbon isotope analysis to determine the nutritional contribution of natural and supplemental foods for Nile tilapia was conducted. Fish (*Clarias* sp. and *Oreochromis niloticus*) were fed one of the following treatment diets: 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. The most distinctive trend in the isotope data was the more positive values for plankton, *Clarias* sp., and *O. niloticus* in treatment 1 versus treatments 2 through 4 for initial and midpoint samples; however, there may have been an undefined pre-treatment effect. At the onset of the

study, isotope values of plankton were more positive in treatment 1 than in the other treatments. Further, significantly higher chlorophyll *a* concentrations were observed in treatment 1 than in the other treatments. Rice bran was not the only nutrient affecting the isotope ratios of plankton given the more negative value for the midpoint isotope ratio of plankton (-29.6‰) in comparison with the isotope ratio of rice bran (-27.8‰). Researchers plan to collect more isotope data in order to develop a more comprehensive discussion of the effects of various nutrient inputs on the production of *O. niloticus* and *Clarias*.

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

Nile tilapia (*Oreochromis niloticus*) are often semi-intensively cultured using fertilizers to increase primary productivity, thereby increasing fish food availability. PD/A CRSP research over the years has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers; however, findings pertaining to optimal nitrogen, phosphorus, and carbon inputs necessary for increased production are inconsistent. Thus, researchers undertook a study—the Global Experiment—to be carried out at all PD/A CRSP sites, to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimum primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rates; and 3) develop a full-cost enterprise for the most profitable nitrogen fertilization rate identified. Researchers at Sagana Fish Farm in Kenya initiated a cool season experiment which is in progress. Prior to filling, 100 kg of TSP was broadcast over the bottom of each pond. Ponds were stocked with fish of an average weight of 17 g at an initial density of 1 t ha^{-1}. Treatments for this experiment consisted of nitrogen (urea and DAP) additions to ponds at 0, 10, 20, and 30 kg ha^{-1} wk^{-1} and phosphorus additions at 8 kg ha^{-1} wk^{-1}. (The ponds that did not receive any nitrogen fertilization were given TSP whereas ponds receiving nitrogen fertilization were given DAP.) Preliminary observations indicated that nitrite levels were very high (with mortality in one pond) in the treatment receiving 30 kg N ha^{-1} wk^{-1}.

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

Nile tilapia (*Oreochromis niloticus*) are often semi-intensively cultured using fertilizers to increase primary productivity, thereby increasing fish food availability. PD/A CRSP research over the years has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers; however, findings pertaining to optimal nitrogen, phosphorus, and carbon inputs necessary for increased production are inconsistent. Thus researchers undertook a study—the Global Experiment—to be carried out at all PD/A CRSP sites, to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimum primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rates; 3) develop a full-cost enterprise for the most profitable nitrogen fertilization rate identified; and 4) investigate the relationship between initial fish size and pond carrying capacity. In Thailand two experiments were conducted. In the first experiment treatment ponds were fertilized with TSP at a rate of 8 kg P ha^{-1} wk^{-1} and with urea at 0, 10, 20, and 30 kg N ha^{-1} wk^{-1} and stocked with sex-reversed Nile tilapia (10.1 to 10.9 g in size) at 1,000 kg ha^{-1}. For the second experiment, 4.6 to 4.8 g, 10.1 to 10.5 g, and 21.3 to 21.8 g fish were stocked in ponds receiving urea and TSP at a rate of 30 kg N and 8 kg P ha^{-1} wk^{-1}. Both experiments indicated that the treatments with higher N inputs showed better growth performance of Nile tilapia. In the first experiment the treatment receiving 30 kg N ha^{-1} wk^{-1} produced the highest yields (2,409.6 ± 46.4 kg ha^{-1} wk^{-1}). Results of the second experiment showed that survival was best in the treatments stocked with large fish. The treatments stocked with medium- and large-size fish had the best growth performance; however, fish biomass and yields were highest in the treatment stocked with medium-size fish.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS
PHR1/Development of low-cost supplemental feeds for tilapia in pond and cage culture/Fitzsimmons [Progress report]

The nutrients of supplemental feeds are necessary when the productivity of a water body is insufficient to sustain a desired fish growth. Thus, low-cost high-quality feeds are requisite in ponds when farmers wish to produce more fish than is attainable given the fertilization system or when fish are cultured in cages and do not have access to an entire water body for feeding. For many small-scale farmers who have decided to cage-culture tilapia in order to increase their household income and nutrition, the cost of feed becomes the major cost for fish production. Supplemental feeds are intended to provide nutrients that would otherwise be limiting to fish growth, and often protein is the limiting nutrient in fertilized ponds. Providing additional protein can be a cost-effective method for increasing growth rates and increasing stocking density; however, dietary protein—typically fishmeal and soybean oil meal—is often expensive to incorporate into the diet. To address these concerns associated with supplemental feeding, two feeding trials were conducted to determine the viability of using yeast and composted rice straw as alternative protein sources for tilapia diets. Experimental diets were fed to both tilapia in ponds and tilapia in cages in a common pond. Results of this study showed that tilapia growth rates were best in the treatments that received the diet which incorporated composted rice straw. From the study results, CRSP researchers concluded that low-cost supplemental feeds would increase pond production and that composted rice straw would be a better source of protein than yeast to replace fishmeal.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR1A and RCR1C/Methods for strain variations in sex ratio inheritance and methods for contribution from the male and female genome to sex inheritance/Phelps [Progress report; results of studies RCR1A and RCR1C submitted as one report]

Uncontrolled reproduction can be a significant factor constraining the culture of tilapia. Intraspecific breeding programs for YY male tilapia are one method for producing all male populations and effectively controlling reproduction; however, sex ratios of progeny from single pair spawnings are skewed despite an expected 50:50 sex ratio (female tilapia are homogametic and male tilapia are heterogametic). To address

this issue a study was conducted to identify strains of *O. niloticus* that exhibit minimal variation in sex ratio inheritance. Three strains of *O. niloticus* were used: Egypt, Ghana, and Ivory Coast. Brooders ranged from 50 to 250 g in size, and paired matings were facilitated by placing fish at a ratio of male to three females in 2-m^2 hapas located in outdoor tanks. Progeny from spawns were then randomly selected and raised at two temperatures (35.3 and 28.3°C) The mean percentage of males, females, and intersex fish did not differ among the strains evaluated, but there was considerable variation in the sex ratios of individual spawns. Sex ratios of the Ivory Coast strain spawns exhibited the greatest variation followed by the Ghana and Egypt strains. In terms of temperature, no one strain appeared to be more sensitive to temperature; however, individual spawns did respond differently to temperature. Siblings reared at higher temperatures showed a range of response to temperature—siblings from four spawns reared at higher temperature had a > 10% increase in males while the percent males from siblings from four spawns differed by < 10%, illustrating that a degree of individual variation may occur in response to temperature and that it is important to select fish of known spawning histories for use in a YY breeding program.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR1B/Nile tilapia gamete management for chromosome manipulation/Shelton [Progress report; report title different than study title in *Eighth Work Plan*]

Refinement of chromosome manipulation techniques continued during the last year's reproduction control research and included: 1) improvement of the efficiency of collecting freshly ovulated eggs from Nile tilapia; 2) development of a tau curve over the spawning temperature range; 3) generation of preliminary data on the UV treatment of eggs for induction of androgenesis; and 4) progeny tests to identify genetic markers in the broodstock of Nile tilapia at the University of Oklahoma. Spawning of Nile tilapia was maintained for a year through photoperiod manipulation. In addition to photoperiod manipulation, preliminary trials of hormonal induction of ovulation evaluated the use of three hormones: gonadotropin-releasing hormone analogue (GnRHa), luteinizing hormone-releasing hormone analogue (LHRHa), and human chorionic gonadotropin (HCG). Eggs stripped from tilapia were naturally and artificially fertilized and incubated at a closely regulated temperature in order to monitor developmental rate. Tau curves were then derived using the mean interval from the initiation of the first and third mitoses in 5 to 10% of the eggs; these intervals were recorded at temperatures within the usual developmental range (20 to 30°C). Eggs were also treated with differential UV exposure (100 to 500 J m^{-2}), fertilized, and then development was monitored through hatching and swim-up stages. A comparison of hatch rates between artificial and natural spawning indicated that both were variable. Photoperiod manipulation appeared to be a reasonable technique for predicting ovulation and time of stripping, whereas hormone induction of ovulation was less reliable. The tau curve from this experiment was calculated to be $\tau = 10^{5.4167}$ $C^{-2.7009}$ ($r^2 = 0.90$), where C is temperature (°C), and the time to first mitosis was $T = 10^{4.9663}$ $C^{-2.1208}$ ($r^2 = 0.91$). These curves can be used to standardize shock treatments. Results of testing of UV exposure to inactivate the DNA indicated that hatch rates were generally near zero at a dose of UV between 400 and 500 J m^{-2}; survival to swim-up was zero with UV dosages of 300 to 400 J m^{-2}. Future research will involve the use of the tau data collected from this study to test thermal shock times.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR1D/Methods for development of YY lines of male and female *O. Niloticus*/Phelps [No report submitted; please see Editor's Note, p. 35.]

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR2A/Steroid immersion for masculinization of tilapia: Immersion of tilapia fry in MDHT/Fitzpatrick [Final report]

Steroid immersion for the masculinization of Nile tilapia (*Oreochromis niloticus*) is another method (in addition to androgenesis) for the control of unwanted reproduction and the production of all-male tilapia populations. Usually hormones are administered through feeds; however, this method tends to be inefficient. Further, there may be hazards associated with worker exposure to steroids and/or the leakage of steroids into the surrounding environment and non-target organisms. As an alternative to hormone-impregnated feed technology, immersion technology research continued with refinements to short-term hormone immersion techniques. Tilapia were immersed for two hours in 500 mg l^{-1} 17α-methyldihydrotestosterone (MDHT) at 280, 310, or 364 CTU (10, 11, and 13 dpf; days post fertilization) or twice at 280 and 364 CTU in 500 mg l^{-1} MDHT at 28°C (CTU refers to the dpf multiplied by the temperature (°C)). Two immersions in MDHT at 280 and 364 CTU resulted in a population of 82.9% males and a single immersion at 364 CTU resulted in 79.3% males, thus demonstrating that masculinization of Nile tilapia was equally effective with a single immersion at 364 CTU or with two immersions at 280 and 364 CTU.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR2B/Effect of fish density on efficacy of masculinization by immersion in MDHT/Fitzpatrick [Final report]

To identify the optimal treatment conditions for short-term immersions of Nile tilapia, density, hormone dosage, and length of exposure were tested in two experiments. In the first experiment fry were stocked in 3.8-l glass jars at densities of 33, 66, 100, or 200 fish l^{-1} and immersed in 500 µg l^{-1} MDHT at 280 and 364 CTU (10 and 13 dpf). In the second experiment, using a fractional factorial design, fry were stocked at 12, 25, 50, 100, and 200 fish l^{-1} and immersed in trenbolone acetate (TBA) at 364 and 392 CTU (13 and 14 dpf); hormone dosages were 62.5, 125, 250, 500, or 1,000 µg l^{-1} at exposures of 0.75, 1.5, 3, 6, and 12 h. For the first experiment, the immersion treatment in which fish were stocked at 33 fish l^{-1} resulted in 80.3% males, which was significantly higher than the control (56.7% males). Data for the second experiment were not analyzed because all controls and treatment groups contained 100% males. Although recommendations from this research can be made regarding stocking density for steroid immersion treatments, it is important to test the effects of hormone dosage, length of exposure, and density in a fractional factorial study to broaden the information base regarding steroid immersion technology.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL
RCR2C/Masculinization of tilapia fry by immersion in trenbolone acetate (TBA) at a production level/Phelps [Final report; report title different than study title in *Eighth Work Plan*]

Research has indicated that steroid immersion is a viable method for inducing masculinization in Nile tilapia; however, the effects of immersion technology are unknown at production levels with tilapia. Thus, to test the efficacy of immersion technology at a production level, researchers examined the masculinization effects of tilapia treated for six hours in a stock solution of trenbolone acetate (TBA) dissolved in ethanol. Broodfish were stocked at a ratio of one male to three females in 2-m^2 hapas; eggs or sac fry were removed (hapas were checked every 10 days) and incubated; swim-up fry were collected as soon as they were able to swim out of the incubator and held until 9, 11, 13, or 15 days post-hatch. Fry were then stocked at a density of 33 fish l^{-1} and immersed in 500 µg l^{-1} TBA for six hours. After steroid immersion, fry were fed four times per day until an age of 20 days and then restocked in outdoor 20-m^2 tanks and reared to 5 cm. Treatment effects were not observed—the non-TBA treatment had a mean of 49.1% males and TBA-treated tilapia ranged from 43.7 to 54.3% males. Results of this study suggest that tilapia with post-hatch ages of 3, 7, 9, 11, 13, and 15 days do not masculinize when immersed in 500 µg l^{-1} TBA for two to six hours, although the lack of intersex fish and/or water quality may have had some bearing on the outcome of this study. Additional studies are suggested to assess the effects of water chemistry on androgens applied as a bath treatment.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **REPRODUCTION CONTROL**
RCR3A/Detection of MT in aquarium water after treatment with MT food/Fitzpatrick [Final report]

The treatment of tilapia feeds with 17α-methyltestosterone to achieve all-male populations is common throughout the world; however, despite the success of this practice there is concern that there is significant "leakage" of MT into the environment. This potential for leakage of MT into the environment poses a threat of exposure to hatchery workers and fish or other non-target aquatic organisms. In a study using model pond systems that tested whether MT was detectable within the pond environment, researchers demonstrated that considerable amounts of MT leak into the environment during dietary treatment. Levels of MT in the water peaked between approximately 1 and 2 µg l^{-1} at 14 and 21 days after the onset of feeding and decreased to background level by day 35. In contrast, however, the level of MT in the soil was 1.4 to 1.7 µg kg^{-1} at 28 days after the onset of feeding with MT treated feed and was detectable in the soil at levels between 0.8 and 1.6 µg kg^{-1} through day 49 (three weeks after ending the treatment with MT-impregnated food).

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

In addition to the above laboratory research to test for the presence of 17α-methyltestosterone (MT) in the treatment environment, an additional field study is in progress. Nile tilapia are stocked in two hapas at 2,000 fish per hapa. The hapas are approximately 50 cm apart in a 400-m^2 earthen pond. Tilapia in one hapa will be fed a commercial trout ration that does not contain MT and tilapia in the other hapa will be given a feed containing 60 mg MT kg^{-1} of feed. Soil samples which have no history of exposure to MT were collected prior to the experiment and MT soil assays were performed. These assays will then be compared with MT assays of soil samples collected during the experimental treatment period to determine if MT is detectable in the soil after the use of MT-treated feeds. In addition to soil samples, water samples will be analyzed as well.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **REPRODUCTION CONTROL**
KR2/Strain variations in sex ratio inheritance/Bowman [Abstract]

In collaboration with reproduction control researchers (see Phelps report RCR1A and RCR1C, pp. 34-35), a study was initiated to determine the sex ratio inheritance of Nile tilapia (*Oreochromis niloticus vulcani*). Spawning success and survival, however, were too low to obtain the number of fingerlings required to complete the study.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **AQUACULTURE SYSTEMS MODELING**
ASMR1A/Model evaluation and application to the ecological analysis of integrated aquaculture/agriculture systems/Piedrahita [Progress 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 past year of research within the aquaculture systems modeling component has involved the evaluation of this model using sensitivity analysis and model verification methods. Additionally, a modeling study was initiated to examine the effects of cycling pathways on system nitrogen retention and productivity and long-term dynamics of pond sediment organic matter. Results of the sensitivity analysis indicate that the model is most sensitive to changes in water infiltration rate, maximum specific phytoplankton production rate per unit of carbon, oxygen threshold for aerobic conditions, organic matter sedimentation rate, and aerobic sediment depth. Based on model verification results, research in the following areas related to processes and management activities would prove beneficial: initial fish weight, aerobic sediment depth, non-phytoplankton light extinction coefficient, crop irrigation rate, water infiltration rate, and mineral soil organic matter decomposition rate coefficient. Simulation of long-term organic matter dynamics in pond sediments revealed that concentrations of organic matter increased over time and were highest for chicken manure and plant waste, followed by chicken manure alone, and then artificial feed. The outcome of this study indicates that the integrated aquaculture/agriculture model will be valuable for the design of integrated aquaculture/agriculture sediment management experiments and the overall management of nitrogen and organic matter in aquaculture ponds.

RESEARCH AREA: **PRODUCTION OPTIMIZATION**
RESEARCH THEME: **AQUACULTURE SYSTEMS MODELING**
ASMR1B/Modeling of temperature, dissolved oxygen, and fish growth rate in stratified ponds using stochastic input variables/Piedrahita [Progress report; report title different than study title in *Eighth Work Plan*]

In addition to the development of an integrated aquaculture/agriculture systems model, researchers have been in the

process of validating and modifying a model designed to predict water temperature, dissolved oxygen, and fish growth using stochastically generated input weather variables. Data from three PD/A CRSP sites—Rwanda, Honduras, and Thailand—were used to calibrate and validate the model. Simulation results of water temperature and DO were in good agreement with the data collected in Rwanda and Honduras, but not with the data obtained from the Thailand site. Results of simulations also revealed that maximum and minimum DO values had the potential to be out of the tolerance range or the no-effects range for some species. Simulations also were sensitive to changes in fertilization rates, indicating that simulation results may be useful for studying the impacts of fertilization rates along with the economic, environmental, and social constraints associated with a given fertilizer. Poor simulation results for chlorophyll *a* at the Thailand site highlight the limitations of the model and suggest that an improved understanding of pond-sediment interactions, phytoplankton dynamics, and fish nutrition should be emphasized in future research.

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

PR1/Development of sustainable pond aquaculture practices for *Piaractus brachypomus* in the Peruvian Amazon/Kohler [Final report; report title different than study title in *Eighth Work Plan*]

As an initial effort to evaluate the aquaculture potential of local and native species and to develop appropriate culture technologies, researchers in Peru conducted a study to evaluate stocking densities of *Piaractus brachypomus* that would be most economic and efficient for the production of market-size fish. Two densities were tested (3,000 and 4,000 fish ha^{-1}) in ponds that ranged in size from 1,015 to 5,320 m^2, and fish were fed a locally available feed at 5% body weight per day. Results of this study indicated that there were no significant differences in grow-out performance. Fish growth rates were 3.0 g d^{-1}; feed conversion ratios were excellent; and water quality remained within an acceptable range for the culture of *P. brachypomus*. Traditionally, stocking densities of *P. brachypomus* are 2,000 to 3,000 fish ha^{-1} in this region. Results of this study indicate that it may be possible to increase the stocking density of *P. brachypomus* to 4,000 fish ha^{-1} with supplemental feeding, but further research is required.

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

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

A long-term water quality monitoring project initiated in 1993 continued in the shrimp producing regions of Honduras. The goal of this project is to provide a scientific basis for estuarine management and sustainable development of shrimp culture in Honduras through the detection of changes in estuarine water quality. Data from this study will then be used to formulate and validate predictive models for estuarine water quality. Additionally the data, in conjunction with farm chemical budgets and estuarine fluid dynamics data, will be used to estimate assimilative capacity of selected estuaries of the shrimp producing regions of Honduras. During the past year water quality was monitored at 20 sites located on 12 estuaries. Study results indicated that water quality in riverine estuaries continues to be influenced directly by seasonal variation in river discharge and watershed runoff, while embayment estuaries of the Gulf of Fonseca experience less seasonal variation in water quality. Overall, data collected from riverine or embayment estuaries during the period from 1993 to 1998 did not evidence any trends of total nitrogen or total phosphorus enrichment.

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

HR2-2/Analysis of Honduran shrimp farm impacts on channel estuaries of the Gulf of Fonseca/Ward [Progress report; report title different than study title in *Eighth Work Plan*]

Due to the concern regarding intensive development of the shrimp farming industry and the accumulation of waste by-products associated with mariculture, research was initiated to: 1) detect changes in estuarine water quality over time; 2) formulate and validate predictive models for estuarine water quality; and 3) estimate assimilative capacity for shrimp mariculture in the Rio Choluteca delta areas of Honduras, on the Gulf of Fonseca. In these reports, water quality trends are discussed in light of the data collected since 1993 and the model development is highlighted as well. Two mathematical models were formulated—a section-mean tidal hydrodynamic model and a section-mean longitudinal mass budget model for the concentration of a parameter (such as salinity, dissolved oxygen, and nutrients) along the axis of the estuary. Preliminary trials of the models using estimates of estuary physiography, hydromechanics, kinetics, and hydrology, and based upon full development of the farm concession extant in 1995, predicted that both the Pedregal and Jagua estuaries would have levels of dissolved oxygen below the critical value of 3 mg l^{-1}. These results, in addition to the expression of concern by CRSP researchers and individuals with interests in the shrimp farm industry, have lead to a moratorium on new farm development. Future modeling work will include incorporation of field data pertaining to physiographic and hydrographic inputs and minor modifications to model nitrogen and phosphorus nutrients, specific toxicants such as ammonia, or indicators such as chlorophyll *a*, and will allow the evaluation of a number of different shrimp-farm development scenarios.

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

HR3/Influence of daily water exchange volume on water quality and shrimp production/Green [Final report]

Shrimp culture practices in Honduras are semi-intensive, i.e., final stocking rates range from 5 to 11 shrimp m^{-2} and daily water exchange rates average 10% of the pond volume. Water exchange is performed to correct low early morning oxygen concentrations and discharge metabolites; however, research has brought into question the usefulness of this practice. Additionally, there are environmental concerns associated with excessive water exchange such as fuel waste, the sedimentation of water supply canals and ponds, and increased nutrient discharge from ponds. Two experiments were conducted in Honduras to develop a more complete picture of the effects of daily water exchange and emergency water exchange on shrimp production and to develop nitrogen and phosphorus chemical budgets. The following two water exchange regimes were evaluated during both the rainy and dry seasons—water exchange at 10% pond volume per day, six days per week (daily) and water exchanged only in response to early morning dissolved oxygen concentrations

≤ 2.0 mg l^{-1} (emergency). Gross yields, growth, survival, and feed conversion ratios of *Penaeus vannamei* were not significantly affected by the different water regimes tested; however, pond water quality was significantly affected and tended to be better for ponds that received daily water exchange. Based on results of this study and the risks perceived by shrimp producers regarding the use of an emergency water exchange regime (especially during the last four to six weeks of the rainy-season culture period), a compromise water exchange regime is suggested—a delayed initiation of daily water exchange until week 10 of the production cycle.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION
HR4/Water exchange to rectify low dissolved oxygen/Green [Abstract]

Based on the results of the above study, which found that emergency water exchange did not significantly affect shrimp production but did significantly affect water quality, CRSP researchers initiated a study, which is in progress, 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 are being used in the completely randomized design study and both rainy- and dry-season experiments will be completed. A daily water exchange rate at 10% of pond volume (six days per week) will be tested beginning four, seven, and ten weeks after stocking.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION
TR3-2/Management to minimize the environmental impacts of pond draining: Effect of harvest draining technique on water quality and fish growth/Diana [Final report; report title different than study title in *Eighth Work Plan*]

Concern has been raised regarding the decrease in water quality of effluents discharged at harvest from aquaculture ponds. Additionally, the seining of ponds prior to draining further increases pollutants in effluent waters. To identify draining and harvest strategies that minimize environmental impacts, researchers initiated a study that tested five harvest draining techniques. The five harvest techniques evaluated were as follows: A) ponds were not drained, fish were anesthetized and harvested by seine net; B) ponds filled with canal water were completely drained after liming and fish were removed from a harvesting pit; C) ponds filled with canal water were completely drained and fish were removed from a harvesting pit; D) ponds filled with drainage water from the harvest of adjacent ponds were drained halfway, seined twice, and then completely drained to collect remaining fish; and E) ponds filled with canal water were drained halfway, seined twice, and then completely drained to collect remaining fish. Means for water quality parameters of all treatments were not significantly different, and fish growth, net fish yield, and survival did not differ among treatments. Fish growth and net fish yields were similar for undrained ponds and ponds filled with drainage water from other ponds. Although there were no significant differences in harvest techniques the results suggest that either harvesting fish without draining or collecting harvest drainage water to fill empty ponds are feasible techniques for minimizing environmental impacts without affecting water quality for fish growth.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS
MEAR1 and MEAR2/Economic and social returns to technology and investment and risk analysis of pond management strategies/Engle [Progress report; results of studies MEAR1 and MEAR2 submitted as one report]

An analysis is underway to ascertain the economic and social returns of PD/A CRSP research for shrimp farmers in Honduras. The preliminary results of 21 interviews with shrimp farm owners and managers, representing approximately one-third of the total number of shrimp farmers in the country, are presented in this report. The shrimp farmers interviewed had yields that ranged from 1,501 to 2,000 lb shrimp ha^{-1} yr^{-1}. Farmers who stocked a higher density of postlarval shrimp obtained greater yields; large-scale shrimp farmers tended to rely on hatchery-raised postlarval shrimp more so than small- and medium-scale farmers. Farmers with yields greater than 2,000 lb shrimp ha^{-1} yr^{-1} provided more than 15 lb feed ha^{-1} d^{-1} during the dry season. Most small- and medium-scale shrimp farmers fertilized, while almost no large-scale shrimp farmers fertilized their systems. An economics of scale also appeared to characterize shrimp farm operations—large farms tended to have lower costs per hectare than smaller farms.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
ADR1A/Tilapia producer perceptions and practices in five PD/A CRSP countries/Molnar [Progress report; report title different than study title in *Eighth Work Plan*]

Adoption diffusion research continued to develop a socioeconomic profile of tilapia farmers from five PD/A CRSP sites: Kenya, Rwanda, Honduras, Thailand, and the Philippines. (Most recently, surveys were conducted in Sagana, Kenya.) The surveys focus on overall respondent characteristics (e.g., gender, age, marital status, and number and age of children), land-holdings, farm enterprise, pond culture techniques, fingerling sources, water management, marketing and its constraints, fish culture impacts, problems associated with tilapia culture, prospects for future fish culture, and technical assistance. Thus far, results of this research indicate that income level affects the amount of capital investment by tilapia farmers and their willingness to undertake risk. Factors such as off-farm employment and life cycle considerations influence the production strategies employed in and the benefits sought from the fish culture enterprise.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
ADR2/The influence of fish culture technology, extension methodology, and socioeconomics on success of fish culture on limited-resource farms/Lovshin [Progress report]

In addition to the development of socioeconomic profiles of tilapia farmers at five PD/A CRSP sites, an investigation was conducted to study the effects of a fish culture project that provided technical assistance to rural communities in Panama and Guatemala by USAID and Auburn University in the late 1980s. Thirty-nine fish projects were contacted in Guatemala and twenty-one cooperative fish pond projects were contacted in Panama. Preliminary results of this research revealed that in Guatemala fifteen family ponds were considered abandoned, eighteen ponds still contained water and a few fish but were not directly important to household food supply, and five ponds were well-attended and considered important to the

household. In Panama six community fish pond projects had been abandoned and the remaining fifteen projects still had ponds in use but the use varied. Six fish culture projects had converted their ponds into rice paddies whereas the remaining nine projects continued to culture fish and fertilize their ponds with manure. Only the ponds of two projects were considered well-managed. Further analysis regarding the reasons for success or failure of fish culture projects is planned and it is intended that this information will assist in developing research agendas and the dissemination of CRSP research results.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
KR4/Training/Bowman [Final report]

To ensure the overall success of CRSP work in Kenya the following activities were conducted: 1) training of station field personnel in fish sampling, handling, and transport; 2) training of technicians in the areas of water, soil, and feed sampling, laboratory glassware cleansing, and computer operation; and 3) training of university students in topics relevant to aquaculture in Africa. Details of these training activities are presented in this report.

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

Regional outreach activities were initiated under the Eighth Work Plan in order to disseminate information obtained via CRSP research; provide CRSP researchers with opportunities to learn about fish culture practices, research priorities, and activities in other parts of Africa; encourage efforts to create linkages between research and extension activities in the region; and continue the process of networking and regionalizing CRSP efforts in Africa. This report describes the various connections and linkages that the CRSP has solidified since its arrival in Kenya and the constraints encountered in establishing extension agent short courses. Additionally, this report lists the meetings attended by CRSP scientists.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION
TR4/High-input green water on-farm trials in Northeast Thailand/Diana [Final report; report title different than study title in *Eighth Work Plan*]

In 1995/96 the Asian Institute of Technology (AIT) Aquaculture Outreach Project (AOP) in Thailand and the Department of Fisheries (DOF) carried out a high-input on-farm trial with 12 farmers from three provinces in Northeast Thailand. In a number of on-station trials at AIT, researchers found that daily supplements of inorganic fertilizers at the rate of 4 kg N and 1 kg P ha^{-1} as urea and TSP, respectively, produced optimum yields. Based on these results, a package of technical recommendations for high-input green water trials was developed and recommended for trial by small-scale farmers. Included in this report are details regarding the farming systems of project farmers, aquaculture subsystems of farmers, pond characteristics, the type of support provided by the DOF and AOP, nursing of fry, and information regarding fish culture (e.g., stocking density, culture period, fertilization, culture species, harvest, and yield). Additionally, the significance of the on-farm trials is discussed in terms of the physical quality of pond water, farmers' perceptions of the success of technical recommendations, production, socio-economic aspects of the trial, and environmental concerns. Overall the trial was quite successful. Expected yield was approximately 600 kg rai^{-1}; however, the average yield recorded was much higher (944 kg rai^{-1}), and virtually all farmers experienced a substantial increase in fish yield which was associated with the change in pond water color from turbid to green or dark green.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: DECISION SUPPORT SYSTEMS
DSSR1A, DSSR1B, and DSSR1C/POND© software development and refinement/Bolte [Final report; results of studies DSSR1A, DSSR1B, and DSSR1C submitted as one report; report title different than study title in *Eighth Work Plan*]

Continued refinement of POND© software characterized the work of the Decision Support Systems component during the second year of the Eighth Work Plan period. In addition to improvements made to the user interface, "wizards" were developed for the automation and completion of frequently utilized tasks and a water budget model was also incorporated into POND© software. The following wizards are now in place: pond setup, lot setup, fertilizer, liming, feed optimizer, water balance, economics, and simulation. The water budget model, used for forecasting water requirements for aquaculture ponds, considers the following water sources: precipitation and runoff. Water losses include evaporation, seepage, effluent discharge, and overflow; water sinks include water discharge, overflow, and evaporation. It is anticipated that the refinements made to POND© will improve simulation of production facility dynamics in addition to enhancing model usability via the newly incorporated wizard interfaces.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: DECISION SUPPORT SYSTEMS
DSSR1D/Macro-level agroecological systems analysis and socioeconomics of pond aquaculture/Bolte [Final report]

Recently Decision Support Systems researchers completed a collaborative project with the Food and Agriculture Organization of the United Nations. POND© software was incorporated into a GIS product to assess the suitability of particular agroecological regions in South America and Africa to aquaculture production. For further information regarding this collaboration, the following two reports are available:

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. FAO COPESCAL Technical Paper No. 10, FAO, Rome, 124 pp.

One of the limitations of this study was that it was unable to compare the suitability of alternative land uses with aquacultural production. Thus, a study was initiated to identify methods for generating terrestrial crop production estimates. Artificial neural networks were used to estimate crop yields, water requirements, fertilizer requirements, and grow-out period or time to harvest. Work in progress includes the development of a framework to analyze and prioritize international development needs and the identification and classification of indicators relating to sustainable development. The overall tool developed from this study will be used to explore alternate land/water use strategies in relation to different crops, which include fish farming, and is intended for use in the inland regions of Honduras.

RESEARCH PROJECTS

POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

Staff

Auburn University, Alabama

Claude E. Boyd	US Principal Investigator, Project Leader
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Background

The interactions among nutrients, primary and heterotrophic productivity, and fish yield are known as pond dynamics. PD/A CRSP research to date has expanded the understanding of factors that affect pond productivity. However, in all of the previous CRSP research, pond sediments have received little attention, and an understanding of how pond sediments affect pond dynamics is limited. It is known from agricultural research that crop response to nutrient management strategies can vary considerably among soil types. It is likely that pond soils can also affect pond dynamics in an analogous manner.

Research on pond dynamics involves the characterization of pond soil samples collected from each of the PD/A CRSP sites. Among other applications, results of the pond sediment characterization research should provide useful information in the interpretation of results of studies to be implemented at the Southeast Asia site on the effects of mud turbidity and pond bottom management.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Pond soil characteristics and dynamics of soil organic matter and nutrients/PDR1. The report submitted for this study was a progress report.

Note: Research under this subcontract is revised from that described in the E*ighth Work Plan*. The new (replacement) work plan appears in the *Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Networking Activities

CRSP Principal Investigator Claude Boyd presented a workshop on pond soil and water quality in shrimp farming to approximately 40 shrimp farmers. The workshop was sponsored by and held at the University of Monterey, Mazatlan, Mexico. Boyd also conducted seminars and discussed CRSP efforts at University of the North, Pietersburg, South Africa.

Boyd was also involved with a number of private sector organizations internationally (Thailand, Chile, Venezuela, Ecuador, and Indonesia) and utilized CRSP data during his consultations on topics that included the development of a design trial for evaluation of water and soil conditioner, soil quality and management in shrimp ponds, fertilizer formulas for shrimp ponds and aquaculture ponds, and sustainable shrimp farming. Boyd also served on an industry liaison committee at the Oceanic Institute, participated in a mangrove working group in Thailand, developed a shrimp farming code of practice in Thailand with the World Bank, and worked to identify best management practices with the Global Aquaculture Alliance.

In addition to consultative work, Boyd has been contacted by fellow researchers from the US, Israel, India, and Australia and by shrimp farmers from Madagascar, Venezuela, Indonesia, and Colombia regarding CRSP soils research. He also plans to speak at the Fifth Asian Aquaculture Conference in Thailand, the World Aquaculture Society Meeting, and two conferences in Brazil. Additionally, a postdoctoral fellow from Brazil, a graduate student from Israel, visiting scientists from Korea and India, and a Belgian researcher have all participated in or received training in relation to CRSP research.

Publication

Boyd, C.E. and B. Green, 1998. Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*). J. World Aquacult. Soc., 29:125-128.

Presentations

Boyd, C.E. Aquaculture pond soils with emphasis on shrimp culture. Soil Science Graduate Seminar, Texas A&M University, 1997.

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. Phosphorus chemistry in pond soils. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Boyd, C. E. Shrimp farming and the environment. Presented to AAAS Annual Meeting, Philadelphia, Pennsylvania, 1998.

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, Las Vegas, Nevada, 15-19 February 1998.

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.

Conferences

IV Ecuadorian Symposium on Aquaculture at Guayaquil, Ecuador, 22-27 October 1997. (Boyd)

Soil Science Society of America Annual Meeting at Anaheim, California, 25-30 October 1997. (Wood)
FAO Technical Consultation on Policy Related to Sustainable Shrimp Farming at Bangkok, Thailand, 1997. (Boyd)
National Strategies and Management of Aquacultural Waste, Portugal, 1998. (Boyd, Queiroz)
AAAS Annual Meeting at Philadelphia, Pennsylvania, 12-17 February 1998. (Boyd)
PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Boyd, Wood)
Aquaculture '98, WAS Annual Meeting, Las Vegas, Nevada, 15-19 February 1998. (Boyd, Wood)

Workshops Given

August 1997, Soil management in shrimp ponds (4 days), Guayaquil, Ecuador (32 participants).
August 1997, Water quality and pond bottom soils (1/2 day), China, four places (total of 385 participants).
November 1997, Water quality in shrimp ponds (3 days), Guayaquil, Ecuador (22 participants).
January 1998, Water and soil quality in shrimp farming (2 days), Mazatlan, Mexico (41 participants).
March 1998, Water quality (1/2 day), University of the North, Pietersburg, South Africa (25 participants)
May 1998, Shrimp pond water quality (2 hr), Chantaburi and Surat Thani, Thailand (total of 73 participants).

POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL ORGANIC MATTER AND NUTRIENTS

Eighth Work Plan, Pond Dynamics Research 1 (PDR1)
Progress Report

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

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

ABSTRACT

Soil cores were collected from ponds at the Sagana Fish Culture Farm, Kenya. The pond bottoms had well-developed S horizons of 6 cm depth, but M and T horizons were weakly developed. Recent renovation of ponds with sediment removal explains the weak M and T horizons. The soils were near neutral in pH, with carbon concentrations between 2 and 5%. Carbon:nitrogen ratios were between 10 and 20. Total sulfur concentrations were around 0.5%, and soil phosphorous concentrations were low. The soils had high concentrations of exchangeable bases, and micronutrient concentrations were within normal ranges. Soil incubation studies on pond soils from Thailand, Honduras, and Kenya revealed relatively low microbial respiration rates as compared to typical terrestrial soils, and there was net negative nitrogen mineralization (nitrogen was immobilized). Equilibrium phosphorus concentrations in soil-water mesocosms were: AIT, new ponds, 0.17 mg l^{-1}; AIT, old ponds, 0.12 mg l^{-1}; Honduras, freshwater ponds, 0.22 mg l^{-1}; Honduras, brackishwater ponds, 0.23 mg l^{-1}; Kenya, 0.06 mg l^{-1}. At all sites, pond soils will be sinks for phosphorus added in fertilizer. Pond soils appear to develop distinct profiles within a few years, in contrast to terrestrial soils where soil development takes much longer.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

Staff

University of Oklahoma, Norman, Oklahoma

William Shelton	US Principal Investigator, Project Leader
Hank Ray	Research Technician
Ana Hiott	Research Technician

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 Work Plan was scheduled to develop appropriate techniques for the androgenetic production of YY male tilapia.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Methods for androgenesis techniques applicable to tilapia/RCR1B. The report submitted for this study was a progress report. The title of the submitted report ("Nile tilapia gamete management for chromosome manipulation") differs from the study title.

Note: The research schedule for this subcontract was revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for revised schedule information. The studies grouped under the research theme RCR1, "Monosex tilapia production through androgenesis," are collaborative projects between Auburn University (under Subcontract No. RD010A-09) and the University of Oklahoma.

Networking Activities

CRSP Principal Investigator William Shelton spent one month in Israel working on a collaborative study on androgenesis in grass carp. Additionally, the collaboration provided a founder stock of red mutant Nile tilapia to be used in future CRSP studies.

Conferences

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Shelton)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Shelton)

NILE TILAPIA GAMETE MANAGEMENT FOR CHROMOSOME MANIPULATION

Eighth Work Plan, Reproduction Control Research 1B (RCR1B)
Progress Report

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

ABSTRACT

Artificial propagation is an important component of chromosome manipulation. Spawning of Nile tilapia (*Oreochromis niloticus*) was manipulated by photoperiod and temperature control and through hormonal intervention. Four males and ten females produced 86 natural spawns, 41 of which developed to hatching. Artificial propagation resulted in 87 pairings, which were successfully used in 23 tau estimates and 11 UV experimental trials. A tau-curve was developed over temperatures ranging from 20.6 to 28.7°C with mitotic intervals from 73.8 to 30.1 min, respectively. A UV dose of 300 to 500 J m^{-2} appears to be sufficient to inactivate the DNA of Nile tilapia eggs. Genetic color markers were identified by progeny testing.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

Staff

Auburn University, Alabama

Ronald P. Phelps	US Principal Investigator, Project Leader
R. Lee Warrington	Graduate Research Assistant
John Arndt	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 reproductive 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 this work plan include a series of studies which address this issue from various perspectives: determining the variability in sex ratios from pair mating of different strains of tilapia; determining whether there is an autosomal influence on the sex ratio of Nile tilapia; developing a pure YY line of male and female Nile tilapia; masculinizing tilapia by steroid immersion. An additional study addresses the health and environmental impacts of a commonly used masculinization technique by detecting androgen from treated feed in pond water.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Methods for strain variations in sex ratio inheritance/RCR1A. The report submitted for this study was a progress report.
- Masculinization of tilapia fry by immersion in MDHT at a production level/RCR2C. The report submitted for this study was a final report. The title of the submitted report ("Masculinization of tilapia fry by immersion in trenbolone acetate (TBA) at a production level") differs from the study title.
- Detection of MT in pond water after treatment with MT food/RCR3B. An abstract was submitted for this study.
- Methods for contribution from the male and female genome to sex inheritance/RCR1C. The report submitted for this study was a progress report.
- Methods for development of YY lines of male and female *O. niloticus*/RCR1D. No report was submitted for this study.

Note: The research schedule for this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. The studies under the research code RCR1, "Monosex tilapia production through androgenesis," are collaborative projects between the University of Oklahoma (under Subcontract No. RD010A-02) and Auburn University. The studies RCR2, "Steroid immersion for masculinization of tilapia," and RCR3, "Detection of masculinizing agents in the pond environment," involve collaboration between Oregon State University (under MOU No. RD009C) and Auburn University.

Presentation

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 at the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997.

Conferences

Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997. (Phelps)

Foro International de Casos de Exito en la Acuacultura, November 1997. (Phelps)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Phelps)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Phelps)

METHODS FOR STRAIN VARIATIONS IN SEX RATIO INHERITANCE AND METHODS FOR CONTRIBUTION FROM THE MALE AND FEMALE GENOME TO SEX INHERITANCE

Eighth Work Plan, Reproduction Control Research 1A and 1C (RCR1A and 1C)
Progress Report

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

ABSTRACT

Effective and practical control of reproduction is the major constraint in tilapia culture. Uncontrolled reproduction can result in less than 25% of the adults being greater than 250 g after a six-month culture period, with the majority of the population being progeny less than 10 g each. Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in the tilapia *Oreochromis niloticus*. Females are said to be homogametic (XX) and males heterogametic (XY), but the sex inheritance of the progeny from a single pair often does not conform to the expected 50:50 ratio. This lack of conformity to a simple XX:XY sex inheritance pattern complicates the intraspecific breeding approach of developing YY males that would give all-male progeny. The identification of tilapia populations with minimal variation in progeny sex ratios from individual spawns would be a

significant contribution to the development of a YY male breeding program. Three strains of *Oreochromis niloticus* — Egypt, Ghana, and Ivory Coast—were spawned in outdoor hapas at 28 to 32°C. A total of 44, 34, and 52 spawns from the Egypt, Ghana, and Ivory Coast strains, respectively, were successfully reared to a sexable size and the sex ratio of each spawn established. The mean percentage of males, females, or intersex fish did not differ among the three strains evaluated. A given male did not give consistent sex ratios when mated with different females. Multiple spawns from a given female also had variable progeny sex ratios.

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

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

Editor's Note:
No report was submitted. Under an approved work plan schedule change (see *Addendum to Eighth Work Plan*), study RCR1D was not scheduled to begin until August 1998, after the end of the reporting period.

MASCULINIZATION OF TILAPIA FRY BY IMMERSION IN TRENBOLONE ACETATE (TBA) AT A PRODUCTION LEVEL

Eighth Work Plan, Reproduction Control Research (RCR2C)
Final Report

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

ABSTRACT

The precocious reproduction of tilapias (*Oreochromis* spp.) had been a serious impediment to successful commercial tilapia production until all-male cultures techniques were developed. Dietary treatment with 17α-methyltestosterone (MT) is an effective means of producing all-male tilapia populations; however, the treatment requires a minimum of several weeks exposure. Administration of steroids to the water containing sexually undifferentiated fish has also been effective in altering sex ratios and may provide aquaculturists with a safe and cost-effective alternative to treating fry with food that contains MT. Immersion requires substantially shorter exposure periods and the steroid is contained for controlled filtration or biodegradation. *Oreochromis niloticus* fry were stocked into aquaria and treated at a density of 33 fish l^{-1} with a stock solution of trenbolone acetate (TBA) dissolved in ethanol at 500 mg TBA l^{-1} for six hours on day 9, 11, 13, or 15 post-hatch. Fish were harvested and mean length, weight and survival were determined. Fish were restocked into outdoor 20-m^2 tanks and reared to 5 cm or larger. Sex ratios were determined by gonadal squashes. There was no treatment effect on sex ratio of Nile tilapia. The non-TBA treatment had a mean of 49.1% males while TBA treatments for the different age groups ranged from 43.7 to 54.3% males. Survival ranged from 64.0 to 82.4% with no observed correlation between age at treatment and survival. Average length and weight at 20 days of age was not correlated to treatment nor survival.

DETECTION OF MT IN POND WATER AFTER TREATMENT WITH MT FOOD

Eighth Work Plan, Reproduction Control Research 3B (RCR3B)
Abstract

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

ABSTRACT

The objective of this study is to determine if 17α-methyltestosterone (MT) can be detected in the treatment environment and if so, for how long after treatment. The field aspect of this study has begun. Nile tilapia fry are stocked in two 2-m^2 hapas at 2,000 $hapa^{-1}$. The hapas are located approximately 50 cm apart in a 400-m^2 earthen pond. One group is receiving a commercial trout ration that does not contain MT; the other receives a feed containing 60 mg MT kg^{-1} of feed. The fish will be cultured 28 days; after harvest, growth and survival will be determined and then in the same hapas the fish will be reared to sexual maturity and fed a non-hormone-treated feed. Preliminary soil samples were collected in 1997 and furnished to Dr. Fitzpatrick for MT assay and refinement of sampling protocols. Assay of these soils, which have had no history of exposure to MT, indicated levels of 269.3 to 1,553.3 pg g^{-1} of soil, suggesting that the assay for MT may cross-react with natural products in the soils. As part of the current field study, samples of water are being collected during the treatment period from within each hapa and at 2, 5, and 10 m from the hapas. Additionally, soil samples are being collected from directly under the hapas and at 2, 5, and 10 m from the hapas. These samples are frozen soon after collection for later assay.

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)
Ruth H. Milston	Undergraduate Student Researcher
Rik Hornick	Undergraduate Student Researcher
Michael Lucero	Undergraduate Student Researcher
Grant W. Feist	Research Assistant

Cooperator:

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico
Wilfrido M. Contreras Sánchez

Background

Broodstock and seed supply was identified as a major constraint in the *Continuation Plan 1996-2001*, resulting in reproductive 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 this work plan include a series of studies which address this issue from various perspectives.

Research under the Eighth Work Plan includes studies on steroid immersion for masculinization of tilapia and detection of masculinizing agents in the pond environment. Research continued on the use of MDHT to masculinize tilapia, with current studies varying the protocol to minimize treatment time and potentially increase efficiency of exposure. In addition to steroid immersion, androgen-treated feed is used to masculinize tilapia. A study to determine the fate of 17α-methyltestosterone (MT) in semi-closed systems such as ponds was undertaken to learn more about both safety and efficacy of MT use for masculinization.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Effect of fish density on efficacy of masculinization by immersion in MDHT/RCR2B. The report submitted for this study was a final report.
- Detection of MT in aquarium water after treatment with MT food/RCR3A. The report submitted for this study was a final report.
- Immersion of tilapia fry in MDHT/RCR2A. The report submitted for this study was a final report.

Note: Research under this subcontract was revised from that described in the *Eighth Work Plan*. The new (replacement) work plan appears in the *Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for revised schedule information. The studies under the research theme code RCR2, "Steroid immersion for masculinization of tilapia," and RCR3, "Detection of masculinizing agents in the pond environment," involve collaboration between Auburn University (under Subcontract No. RD010A-09) and Oregon State University.

Networking Activities

Within the last reporting period CRSP Co-Principal Investigator Martin Fitzpatrick has offered his expertise to individuals involved with academia and the private sector. Fitzpatrick provided guidance to Mr. Ahmed Nassr Alla who recently completed his thesis, "Comparison between the efficiency of oral and immersion (aqueous solution) administering of 17α-MT for the production of monosex tilapia (*Oreochromis niloticus*)." Fitzpatrick also presented two workshops—one on experimental design in aquaculture and the other on the safe handling of chemicals in aquaculture—to four host country scientists who visited Oregon State University under sponsorship of the EDC project (Principal Investigator: McNamara). Additionally, Fitzpatrick assisted a prospective fish farmer from the state of Washington who was interested in establishing a recirculating system for aquaculture in her town. Fitzpatrick invited the farmer to visit Oregon State University to tour its Warm Water Research Facility and provided contact information for the American Tilapia Association and aquaculture extension agents and basic instruction on the culture of tilapia.

Graduate Research Assistant Wilfrido Contreras Sánchez, a Ph.D. student at Oregon State University, spent two months at the Universidad Juárez Autónoma de Tabasco (UJAT) in Mexico conducting trials of the immersion protocol for masculinization of tilapia. During his two months at the university he trained eight undergraduate students and two faculty members. Also while in Mexico, Contreras Sánchez contacted a local government farm that produces tilapia fry for small-scale farmers. He also gave a one-day workshop on statistics and research methods in aquaculture to CRSP host country researchers from Honduras, Peru, Kenya, and the Philippines in October 1997, as part of a workshop sponsored by the EDC.

Professor Gabriel Márquez Couturier, from the División Academica de Ciencias Biologicas, UJAT, Mexico, was invited by Fitzpatrick to travel to Oregon State University. Márquez Couturier recently began participating in CRSP-related projects. The purpose of his visit was to receive training in steroid immersion techniques and in safe handling of steroids and design experiments on the masculinization of tilapia to be conducted in Mexico. A Memorandum of Understanding between UJAT and OSU is presently under consideration.

During the Fourth International Symposium on Tilapia in Aquaculture, Fitzpatrick and Contreras Sánchez discussed the potential for collaboration with a representative of Constain Asociados Ltda. in Colombia who is interested in having his pond soil tested for methyltestosterone residues. OSU

researchers are also working together with Dr. Samuel Maranon Herrera of Universidad Autónoma Metropolitana in Mexico City to test trenbolone acetate as a masculinization compound for tilapia and on histological analyses of tilapia gonads.

Publications

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.

Gale, W.L., M.S. Fitzpatrick, and C.B. Schreck, 1998. Binding characteristics of a gonadal androgen receptor in Nile tilapia. Gen. Comp. Endocrin. (Submitted).

Conferences

Fourth International Symposium on Tilapia in Aquaculture, Orlando, Florida, 9-12 November 1997. (Contreras Sánchez, Fitzpatrick)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998 (Contreras Sánchez, Fitzpatrick)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Contreras Sánchez, Fitzpatrick)

Steroid Immersion for Masculinization of Tilapia: Immersion of Tilapia Fry in MDHT

Eighth Work Plan, Reproduction Control Research 2A (RCR2A)
Final Report

Martin S. Fitzpatrick, Wilfrido M. Contreras Sánchez, Ruth H. Milston, Michael Lucero, and Grant W. Feist
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

The effects of a single immersion of fry in the androgen 17α-methyldihydrotestosterone (MDHT) on masculinization of Nile tilapia were investigated. Previous experiments had demonstrated that two immersions in 500 μg l^{-1} of this steroid for three hours each on days 10 and 13 after fertilization resulted in greater than 90% male populations. In the study described below, tilapia fry were immersed once in 500 μg l^{-1} of MDHT for two hours on days 10, 11, or 13 after fertilization. Significant masculinization occurred only in the group immersed on day 13 after fertilization, and the proportion of males produced (79.3%) was not significantly different from the proportion of males produced (82.9%) after two immersions on days 10 and 13 after fertilization.

Effect of Fish Density on Efficacy of Masculinization by Immersion in MDHT

Eighth Work Plan, Reproduction Control Research 2B (RCR2B)
Final Report

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Biological Resources Division-U.S. Geological Survey
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Corvallis, Oregon, USA

Abstract

The effect of fish density on the capacity of the synthetic androgen 17α-methyldihydrotestosterone (MDHT) was investigated. As in previous studies in this laboratory, significant masculinization occurred when fish were immersed in 500 μg l^{-1} of MDHT for two hours at 280 and 364 CTU at a density of 33 fish l^{-1} (80.3% males vs. 56.7% males in the controls). When the density during treatment was increased to either 66 or 100 fish l^{-1}, MDHT immersion resulted in 71.7% males in both treatments, which was nearly significantly more than controls, and suggests an effect of stocking density on masculinization.

Detection of MT in Aquarium Water after Treatment with MT Food

Eighth Work Plan, Reproduction Control Research 3A (RCR3A)
Final Report

Martin S. Fitzpatrick, Wilfrido M. Contreras Sánchez, Ruth H. Milston, Rik Hornick, and Grant W. Feist
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Carl B. Schreck
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Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Abstract

The following study tested the hypothesis that 17α-methyltestosterone (MT) persists in the environment after its use for masculinizing Nile tilapia (*Oreochromis niloticus*). 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 3.7-l jars that contained 3 cm of 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 between approximately 1 and 2 $\mu g\ l^{-1}$ at 14 and 21 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 contrast, the levels in the soil were 1.4 to 1.7 $\mu g\ kg^{-1}$ at 28 days after the onset of feeding with MT-impregnated food and remained detectable in the soil at between 0.8 and 1.6 $\mu g\ kg^{-1}$ through 49 days (three weeks after ending treatment with MT-impregnated food). These results suggest that MT persists in sediments for at least weeks after cessation of MT treatment, which raises the possibility that unintended exposure to MT may occur.

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)
Zhimin Lu	Research Assistant (People's Republic of China)

Background

The current work on aquaculture systems modeling 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.

The models are being tested with data from various PD/A CRSP sites. The stochastic model being developed 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 developed can be useful as components of decision support systems being developed under 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.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

Note: The research schedule under this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Networking Activities

CRSP Principal Investigator Raul Piedrahita taught a five-day course on aquacultural engineering at the Universidad Autónoma de Baja California, Ensenada, Baja California.

CRSP Research Assistant Daniel Jamu, who specializes in systems modeling, traveled to Malawi in the current reporting period with funding from the Rockefeller Foundation and made contacts with individuals affiliated with universities, government agencies, and the International Center for Living Aquatic Resources Management (ICLARM). During his trip Jamu obtained data from various experimental plots in addition to detailed weather data.

Within the last year Piedrahita has received four requests regarding the use of models or information about the models from donor agencies, researchers, and host country officials.

Publications

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.

Lu, Z., R.H. Piedrahita, and C. Dos Santos Neto, 1998. Generation of daily and hourly solar radiation values for modeling water quality in aquaculture ponds (Submitted).

Conferences

Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997. (Jamu, Lu, Piedrahita)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Piedrahita)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Piedrahita)

MODEL EVALUATION AND APPLICATION TO THE ECOLOGICAL ANALYSIS OF INTEGRATED AQUACULTURE/AGRICULTURE SYSTEMS

Eighth Work Plan, Aquaculture Systems Modeling Research 1A (ASMR1A)
Progress 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 verification methods. The verified model was used to identify priority areas for future research in integrated aquaculture/agriculture systems and to study the long-term accumulation of nitrogen in pond

sediments. Sensitivity analysis results showed that the most sensitive parameters were maximum specific phytoplankton production rate per unit of carbon, aerobic sediment depth, oxygen threshold for aerobic conditions, water infiltration rate, and organic matter sedimentation rate. 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. Model verification 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. A ten-year simulation showed a marginally greater increase in sediment organic matter concentration in ponds receiving chicken manure and artificial feed inputs when compared to ponds receiving a combination of chicken manure and plant wastes. Steady-state conditions for sediment organic matter concentrations were not achieved within the ten-year simulation period. These results were consistent with observations made in fish ponds but different from published model predictions. Based on the verification and application 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 these systems.

MODELING OF TEMPERATURE, DISSOLVED OXYGEN, AND FISH GROWTH RATE IN STRATIFIED PONDS USING STOCHASTIC INPUT VARIABLES

Eighth Work Plan, Aquaculture System Modeling Research 1B (ASMR1B)
Progress 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 was run 20 times for each data set in the calibration and validation process. The simulation results obtained and presented in this report include mean, maximum, and minimum values for each time step. The simulated water temperature and DO are in good agreement with data for the Honduras and Rwanda sites; however, simulated and observed values for chlorophyll *a* at the Thailand site differ. Probability distributions for water quality and fish yield can be calculated from the simulation results and are useful to pond managers, planners, researchers, and teachers.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

Staff

University of Arkansas at Pine Bluff, Pine Bluff, Arkansas

Carole Engle	US Co-Principal Investigator, Project Leader
Pierre-Justin Kouka	US Co-Principal Investigator (to 31 October 1997)
Siddharta Dasgupta	US Co-Principal Investigator (from 1 February 1998)
Diego Valderrama	Graduate Research Assistant (Colombia) (15 January-30 June 1998)

Background

The involvement of social scientists in the PD/A CRSP has increased gradually over time. In the past, economists and social scientists conducted studies of a localized nature which focused on specific research questions. A broader approach was implemented in the *Continuation Plan 1996-2001* which proposed more comprehensive economic analyses across regions. The studies underway seek to understand the constraints to aquaculture development as well as the key factors that determine economic feasibility of aquaculture that are common to all regions. This regional approach links prime and companion sites with on-going economic analysis in the US.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Economic and social returns to technology and investment/MEAR1. The report submitted for this study was a progress report.
- Risk analysis of pond management strategies/MEAR2. The report submitted for this study was a progress report.

Note: One report combining studies MEAR1 and MEAR2 was submitted under this subcontract. The research schedule under this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Networking Activities

CRSP Principal Investigator Carole Engle visited Honduras in October 1997 to facilitate two workshops on marketing, business plan development, and farm management efficiency. The workshops, conducted in Spanish, drew a diverse group of 30 individuals representing the Honduran government, producer organizations, tilapia and shrimp farmers, and bank lenders. In addition to facilitating workshops Engle met with numerous officials from the Federación de Agroexportadores de Honduras (FPX) and Asociación Nacional de Acuicultores de Honduras (ANDAH).

As noted above, Pierre-Justin Kouka left the CRSP in October 1997 to assume a post at the West Africa Rice Development Association in Côte d'Ivoire, thus establishing an informal linkage between the CRSP and WARDA. (WARDA is one of the international agricultural research centers supported by the Consultative Group on International Agricultural Research.)

Kouka and the PD/A CRSP have also continued participation in InterCRSP efforts in the West African countries of Cape Verde, The Gambia, Mali, and Senegal, where research is presently focusing on reversing soil acidification, loss of organic matter, reducing the effect of runoff on food production systems, and economic analysis.

Presentation

Engle, C.R. Teaching aquaculture economics. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Conferences

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Engle)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Engle)

ECONOMIC AND SOCIAL RETURNS TO TECHNOLOGY AND INVESTMENT AND RISK ANALYSIS OF POND MANAGEMENT STRATEGIES

Eighth Work Plan, Marketing and Economic Analysis Research 1 and 2 (MEAR 1 and 2)
Progress Report

Carole Engle and Pierre-Justin Kouka
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

Printed as submitted

ABSTRACT

Analyses of economic and social returns to technology and investment and for risk analysis require farm production data. Twenty-one shrimp farm owners and managers were interviewed in Honduras in March, 1998, representing approximately 1/3 of the total number of shrimp farms in the country. The total hectareage represented in the study sample was 54% of the total hectareage in shrimp production in the country. Survey data were entered into an EXCEL spreadsheet for summarization and cross-tabulation. Most of the farms participating in the survey had yields of shrimp that were either in the range of 1,000 - 1,500 lb of head-off shrimp/ha/yr (33%) or 1,501 - 2,000 lb/ha/yr (38%). Farms that stocked PL's at higher rates achieved higher yields. Farms that stocked more than 20 PL/m^2 achieved yields greater than 1,500 lb/ha/yr while those stocking 15 PL/m^2 had lower yields. Farms with yields over 2,000 lb/ha/yr also fed more than 15 lb/ha/d during the dry season. Over half of the respondents fertilized ponds, but most of these were small and medium-sized farms. Most large farms did not fertilize at all. Large farms also tended to be more reliant on hatchery-raised PL's, than were small and medium-sized farms. Shrimp farms appeared to exhibit economics of scale in that large farms tended to have lower costs per hectare than smaller farms.

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) (from October 1997)

Sagana Fish Farm, Kenya

Judith Amadiva	Social Development Officer

Cooperator:

Sagana Fish Farm, Kenya
Bethuel Omolo

Background

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. This research addresses these issues at new sites and expands the scope of and clarifies socioeconomic dimensions as they affect the conduct and progress of the overall research program through the efforts of individual scientists and their host institutions.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Socioeconomic dimensions of aquaculture development: Baseline conditions, human capital impacts, and technology diffusion processes/ADR1. The report submitted for this study was a progress report. The title of the submitted report ("Tilapia producer perceptions and practices in five PD/A CRSP countries") differs from the study title.

Note: The research and the research schedule under this subcontract are revised from that described in the Eighth Work Plan. The new (replacement) work plan will appear in the forthcoming *Second Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Networking Activities

CRSP Principal Investigator Joe Molnar was organizer and chair of a three-hour symposium, "Global shrimp farming, mangroves, and people: Finding a sustainable path," featuring presentations by shrimp farmers from Ecuador and Honduras, PD/A CRSP researchers Claude Boyd and Kwei Lin, Rural Sociologist Conner Bailey, and representatives of several environmental organizations. The symposium was part of the February 1998 Annual Meeting of the American Association for the Advancement of Science, held in Philadelphia, Pennsylvania. In addition, Molnar reviewed an evaluation strategy and design to identify outcomes for interventions intended to advance aquacultural development in Africa for the International Center for Living Aquatic Resources Management (ICLARM).

Publication

Molnar, J. 1998. Sound policies for food security: The role of culture and social organization. Rev. Agricult. Econ. (in press).

Presentations

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.J. and J. Amadiva. Aquacultural development in central Kenya: Farming system, household, and community considerations. Poster presentation to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, February 1998.

Conferences

Annual Meeting of the Rural Sociological Society, Toronto, Canada, 1997. (Molnar)

Annual Meeting of the American Association for the Advancement of Science, Philadelphia, Pennsylvania, 12-17 February 1998. (Molnar)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Lockhart, Molnar)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Lockhart, Molnar)

TILAPIA PRODUCER PERCEPTIONS AND PRACTICES IN FIVE PD/A CRSP COUNTRIES

Eighth Work Plan, Adoption and Diffusion Research 1A (ADR1A) Progress Report

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

Judith Amadiva and Bethuel Omolo
Fisheries Department
Sagana Fish Culture Farm
Sagana, Kenya

ABSTRACT

The PD/A CRSP site in Sagana, Kenya, is situated in the highlands of Central Province, which provide excellent growing conditions for many types of farm enterprises. This is mainly due to the great abundance of fertile volcanic soil in the lands around Mount Kenya. The area is well watered and cool temperatures make the area very productive in food crops, but other factors affect the potential for fish culture. Central Province had about 2,230 fishponds in 1995. In contrast, the Lake Basin area (Western and Nyanza Provinces) has about

5,000 to 10,000 active ponds, although there were as many as 25,000 in the area during the mid sixties and mid seventies. This article summarizes the results of a five-year program of farm-level surveys conducted in five PD/A CRSP countries, updating previous reporting with new data from tilapia producers in Central Province. Kenya is the new PD/A CRSP site in Africa, and data were collected from practicing fish farmers in 1998.

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

The CRSP has investigated methods of improving fish production from small, family, or community operated fish ponds to increase supplies of animal protein for ten years. For the research information to have an impact on rural populations in developing countries, appropriate technology must be transferred from the research stations to the farmers. To date no measure of the sustainability of the introduced technology by pond owners five to ten years after project termination has been published.

This subcontract for Eighth Work Plan research was effected in April 1998 due to the unavailability of the principal investigators until 1998 (in contrast to most other subcontracts, which were in place in 1996) and is anticipated to provide information on the appropriateness of introduced technology and extension methodology and on the socioeconomic influences on the sustainability of pond projects. Work will focus on pond projects in Panama and Guatemala.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Influence of fish culture technology, extension methodology and socioeconomics on success of fish culture on limited-resource farms/ADR2. The report submitted for this study was a progress report.

Note: The work plan for this research will appear in the forthcoming *Second Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for schedule information.

Networking Activities

During a two-week visit to Panama, CRSP Co-Principal Investigator Leonard Lovshin met with the Director of Aquaculture from the Ministry of Agricultural Development. The intent of the meeting was to brief the director on preliminary research findings. In Guatemala, meetings were also held with the following individuals to communicate PD/A CRSP research activities: the Director General, the Associate Director, the Associate Director for Programming and Training, the National Director of CARE, and the Program Implementation Specialist of USAID. Additionally, Lovshin traveled with and had the opportunity to interview the extension agents from both Panama and Guatemala who have provided technical assistance to the community pond projects of CRSP research focus.

THE INFLUENCE OF FISH CULTURE TECHNOLOGY, EXTENSION METHODOLOGY, AND SOCIOECONOMICS ON SUCCESS OF FISH CULTURE ON LIMITED-RESOURCE FARMS

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

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

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

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

ABSTRACT

The governments of Panama and Guatemala installed family and community fish pond projects to improve household nutrition and economic well-being in the 1980s. Financial assistance to both countries to support the construction and installation of fish ponds was provided by USAID. This research team made a rapid evaluation of 39 family fish ponds and 21 community fish ponds in Guatemala and Panama, respectively, during June 1998. The rapid evaluation of fish pond sites was followed at a later date by interviews with active and non-active project participants to learn the reasons for sustainability or abandonment of fish ponds. Of the 39 family fish ponds visited in Guatemala, 14 were abandoned, 20 were poorly cared for and were considered underutilized, and 5 were well cared for. In Panama, 6 community pond projects were abandoned and 15 were still utilized. Of the projects still utilized, 6 no longer cultured fish and grew only rice in some ponds and 9 continued to culture fish. Only 2 of the 9 projects culturing fish were considered well-managed, while the 7 remaining projects had average or poor fish pond management. Data from 46 household interviews in Guatemala and 114 household interviews in Panama are being entered into a computerized database for further evaluation. A final report will be available by early 1999.

DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

Staff

Oregon State University, Corvallis, Oregon

John Bolte	US Co-Principal Investigator, Project Leader
Shree Nath	US Co-Principal Investigator (to November 1997, then at University of Georgia)
Duncan Lowes	Graduate Research Assistant (Australia) (to April 1998)
Priscila Darakjian	Graduate Research Assistant (Brazil)

Cooperators:

Auburn University, Auburn, Alabama
Joseph Molnar

Food and Agriculture Organization, Rome, Italy
James Kapetsky

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. Such decision-makers require analytical tools that integrate various components of the knowledge base and provide capabilities to rapidly examine the economic and environmental consequences of different decisions. These tools, termed decision support systems, integrate knowledge in the form of mathematical models, rule-based (expert) systems, and/or databases into user-friendly software systems focused on developing, analyzing, and optimizing management strategies.

CRSP research in Decision Support Systems has developed a Windows-based software (POND©) that provides capabilities for simulation modeling and economic analyses of entire pond facilities. POND© facilitates the exploration of economic, biological, and physico-chemical issues relevant to pond production, planning, and optimization. It also provides a mechanism for synthesizing CRSP work conducted at various sites because the simulation models in the software are based on fundamental principles of pond aquaculture.

POND© is increasingly being used as a tool to supplement education, extension, and training programs both in the US and overseas. Its use has been promoted via the development of training materials and workshops. Distribution of the software occurs primarily from a World Wide Web site, and copies of the software are also available by direct request.

Although POND© has been used for a variety of applications, further refinement of the simulation models in the software is required to address pond sediment-water column interactions and the relationships between fish species and natural food availability under polyculture conditions. The overall deliverable of the research will be a revised version of POND© with supporting documentation.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- A pond sediment-water column model for phosphorus cycling/DSSR1A. The report submitted for this study was a final report.
- Models for heterotrophic dynamics and polyculture species interactions in ponds/DSSR1B. The report submitted for this study was a final report.
- Application of POND models for optimization of pond facilities based on economic performance and environmental impact constraints/DSSR1C. The report submitted for this study was a final report.
- Macro-level agroecological systems analysis and socioeconomics of pond aquaculture/DSSR1D. The report submitted for this study was a final report.

Note: A combined report for studies DSSR1A, DSSR1B, and DSSR1C was submitted under the title "Pond software development and refinement." The research schedule under this subcontract was revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Networking Activities

CRSP Co-Principal Investigator John Bolte continued his collaboration with the Senior Fishery Resources Officer of the Inland Water Resources and Aquaculture Service (Fisheries Department) at the Food and Agriculture Organization (FAO) regarding water temperature projections that were made for the GIS project in Africa and the POND© bioenergetic models that were refined for use in predicting fish performance for pond systems in Africa.

Bolte also met with the Leader of Hillsides AgroEcosystem Program, Centro Internacional de Agricultura Tropica (CIAT), to discuss the possible collaborative assessment of aquacultural production potential in Honduras. This connection with CIAT has led to further linkages for Shree Nath, who is now an Assistant Research Scientist at the University of Georgia. Additionally, Bolte met with a professor at the University of Georgia who specializes in fisheries extension to discuss the possible applications of POND© software for catfish operations in Georgia.

CRSP Co-Principal Investigator Shree Nath discussed the potential for future collaboration with Johan Verreth of Wageningen University, Holland, during a visit to Wageningen to present results from pond modeling work.

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. FAO COPESCAL Technical Paper No. 10, FAO, Rome, 124 pp.
Nath, S.S. and J.P. Bolte, 1998. A water budget model for pond aquaculture. Aquacult. Eng., 18(3):175-188.

Presentations

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.
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.
Nath, S.S., B.P. Verma, G. Rosenberg, and D. Nute. Integrated, multi-perspective approaches to decision support: Case study in Honduras. Presented at the 1998 Institute of Biological Engineering Meeting, 10-12 July 1998, Orlando, Florida.

Conferences

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Bolte, Nath)
Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Bolte, Nath)

POND© Software Development and Refinement

Eighth Work Plan, Decision Support Systems Research 1A, 1B, and 1C (DSSR 1A, 1B, and 1C)
Final Report

John P. Bolte
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Oregon State University
Corvallis, Oregon, USA

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

Abstract

The POND© software has undergone continued development during the Eighth Work Plan. In addition to the model and user interface improvements accomplished during the first year of the work plan, additional work on the development of wizards for automating and completing specific frequently used tasks, model refinement and development, and economic decisionmaking was accomplished. Wizards were refined to improve their usability, and new wizards were developed to assist in determining water balances and water requirements and to interpret simulation results. Models of fish production were refined and calibrated. The ability to schedule tasks of fixed and period duration was incorporated into POND© and the associated enterprise budgeter. An economic module estimating production cycle costs and returns was developed to assist in determining optimal harvest points based on the value of different fish sizes.

Macro-Level Agroecological Systems Analysis and Socioeconomics of Pond Aquaculture

Eighth Work Plan, Decision Support Systems Research (DSSR1D)
Final Report

John P. Bolte
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Oregon State University
Corvallis, Oregon, USA

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

Abstract

Recent work has been completed relating climatic and geographic factors to assess the suitability of particular agroecologic regions to aquaculture production. These studies were unable to compare the suitability of alternative land uses with aquacultural production. A study was therefore initiated to explore methods of generating terrestrial crop production estimates that: a) involve minimal use of complex simulation models and b) enable the use of biophysical input data likely to be available at the regional scale (e.g., monthly weather datasets). Such estimates are expected to assist regional-level decision makers to compare pond aquaculture with other types of farming systems. This work involved developing a framework to analyze and prioritize international development needs, and identifying and classifying indicators relating to sustainable development. Artificial neural networks were used to relate crop production to agricultural drivers. The Concurrent Decision-Making methodology appears to be a successful approach to facilitate stakeholder input into decision making and evaluation of alternatives intended to be used within group decision support tools. Development of a framework to assess international development needs and concomitant use of sustainable development indicators (SDI) should provide the target audience (i.e., international donor agencies, government organizations, and local groups) with a tool to examine where intervention would likely result in the greatest benefits. More specifically, such a tool can help to identify appropriate roles for aquaculture as well as other farming systems in disadvantaged communities.

HONDURAS PROJECT

Subcontract No. RD010A-06

Staff

Auburn University, Auburn, Alabama

Bartholomew Green	US Co-Principal Investigator, Project Leader (stationed in Tegucigalpa, Honduras)
David Teichert-Coddington	US Co-Principal Investigator
Claude Boyd	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
Delia Martinez	Chemist
Eneida Ramírez	Assistant Chemist

Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras

Nelson Claros	Chemist
Rene Palcios	Lab Technician
Carolina Cardona	Biologist

Cooperators:

Grupo Granjas Marinas, S.A., Choluteca, Honduras
John Wigglesworth
Brian Boudreau
Hector Corrales
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 focus of the program was shifted to Laboratoria de Calidad de Agua La Lujosa, a coastal site in southern Honduras, with the caveat that work at El Carao would continue unabated. The program in southern Honduras is in collaboration with four Honduran groups.

Work at the inland site concentrated 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 is being conducted at both inland and coastal sites.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Intensification of tilapia production: Effects of feeding at different stocking rate on pond water quality/HR1. No report was submitted for this study.
- Estuarine water quality monitoring and estuarine carrying capacity/HR2-1. The report submitted for this study was a progress report.
- Influence of daily water exchange volume on water quality and shrimp production/HR3. The report submitted for this study was a final report.
- Water exchange to rectify low dissolved oxygen/HR4. An abstract was submitted for this study.
- Global experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/FFR1H. The report submitted for this study was a final report.

Note: Research under this subcontract is revised from that described in the *Eighth Work Plan*. The new (replacement) work plan appears in the forthcoming *Second Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. No report was submitted for HR1; please see Editor's Note to HR1 abstract. The study HR2, "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 HR2 report (HR2-1) submitted by Auburn University addresses the first HR2 work plan objective; the second study objective is addressed in the HR2 report (HR2-2) submitted by the University of Texas.

Site Improvement

At the Centro Nacional de Investigación Piscícola El Carao in Comayagua renovation of the water quality laboratory, pond retaining walls, and the sampling platform were completed during the first year of the Eighth Work Plan. To improve water supply and flow to the La Lujosa site in Choluteca the PD/A CRSP drilled a new well and the Asociación Nacional de Acuicultores de Honduras (ANDAH) oversaw the installation of new pump electronics, plumbing, and a pump house.

Networking Activities

The PD/A CRSP continued to develop new linkages and renew its existing linkages in Honduras through meeting attendance, presentations, workshops, sponsorship, advising, and consultation. Honduras Co-Principal Investigator Bart Green met with the Board of Directors and the Semi-Annual General Assembly of ANDAH to discuss the status of the

estuarine water quality monitoring study and to present study results from the previous year. A presentation of this study's results was also made at a press conference on the Gulf of Fonseca. Additionally, Green assisted the National Animal Health Service and the Secretaría de Agricultura y Ganadería in formulating aquatic animal health import and export regulations and provided advice on the structure and management of an aquatic animal pathology lab being jointly developed by ANDAH, the Secretaría de Agricultura y Ganaderia, and the National Autonomous University of Honduras. Green also joined forces with ANDAH personnel to initiate contacts with Honduran tilapia farmers to organize them. In late May 1998 Green brought together ANDAH personnel and eight farmers to discuss how tilapia farmers might benefit by organizing, either independently or by joining ANDAH. Green also assisted with the planning for a seminar on shrimp culture and the environment along with representatives from the Programa Ambiental Regional para Centroamerica (PROARCA), Dirección General de Pesca y Acuicultura (DIGEPESCA), Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (CODDEFFAGOLF), ANDAH, and the United States Agency for International Development (USAID). The planning session was hosted by PROARCA/Costas. Additionally, the Honduran project co-sponsored, with the Education Development Component (EDC), two women—both chemists who are CRSP participants working at the Laboratorio de Calidad de Agua La Lujosa in Honduras—to attend training events. One participant (along with other Host Country collaborators from the Philippines, Peru, and Kenya) traveled to Oregon State University and to Auburn University in October 1997 under the auspices of the EDC to participate in a CRSP orientation training (for more detail, please see the report of the EDC). The other individual attended a CRSP-sponsored aquaculture economics workshop in Honduras conducted by CRSP Principal Investigator Carole Engle from the University of Arkansas at Pine Bluff. Each of the women had the opportunity to develop her knowledge and skills and to network with aquaculture colleagues.

Collaboration involving regional plans, communication linkages, and information exchange were discussed with the Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (PRADEPESCA) and CODDEFFAGOLF. PRADEPESCA invited the CRSP to make a presentation on CRSP-developed production systems as a portion of the regional planning meeting for field trials.

Future CRSP collaboration is planned with the Coastal Resources Center at the University of Rhode Island, facilitated by the PMO through EEP advice. Two representatives of the center traveled to Honduras to identify collaborators for a project that will identify best management practices for shrimp culture. During the representatives' stay in Honduras, Green coordinated visits with ANDAH and shrimp farmers.

Green also is representing the CRSP by serving as a co-organizer of the Fifth Central American Symposium on Aquaculture in 1999 and coordinating the invited speaker selection.

The CRSP site in Honduras has received several visits which have provided additional opportunities for creating linkages. CRSP Co-Principal Investigator Shree Nath of the University of Georgia, using Centro Internacional de Agricultura Tropica (CIAT) and other non-CRSP resources, visited Honduras where he toured the La Lujosa laboratory and research site and spent a day with Green discussing current and future project activities and progress. An ANDAH representative and the adviser to the head of Administración Forestal del Estado—Corporación Hondureña de Desarrollo Forestal (AFE-COHDEFOR, the Honduran government forestry agency) visited the La Lujosa laboratory. During the visit, Green presented an overview of the CRSP project activities and discussed the anthropogenic impacts on mangroves. The new director of DIGEPESCA visited El Carao station and met with Green to discuss the activities of the PD/A CRSP. A graduate student from Texas A&M University whose work focuses on the impacts of upland agricultural practices on shrimp culture also visited Honduras and spoke with Green of the possibility of the CRSP providing her with data which may be relevant to her thesis.

The PD/A CRSP also facilitated linkages on the ground and electronically. Green visited Nuestros Pequeños Hermanos orphanage to provide technical assistance on siting ponds to be used for wastewater polishing and, possibly, fish culture. Green learned of the orphanage's request for assistance via the PD/A CRSP website based at Oregon State University. In addition to linkages on the ground, electronic linkages were fostered with, among others, a graduate student from the University of California, Davis; a returned Peace Corps Volunteer, USA; a CRSP researcher at the Asian Institute of Technology; and individuals representing Empresa de Projetos Biodinamicos Ltda., Brazil; Escuela Agricola Panamericana, Honduras; Dirección General de Biodiversidad, Honduras; and Escuela de Agricultura de la Region Tropical Humeda (EARTH), Costa Rica.

Publications

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 Acuacultura, Guayaquil, Ecuador, CD-ROM.

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.

Presentation

Green, B.W. Mass production of *Oreochromis niloticus* and *Oreochromis aureus* fry in relation to water temperature. Presented at the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997.

Conferences

Fourth Ecuadorian Aquaculture Symposium at Guayaquil, Ecuador, 22-27 October 1997. (Green)

Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 12-19 November 1997. (Green, Ramírez)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Green)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Green)

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

Eighth Work Plan, Honduras Research 1 (HR1)
No Report Submitted

Editor's Note:
As per the researcher's account, this study was delayed because of a delay in harvesting a separate study (FFR1H) and because the well at the El Carao station was non-functional. Over several days in August the crew at El Carao had managed to fill eight 20-m^3 concrete tanks using all the output from a low-yielding well on-site. Regretfully, during a fish transfer, about 40,000 advanced fingerlings died, leaving approximately 20,000 advanced fingerlings, which were too few to stock HR1. The researcher reported that it would take four to five months to produce enough advanced fingerlings to stock this study. Therefore, the researcher requested and received approval for a work plan change. The new schedule for study completion is reflected in Appendix 4 (please see "Completion Dates for Eighth Work Plan Studies").

ESTUARINE WATER QUALITY MONITORING AND ESTUARINE CARRYING CAPACITY

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

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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: 1) detect changes in estuarine water quality; 2) formulate and validate predictive models for estuarine water quality; and 3) 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 June 1997 to June 1998 from 20 sites on 12 estuaries. Data were added to the database on estuarine water quality established in 1993. 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. Examples of this effect already have been observed in the upper reaches of a couple of estuaries where stands of mangroves have died apparently because of sedimentation, which resulted from severe reduction of runoff caused by watershed land-use changes. 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 El Niño in Honduras this past year was 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 and 1997. Embayment water quality was less affected by the El Niño. Declines in water quality in riverine estuaries were exacerbated with increasing distance upstream because water exchange with the Gulf of Fonseca decreases rapidly with distance upstream. No trends for total nitrogen or total phosphorus enrichment were evident in riverine estuaries or embayments during the period from 1993 to 1998. Total nitrogen and total phosphorus concentrations in riverine estuaries were reduced by 10 to 30% during the rainy season because of river discharge and watershed runoff.

INFLUENCE OF DAILY WATER EXCHANGE VOLUME ON WATER QUALITY AND SHRIMP PRODUCTION

Eighth Work Plan, Honduras Research 3 (HR3)
Final Report

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ABSTRACT

Daily water exchange is a common practice in semi-intensive shrimp culture in Central America. Rationales for water exchange are to improve pond dissolved oxygen concentrations and to flush out nutrients before they reach toxic levels. However, the benefit of water exchange in semi-intensive shrimp culture has been poorly demonstrated. Two experiments were conducted in Honduras to determine the effects of daily water exchange and emergency water exchange on shrimp production, and to develop nitrogen and phosphorus chemical budgets. Ten 0.93-ha ponds located on a commercial shrimp farm were used for this completely randomized design study to test two water exchange regimes: water exchanged at 10% of pond volume per day, six days per week; and water exchanged only in response to early morning dissolved oxygen concentrations ≤ 2.0 mg l^{-1}. Ponds were stocked with hatchery-spawned post-larval (PL) *Penaeus vannamei* at 15 PL m^{-2}. A survival rate of 50% was assumed because of Taura Syndrome effects on hatchery-produced larvae. The experiment was conducted during the rainy season (109-day duration) and during the dry season (96-day duration). Gross yield of *P. vannamei* was not affected significantly by the different water exchange regimes during either the rainy season or dry season experiment. Gross yield averaged 1,060 and 997 kg ha^{-1} during the rainy season, and 637 and 689 kg ha^{-1} during the dry season for the daily and emergency exchange treatments, respectively. Feed conversion ratios averaged 1.45 and 1.2 during the rainy and dry season

experiments, respectively. Pond water quality variables during each study were affected significantly by water exchange regime; water quality tended to be better in ponds with daily water exchange. Exchange water and feed were the two largest sources of nutrients to ponds during both seasons. Shrimp harvest accounted for 23 to 24% and 40 to 45% of total nitrogen inputs in the daily and emergency exchange treatments, respectively, while exchange discharge accounted for 56 to 69% and 16 to 22% of total nitrogen inputs, respectively. Phosphorus harvested as shrimp accounted for 13% and 18 to 24% of total phosphorus inputs in the daily and emergency exchange treatments, respectively, and water exchange accounted for 45 to 62% and 12% of total phosphorus inputs, respectively.

WATER EXCHANGE TO RECTIFY LOW DISSOLVED OXYGEN

Eighth Work Plan, Honduras Research 4 (HR4)
Abstract

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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. Recently completed research (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-week 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 the fourth week post-stocking is not the most efficient exchange strategy. This experiment builds on the previous experiment. 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 are being used for this completely randomized design study. Water will be exchanged at 10% of pond volume per day, six days per week beginning four, seven, or ten weeks after stocking. The experiment is being conducted during the rainy season and will be repeated during the dry season. Ponds for the rainy season experiment were stocked with hatchery-spawned post-larval *Penaeus vannamei* at 150,000 PL ha^{-1} (15 PL m^{-2}) on 14 August 1998. Shrimp are fed six days per week beginning two weeks after stocking. Feed rate for all ponds is based on the theoretical feeding curve for *Penaeus vannamei*:

$$Log_{10}Y = -0.899 - 0.56Log_{10}X$$

where

Y = feed rate as a percent of biomass and
X = mean shrimp weight in grams.

Daily feed rate is calculated for individual ponds and then averaged so that all ponds receive the same quantity of feed on a daily basis. Feed is offered once daily. Shrimp growth is monitored weekly by cast net samples of each pond's population. Feed rate is adjusted weekly based on shrimp samples. Water quality variables in each pond are measured monitored weekly in pond and intake water. Water samples are analyzed for pH measured potentiometrically, nitrate-nitrogen by cadmium reduction, total ammonia-nitrogen, soluble reactive phosphorus, chlorophyll *a*, total alkalinity by titration to pH 4.5 endpoint, salinity, and 2-d biochemical oxygen demand at 20°C. Total nitrogen and total phosphorus are determined by nitrate and phosphate analysis, respectively, after simultaneous persulfate oxidation. Dissolved oxygen concentration and temperature are measured in ponds twice daily (0400 and 1600 h) at 25 cm below the water surface.

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

Eighth Work Plan, Feeds and Fertilizers Research 1 (FFR1H)
Final Report

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ABSTRACT

Results of previous research at PD/A CRSP sites have demonstrated that increased fertilization rates have increased fish production, but optimum inputs of nitrogen, phosphorus, and carbon have not been defined. These experiments, the first of a series to identify optimum nutrient input levels at PD/A CRSP sites, addressed identification of the optimal nitrogen fertilization rate in freshwater tilapia production ponds. This research was conducted at the El Carao National Fish Culture Research Center, Comayagua, Honduras, using 0.1-ha earthen ponds. Nitrogen was added to ponds weekly at rates of 0, 10, 20, and 30 kg N ha^{-1}. Phosphorus was added to all ponds weekly at 8 kg P ha^{-1}, and sodium bicarbonate was added to ponds as needed to maintain total alkalinity ≥ 75 mg l^{-1}. Sex-reversed *Oreochromis niloticus* fingerlings (average weight 46 g) were stocked into ponds. The experiment was repeated during the rainy season and the dry season. During the rainy season trial, tilapia yield varied curvilinearly in response to increased weekly nitrogen inputs. Gross tilapia yields varied from 1,128 to 2,490 kg ha^{-1} per 128 d in the 0 and 20 kg N ha^{-1} wk^{-1} treatments, respectively. No significant differences in tilapia yield among treatments were detected during the dry season

experiment because of increased variability, although the data appeared to show a quadratic tendency when plotted. Gross yields varied from 1,360 to 1,729 kg ha^{-1} per 107 d in the 30 and 20 kg N ha^{-1} wk^{-1} treatments, respectively. Chlorophyll *a* and primary production increased with increasing fertilizer application, as did total net tilapia yield. Total input costs ranged from \$1,072 ha^{-1} for the 0 kg ha^{-1} treatment to \$2,020 ha^{-1} for the 30 kg ha^{-1} treatment and from \$1,173 ha^{-1} for the 0 kg ha^{-1} treatment to \$1,894 ha^{-1} for the 30 kg ha^{-1} treatment during the rainy and dry season experiments, respectively. Highest total revenues were observed for the 20 kg N ha^{-1} wk^{-1} fertilization rate during both seasons. Partial budget analysis demonstrated that weekly pond fertilization at 20 kg N ha^{-1} was the economically optimal rate for Honduras under current economic conditions. The full-cost enterprise budget developed for this fertilization rate indicated that income above variable costs was \$991 ha^{-1} per five-month production cycle.

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. Models will 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 estuary responses to shrimp farm operations.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Estuarine water quality monitoring and estuarine carrying capacity/HR2-2. The report submitted for this study was a progress report. The title of the submitted report ("Analysis of Honduran shrimp farm impacts on channel estuaries of the Gulf of Fonseca") differs from the study title.

Note: The research schedule under this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. The Eighth Work Plan study HR2, "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 HR2 work plan objective; the first study objective is addressed in the HR2 report (HR2-1) submitted by Auburn University.

ANALYSIS OF HONDURAN SHRIMP FARM IMPACTS ON CHANNEL ESTUARIES OF THE GULF OF FONSECA

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

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ABSTRACT

This report summarizes progress on a project to analyze water quality and hydromechanical data from the channel estuaries of the Gulf of Fonseca in Honduras and to develop suitable water quality models. The overall objective is to perform quantitative computation of the carrying capacity of the estuarine system for a viable shrimp farming industry. The study addresses Estero el Pedregal and Estero San Bernardo, which are typical of many of the river-channel estuaries within the larger Gulf of Fonseca along which shrimp farming is being developed. It has been established that hydrographic conditions in the regions in which shrimp farming operates, including tidal range and period, freshwater throughflow, physiography and morphology (especially the role of tidal flats), and tidal currents and related parameters—mixing and dispersion—are at least as important as chemical quality in the effects of farm effluent on estuary quality. Models are under development for tidal hydrodynamics, salinity, and dissolved oxygen. The lack of good field data has been the principal impediment to modeling these systems in the past, and the database has been considerably improved in the past several years due to the efforts of CRSP researchers, the Peace Corps,

PERU PROJECT

Subcontract No. RD010A-12

Staff

Southern Illinois University at Carbondale, Carbondale, Illinois

Christopher C. Kohler	US Co-Principal Investigator, Project Leader
Susan T. Kohler	US Co-Principal Investigator
Marcos J. De Jesus	Graduate Student (Peru)
Karen Vincent	Data Analysis Support (to September 1997)

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

Gonzalo Llosa Talavera	Host Country Project Leader
Fernando Alcántara	Host Country Co-Principal Investigator
Palmira Padilla Perez	Aquaculturist
German del Aquil	Technician
Armando Conde Sánchez	Technician
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

The 1996 addition of a Peru site to the PD/A CRSP provides considerable and unique opportunities to expand the CRSP Central Database. A new prime site has been established at Iquitos, Peru, in the heart of the Peruvian Amazon (Loreto Region). The Loreto Region, with a population of 602,000, constitutes 27% of the country's total area. Almost half of the region's population resides in the city of Iquitos. The main resource in the region is the integrated rain forest. The people in the region are primarily engaged in agriculture, cattle-raising, forestry, hunting, fishing, and tourist activities. Other economic activities of major importance to the region include the mining and drilling of non-renewable resources such as oil, gold, and silica.

Three important institutions conduct research on aquaculture in the region: the Instituto de Investigaciones de la Amazonia Peruana (IIAP), the Peruvian Government, and the Universidad Nacional de la Amazonia Peruana (UNAP). In the past ten years they have produced thousands of fry and have developed various aquacultural techniques. *Colossoma* and *Piaractus* are considered by local aquaculturists as the best fishes 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.)

A Memorandum of Understanding is in place linking IIAP, UNAP, and Southern Illinois University at Carbondale (SIUC) into the CRSP network. Between IIAP and UNAP there exist 49 earthen culture ponds ranging in size from 60 m^2 to nearly a hectare. Laboratory facilities also exist to monitor water quality variables of ponds and sustainable development of important fish species native to South America. These fishes also have potential for aquaculture development in the US.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Development of sustainable pond aquaculture practices for *Colossoma macropomum* and/or *Piaractus* spp. in the Peruvian Amazon/PR1. The report submitted for this study was a final report.
- New site development and characterization/PR2. The report submitted for this study was a final report.

Note: The research schedule under this subcontract was revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information.

Site Improvement

In the reporting period, the hatchery facility at IIAP was refurbished, including the addition of a filtered water supply. Additionally three ponds were renovated while another nine ponds were stocked with *Colossoma* for a study of density.

Networking Activities

PD/A CRSP Co-Principal Investigators Christopher Kohler, Susan Kohler, and Fernando Alcántara are exploring further collaboration with various organizations in Peru and are receiving networking support from a member of Peru's congress. CRSP scientists visited the Marine Research Institute in Callao, Peru, and toured various aquaculture facilities. While at the Marine Research Institute, plans for CRSP collaboration on a marine aquaculture development project were discussed. This project entails the construction of a large public aquarium, which will include an aquaculture research facility. Plans for collaboration are also in the initial stages with the Universidade de São Paulo, Brazil.

Alcántara also contacted a Peruvian congressman who is assisting in the identification of institutions to participate in CRSP research and activities.

The Peru site has made good progress toward integration with other CRSP projects. For example, Alcántara (along with other new Host Country collaborators from Honduras, Kenya, and the Philippines) traveled to the Oregon State University and to Auburn University in October 1997 under the auspices of the Education Development Component (EDC) to participate in a CRSP orientation training (for more detail, please see the report of the EDC). In addition, the work plans of several scientists involved in cross-cutting CRSP research projects, among them Claude Boyd and Joseph Molnar, include visits to the Peru site to collect field data associated with their respective areas of study.

Publication

De Jesus, M.J., C.C. Kohler, and S.T. Kohler, 1998. Sustainable aquaculture in the Peruvian Amazon. Aquanews, 13(2):1,6.

Presentation

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.

Conference

Fourth International Symposium on Tilapia in Aquaculture in Orlando, Florida, 9-12 November 1997. (Alcántara)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (C. Kohler, S. Kohler, Llosa)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (C. Kohler, S. Kohler, Llosa)

DEVELOPMENT OF SUSTAINABLE POND AQUACULTURE PRACTICES FOR *PIARACTUS BRACHYPOMUS* IN THE PERUVIAN AMAZON

Eighth Work Plan, Peru Research 1 (PR1)
Final Report

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ABSTRACT

Piaractus brachypomus growth performance did not significantly differ in trials conducted in ponds stocked at 3,000 and 4,000 fish ha^{-1} in Iquitos, Peru. Fish initially weighing 27.5 g were fed a locally prepared diet (26.7% crude protein; 9.0% crude lipid) in rations ranging from 3 to 5% body weight per day. Fish were harvested after 153 days and had mean weights of 463.7 and 494.0 g in the low and high densities, respectively. Survival exceeded 90% in all ponds. Feed conversion efficiency was 53.6 and 60.4% for low and high densities, respectively. Fish in one pond of each density were reared for an additional five months and attained mean weights of 0.95 kg for the low density and 1.04 kg for the high density. Water quality levels generally remained throughout the trial within acceptable levels for tropical aquaculture. The study suggests the economic feasibility of rearing *P. brachypomus* in the Peruvian Amazon under intensive aquaculture. The combined cost of fingerlings (US$0.14 each, corrected for 90% survival) and feed (US$1.02 kg^{-1} to produce 1.0 kg fresh fish) is slightly above half of the price (US$2.08 kg^{-1}) for which the fish are sold in the Iquitos market. Currently, most farmers in the Peruvian Amazon grow fish using extensive techniques.

NEW SITE DEVELOPMENT AND CHARACTERIZATION

Eighth Work Plan, Peru Research 2 (PR2)
Final Report

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ABSTRACT

This report is a descriptive overview of the South American PD/A CRSP site located at the Instituto de Investigaciones de la Amazonia Peruana research facility in Iquitos, Peru, and contains information pertaining to the physical, geological, meteorological, and hydrological characteristics of the region. The facility is located in a densely populated region that has undergone significant commercialization, industrialization, and subsequent deforestation. The region surrounding the facility ranges from an elevation of 100 to 120 m above sea level and the soil is composed of sand in a mixture with clay and a slight amount of silt. The regional climate is tropical; the average temperature is 26.5°C; annual precipitation of the region is greater than 2,500 mm; and maximum sunshine hours range from 11 h 36 min to 12 h 38 min. The Amazon River levels fluctuate between 107 and 118 m, flooding nearly 10 m. The research facility is located at an elevation high enough to avoid the flooding common to the region. As a result of precipitation there are three categorizations of water chemistry in the Amazon region: white, clear, and black. White water is turbid with silt particles, ochre-colored, has transparencies (Secchi disk depth of 0.10 to 0.50 m), and pH ranges from 6.2 to

7.2; clear water is more transparent (Secchi disk depth) of 1.10 to 4.30 m green to olive-green in color, and pH ranges from 4.5 to 7.8; black water is mostly transparent (Secchi disk depth of 1.30 to 2.90 m, olive-brown to coffee-brown in color, and pH ranges from 3.8 to 4.9. The research ponds exhibited chemical properties characteristic of white and black water categorizations and their water was classified as soft and slightly acidic. Water temperature ranged from 29.3 to 31.7°C; DO averaged in excess of 4.0 mg l^{-1} ; total ammonia nitrogen was < 1 mg l^{-1} ; carbon dioxide reached as high as 22 mg l^{-1} ; and average transparency ranged between 29 and 125 cm. Additionally, the report describes the research facility's flow-through system, research ponds, and additional infrastructure.

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 (from December 1997)

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	Director of Fisheries, Kenya, and Host Country Principal Investigator

Sagana Fish Farm, Sagana, Kenya

Bethuel Omolo	Senior Fisheries Officer & Head of Station, Host-Country Research Associate
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J. Karuri Maina	Lab Technician
William Kibe	Fishing Team Supervisor
Jonathan Makau	Fishing Team Supervisor
J.M. Kamau	Computer Operator/Storekeeper
Thomas Ndegwa	Assistant Lab Technician
John Ngofia	Driver
Wilson Maina Gichuri	Graduate Student, University of Nairobi
Paul Bilal Izaru	Graduate Student, University of Nairobi
Patricia Mwau	Graduate Student, University of Nairobi
Bernard Meso	Graduate Student, University of Nairobi
Winifred S. Kaki	Undergraduate Student, Moi University
Wabitah P. Wamwea	Undergraduate Student, Kenyatta University

Site Background

After the CRSPs Rwanda research site was lost because of the outbreak of war and civil violence in 1994, a formal site-selection strategy was employed to establish a new Africa site. A preliminary site assessment was undertaken in December 1994 by the Management Entity (ME) and members of the Africa project. Fifteen site evaluation criteria were developed with assistance from the ME and Technical Committee of the PD/A CRSP to guide data collection. USAID site-selection criteria were incorporated into the process. Funding under the Interim Work Plan was provided to help establish a new site in Africa. The Sagana Fish Culture Farm in Kenya was recommended as a prime site during the Annual Meeting in January 1996. Once approved, a proposal to develop a CRSP site at Sagana in cooperation with the Kenya Ministry of Tourism and Wildlife and its Department of Fisheries was submitted to the government of Kenya. A development plan for that station was also outlined. The government of Kenya, through the Ministry of Treasury and the Ministry of Tourism and Wildlife, approved the CRSPs preliminary proposal. A Memorandum of Understanding (executed in March 1997) between the Ministry of Tourism and Wildlife and Oregon State University has formalized the working relationship at Sagana Fish Culture Farm.

Research activities in the reporting period address aquaculture development constraints and research priorities identified in the *PD/A CRSP Continuation Plan*. 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, and regionalizing the benefits of the CRSP research program through outreach activities.

Eighth Work Plan Research

These subcontracts were awarded funding to conduct the following studies:

- New site development and characterization/KR1. An abstract was submitted for this study.
- Strain variations in sex ratio inheritance/KR2. An abstract was submitted for this study.
- Relative contribution of supplemental feed and inorganic fertilizers in semi-intensive tilapia production/KR3. The report submitted for this study was a progress report.
- Training/KR4. The report submitted for this study was a final report.
- Regional outreach in Africa/KR5. The report submitted for this study was a progress report.
- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/FFR1K. The report submitted for this study was a progress report.

Note: Research under these subcontracts is revised from that described in the *Eighth Work Plan*. The new (replacement) work plan appears in the *Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. The studies listed above are collaborative projects between Oregon State University and Auburn University. In addition, the study

KR3A, "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 following project description).

Site Improvement

In the Eighth Work Plan period, new site development activities have included modifying the chemistry laboratory and equipping it to handle CRSP analyses, renovating ponds to fit CRSP requirements, training lab and pond personnel, and characterizing the site soils, source water, and weather. Project equipment and supplies lost in Rwanda had to be replaced to establish a new CRSP site in Africa.

Ponds renovations were completed at the Farm, which is now equipped with twelve 800-m^2 research ponds, two fry production ponds that are 880 and 750 m^2, and an additional two ponds of 800 m^2. As a result of renovations of the fry production ponds, fry production has increased from less than 5,000 fry per month to approximately 40,000 fry per month. To improve the air and water supply to aquaria in the hatchery, electrical and water installations were completed. Laboratory construction is in progress; the lab equipment was received in September of 1997 and installation is underway. Ground wire and grounding rod were installed in the computer room and the already-existing laboratory. In the newly refurbished laboratory grounded and correctly sized electrical wiring were installed. In addition to laboratory refurbishment a waste water treatment tank is currently under construction.

Networking Activities

CRSP Co-Principal Investigator Karen Veverica sought to strengthen CRSP linkages with Kenyan universities and facilitate connections with public and private groups and individuals affiliated with aquaculture. Veverica fortified the CRSPs affiliations with students and professors from the University of Nairobi, Moi University, and Egerton University. Four university students (two undergraduate and two graduate) have been conducting their research at Sagana Fish Farm under the mentorship of CRSP researchers, and arrangements for adding several new graduate students are in progress.

In addition to creating linkages with universities, CRSP researchers and program participants have also visited farmers, feed producers, and a women's self-help group and presented research results. Issues related to pond stocking and pond management were discussed with private sector farmers as was the diversion of a canal at the Sagana Fish Farm to assist a group of nearby small-scale farmers with irrigation. Feed producers and CRSP participants discussed the constraints of the fish feed industry, the use of soy in fish feeds, and manufacturing. For example, a private engineering company expressed an interest in making steam-extruded feeds. Contacts were also made with a Sagana women's self-help group regarding the possibility of their participation in on-farm trials. CRSP participants visited fish farmers operating in a high-elevation cool water zone who are culturing trout and tilapia side by side. Karen Veverica attended a meeting for district fisheries officers held at Kiganjo, 7-8 April 1998, and presented guidelines for farmers wishing to try all-male tilapia fingerlings.

In early May, the Farm was visited by the Executive Secretary of the Inter-African Committee on Oceanography, Sea and Inland Fisheries of the Organization of African Unity.

To further extend its breadth in Africa, the CRSP is also exploring the potential of Malawi as a companion site for the Kenya prime site and has discussed this possibility with a project representative of ICLARM based in Malawi. In addition, Veverica participated in an impact assessment undertaken by ICLARM in Uganda.

Omolo (along with other new Host Country collaborators from Honduras, Peru, and the Philippines) traveled to Oregon State University and to Auburn University in October 1997 under the auspices of the Education Development Component to participate in a CRSP orientation training (for more detail, please see the report of the Education Development Component). In addition, the work plans of several scientists involved in cross-cutting CRSP research projects, among them Claude Boyd and Joseph Molnar, include visits to the Kenya site to collect field data associated with their respective areas of study.

The Sagana Fish Farm also hosted Oregon State University anthropology graduate student Deborah Burke for approximately nine weeks in the spring of 1998. Burke, whose graduate work is supported by a fellowship from OSUs International Programs, conducted interviews with employees of the Farm to form an understanding of the relationship between a donor project and the individuals employed at the fish farm.

Presentation

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.

Conferences

Fourth International Symposium on Tilapia in Aquaculture, Orlando, Florida, 12-19 November 1997. (Omolo)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Bowman, Omolo, Pertet, Popma, Veverica)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 12-19 February 1998. (Bowman, Omolo, Pertet, Popma, Veverica)

New Site Development and Characterization

Eighth Work Plan, Kenya Research 1 (KR1)
Abstract

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Jim Bowman
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Oregon State University
Corvallis, Oregon, USA

Abstract

Site development and characterization activities for the new prime site at Sagana, Kenya, began immediately upon arrival of the Africa Project's resident researcher, Karen Veverica, 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 (datalogger) 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 1987. Four existing 4000-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 1500 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, including a new desktop computer, laboratory instruments, and seines, were shipped from the US on 30 June and arrived at Sagana on 3 September. 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 begun to allow complete characterization of the new 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, photosynthetic 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 5, 25, 50, and 75 cm depth 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 tons ha^{-1} have been calculated. The phosphorus adsorption capacity of these soils is expected to be 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 $CaCO_3$. 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, will be included in the final report for this activity.

STRAIN VARIATIONS IN SEX RATIO INHERITANCE

Eighth Work Plan, Kenya Research 2 (KR2)
Abstract

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ABSTRACT

Pond D3 at Sagana Fish Farm, Sagana, Kenya, was dedicated to pair spawns and rearing of fry for this activity. In addition to work conducted in 1997, fry from 24 pair spawns were transferred to hapas from January through April 1998. Although more than 100 fry were obtained from most spawns, survival to 3 g was very low in the rearing hapas, and fewer than 25 fingerlings per spawn were obtained. This number was too low to complete the protocol as planned, and the fingerlings were discarded. Survivals of about 80% were obtained during sex reversal in similar hapas in a similar pond. The only difference is that fry being sex-reversed are reared at much greater densities than the single-spawn fry. To date, only six batches of single-spawn fingerlings with adequate survival beyond a size of 3 g have been 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 is an insufficient number for this study. Recently a blower has been installed in the hatchery and a complete diet has become available, so we plan to grow out single spawns in the hatchery after the end of the cool season (end of August). Temperatures in the cool season are too low (20°C and less) for growing tilapia fry in the hatchery.

Editor's Note:
Kenya Research 2 (KR2), "Strain Variations in Sex Ratio Inheritance," was to be a collaborative project between the Africa CRSP and Auburn University's project (under Subcontract No. RD010A-09), "Monosex tilapia production through androgenesis" (RCR1A). For context, a summary of the original project description from the *Eighth Work Plan* is included:

The few populations of *O. niloticus* that have been studied give mean population sex ratios of 50:50 that would be expected from a XX:XY inheritance pattern but with considerable variation from 50:50 when individual pairs are considered. The source of this variation is unknown and may be a characteristic of the species or only the strain which was evaluated. A minimum of 50 pair spawns of non-hormone-treated *O. niloticus vulcani* will be made in outdoor hapas. Fry will collected and reared as individual sets to a minimum of 5 cm in length. The sex ratio of each set of progeny will be determined by examining the gonads of a minimum of 100 fish per set of progeny. Sex ratio data from each spawn will be analyzed by Chi square to determine whether it differs from the expected 50:50. The frequency distribution of all spawns within this strain will also be determined and compared across other strains that will be examined in the larger study.

RELATIVE CONTRIBUTION OF SUPPLEMENTAL FEED AND INORGANIC FERTILIZERS IN SEMI-INTENSIVE TILAPIA PRODUCTION

Eighth Work Plan, Kenya Research 3 (KR3)
Progress Report

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ABSTRACT

A 20-week experiment was conducted at Sagana Fish Farm, Kenya, to achieve the following: 1) characterize the productive capacity of ponds at this new CRSP research site; 2) evaluate the relative contributions of inorganic fertilizers and supplemental feeds to fish production; and 3) determine lowest-cost combinations of rice bran and inorganic fertilizer. Twelve 800-m^2 ponds were stocked with juvenile (32 g each) *Oreochromis niloticus* at 2 m^{-2} and *Clarias gariepinus* fingerlings (average weight 4.6 g) at 0.24 m^{-2}. 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 Treatments 2 through 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 in Treatment 1 may never reach market size at this stocking density, because of their reduced growth towards the end of the culture period and their resulting low final average weights, which were less than 100 g.

TRAINING

Eighth Work Plan, Kenya Research 4 (KR4)
Final Report

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Fred Pertet
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Nairobi, Kenya

ABSTRACT

Training of farm personnel and university students at Sagana Fish Farm, Sagana, Kenya, was undertaken under the Eighth Work Plan to ensure the success of the overall project in Kenya. Training was planned and carried out in three main areas:

a) Training of station field personnel in fish sampling, fish handling, and fish transport;
b) Training of technicians in the areas of water, soil, and feed sampling, in laboratory glassware cleaning, and in computer operation; and
c) Training of university students in a variety of topics relevant to aquaculture in Africa.

Sagana field crew members received approximately 100 hours of practical instruction in seining techniques, seine maintenance, fry harvest for sex reversal, fish handling, and stratified sampling. Fish survival in between-pond transfers at Sagana has improved markedly as a result of this training, increasing from less than 30% at the beginning of CRSP involvement at Sagana to a current level of 95 to 100%. Laboratory technicians have received training on water quality analyses, proper washing of glassware, lab safety, and equipment maintenance. All water quality analyses and sampling procedures called for in standard CRSP sampling protocols are now carried out routinely by the lab staff.

Four M.S. students and one undergraduate student received stipends during the 1997-98 reporting period. Three of the M.S. students finished their research in April, and all three will file an "intention to submit" form to their university by the end of July 1998. The fourth student will continue his studies under activities planned under the Eighth Work Plan. One student used data obtained during her studies at Sagana to make an easy-to-follow feed schedule for workers at the station and trained two laborers in procedures for the production of all-male tilapia fry. Three more undergraduates have arrived at Sagana for practical training.

Individuals trained under this activity are already contributing to improved daily farm operations at Sagana, as reflected in greatly improved fish survival after transport, and are conducting analyses in the laboratory. University students have had first-hand experience with farm operations, have

worked on real-world aquaculture problems as part of their studies, and have increased their understanding of how to plan and conduct aquaculture research. They should be able to apply what they have learned as they finish their university studies and move out into various parts of the aquaculture sector in Kenya. These benefits will continue to accrue as this type of training continues at Sagana under subsequent work plans.

REGIONAL OUTREACH IN AFRICA

Eighth Work Plan, Kenya Research 5 (KR5)
Progress Report

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Nairobi, Kenya

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. In an effort to disseminate information to extension personnel, CRSP researchers 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 our first 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, hosted by Fred Pertet, member of the OAU/STRC and Host Country Principal Investigator for the Africa Project. 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 in 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 Africa Project team members from Kenya and the US plan to attend a Fisheries Society of Africa (FISA) meeting scheduled to take place in Grahamstown, South Africa, 13-19 September 1998, and have submitted abstracts for five presentations. In addition, CRSP researchers contacted the conference organizers to inquire about and encourage the inclusion in the conference of a special discussion session on the status, constraints, and priorities of aquaculture in Africa. This has been accepted and Jim Bowman will serve as rapporteur for the session, to be entitled *Aquaculture in Africa—Quo Vadis*. These outreach efforts are helping to inform interested regional parties about the CRSP; to develop a better understanding of regional research needs among CRSP participants and others; and to encourage communication and the formation of linkages among regional organizations and individuals interested in aquaculture. It is anticipated that participation in the upcoming FISA conference will greatly increase the level of benefits realized under this activity.

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

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

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Jim Bowman
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ABSTRACT

The Global Experiment for the prime Africa site (Sagana Fish Farm, Sagana, Kenya) was initiated by starting fertilization for the cool season experiment on 29 April 1998. Ponds were stocked on 13 May, and the experiment will continue through June, July, and August, which are the only three months of the year that can be considered "cool" at Sagana. Prior to filling, 100 kg of TSP (250 kg ha^{-1} P) was broadcast over the bottom of each pond. The ponds were stocked with all-male Nile tilapia at an initial density of 1 t fish ha^{-1}, and an average weight of 17 g. Nitrogen, as urea and DAP, is being added to ponds at rates of 0, 10, 20, and 30 kg N^{-1} ha^{-1} wk^{-1}. Phosphorus, as triple superphosphate, is being added to zero-N ponds at a rate of 8 kg P^{-1} ha^{-1} wk^{-1}, whereas DAP is used to provide phosphorus for all other treatments, also at a rate of 8 kg P^{-1} ha^{-1} wk^{-1}. Alkalinity is being maintained at or above 70 mg l^{-1} as $CaCO_3$, by adding sodium carbonate (soda ash). Preliminary observations after the first month of the experiment include very high nitrite levels (> 0.5 mg l^{-1}) in the highest-N treatment and a high mortality rate (almost 25%) in one pond of the high-N treatment. No mortalities have been observed in the other two ponds of this treatment. Morning and afternoon DO and temperature are measured weekly at four depths (5, 25, 50, and 75 cm), pH is measured weekly at 5 cm, and column total alkalinity is measured weekly; chlorophyll *a*, nitrates, nitrites, TAN, and soluble reactive P on column samples are measured biweekly, and total N, total P, total suspended solids, and total

volatile solids will be measured on the days of the diurnal oxygen samplings (three times during the experiment). The sampling protocol is much more intensive than that called for in the work plan, but is necessary to be able to draw conclusions on the fate of N added to the ponds. It also serves to train the lab staff in intensive sampling and analysis of water quality parameters that is anticipated for the Global Experiment for the Ninth Work Plan. The warm season experiment was scheduled for the Spring of 1998, but is being postponed until the Fall of 1998 because of the late completion of the feed study ("Relative Contributions of Supplemental Feed and Inorganic Fertilizers in Semi-Intensive Tilapia Production," KR3, harvested the last week of March), which resulted in there being insufficient time to complete the warm-season experiment before the beginning of the cool-season phase of the Global Experiment. The cool-season phase must be conducted during the period from June through August, whereas the warm-season phase can be conducted almost any time during the remainder of the year, although December, November, and January are the most reliably warm months.

KENYA PROJECT

Subcontract No. RD010A-13

Staff

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann	US Co-Principal Investigator, Project Leader
Peter Perschbacher	US Co-Principal Investigator

Background

Isotope analysis may be a useful tool to measure the relative nutritional contribution of supplemental feeds and natural foods to tilapia production at different rates of supplemental feeding. Verification of the acceptability of a modified isotope method using preserved samples rather than freeze-dried samples could expand the use of the method to areas where freeze-drying is not available or easily accessible.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

Note: The research schedule under this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. This study is a collaboration among the University of Arkansas at Pine Bluff, Oregon State University (under MOU No. RD009A), and Auburn University (under Subcontract No. RD010A-08).

Networking Activities

CRSP Co-Principal Investigator Rebecca Lochmann continues to maintain contact with a graduate student (Wilson Maina Gichuri) from the University of Nairobi conducting his research at Sagana Fish Farm. He will be using a portion of CRSP data, including isotope analysis data, for his M.S. thesis.

Lochmann is also discussing a tentative project with a representative from the International Center for Living Aquatic Resources Management (ICLARM) in Malawi. The project involves the possible application of the isotope tracer technique that Lochmann has been working on to delineate detrital food webs in aquaculture ponds in Malawi.

Conferences

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Lochmann)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Lochmann)

Award

Rebecca Lochmann received the B.D. Mayberry Young Scientist award. This award is specifically aimed at professors who have been awarded their doctorates in the last five years and who have demonstrated outstanding achievements in research. Lochmann's work for the CRSP involves the use of carbon isotopes to determine the sources of food (natural and supplemental) ingested by tilapia. The award was presented on 3 October 1997 at the Association of Research Directors of the US Chapter of the World Aquaculture Society meeting in San Antonio, Texas.

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

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

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ABSTRACT

Stable carbon isotope analysis is a useful technique to obtain quantitative estimates of the relative contributions of different food sources to the nutrition of aquatic animals in ponds. This technique is being used to obtain quantitative estimates of the contribution of natural and supplemental feeds to the nutrition of tilapia in ponds in Sagana, Kenya. Results can be used to adjust feeding/fertilization practices and minimize feed costs while maximizing fish production. Samples of *Oreochromis niloticus*, *Clarias*, chemical fertilizers (DAP and urea), rice bran, plankton, and mud taken from ponds in Sagana at three times during the study (initial, midpoint, final) have been submitted to a commercial lab for carbon isotope analysis. Results for initial and some of the midpoint samples are summarized and discussed in this report. The most distinct trend in the isotope data was the more positive values for plankton, *Clarias*, and *O. niloticus* found in Treatment 1 versus Treatments 2 through 4 for both initial and midpoint samples. Possible reasons for this trend are discussed in light of experimental and non-experimental variables. A more comprehensive discussion of the effects of various nutrient inputs on the production of *O. niloticus* and *Clarias* will be possible once the remaining isotope data are obtained.

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

Peter Edwards	Host Country Principal Investigator
Madhav Shrestha	Postdoctoral Researcher
Chintana Boonthamchinda	Research Administrator
M.A. Kabir Chowdhury	Research Associate
Raghunath B. Shivappa	Research Associate
Sunil Man Shrestha	Research Associate
Dhirendra P. Thakur	Research Associate
Manoj Yomjinda	Research Assistant

Cooperators:

Asian Institute of Technology, Pathum Thani, Thailand
Harvey Demaine
Jharendu Pant

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.

Studies conducted in the reporting period have concentrated on three areas of emphasis: environmental impacts of aquaculture, production optimization, and human capacity development. 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 work on mud turbidity, pond draining, supplemental feeding, and nutrient regeneration in pond bottoms, all of which are related to farmer practices in the wet and dry seasonal climates of the region. Outreach activities have focused on aquaculture practices in rainfed ponds.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

- Effects of mud turbidity on fertilization, and an analysis of techniques to mitigate turbidity problems/TR1. The report submitted for this study was a final report.
- Management of organic matter and nutrient regeneration in pond bottoms/TR2. The report submitted for this study was a final report.
- Management to minimize the environmental impacts of pond draining/TR3. The report submitted for this study was a final report. The title of the submitted report ("Management to minimize the environmental impacts of pond draining: Effect of harvest draining technique on water quality and fish growth") differs from the study title.
- Technical transfer from on-station research to producers/TR4. The report submitted for this study was a final report. The title of the submitted report ("High-input green water on-farm trials in northeast Thailand") differs from the study title.
- Global experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/FFR1T. The report submitted for this study was a progress report.

Note: Research under this subcontract is revised from that described in the *Eighth Work Plan*. The new (replacement) work plan appears in the *Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information for FFR1T.

Site Improvement

Physical enhancements at AIT in Pathum Thani entailed the repair of the water supply canals and dykes of twelve ponds. At the University of Agriculture and Forestry in Ho Chi Minh City the PD/A CRSP also assisted with pond design.

Networking Activities

PD/A CRSP researchers in Thailand continued to extend research results through their efforts in training, education, and outreach via AIT. They will be responding to a recently received request from a farmer's representative for tilapia seed production training for a number of farmers in the Ubon Province. Co-Principal Investigator Kwei Lin trained eight students from two Thai universities in water quality analysis and instructed a course on water quality management at the Fisheries College in Nhatrang, Vietnam. AIT, continuing its outreach efforts, is planning trainings and workshops on pond fertilization for provincial fisheries officers with the Royal Thai Department of Fisheries and farmers who have requested training on tilapia seed production. Lin also conducted a short course at AIT on reservoir water quality analysis for 18 Asian participants.

The PD/A CRSP extended its reach through consultation with a number of institutions and organizations throughout the Southeast Asia region—Mekong River Commission, We Care, Research Institute for Aquaculture Number One in Hanoi, University of Agriculture and Forestry in Ho Chi Minh City,

and the University of Cantho in the Mekong Delta—on various topics regarding fish culture (e.g., reservoir cage culture), extension of pond aquaculture to small-scale farmers, and aquaculture curriculum development.

At the University of Agriculture and Forestry in Ho Chi Minh City, Lin discussed aspects of the Fifth Asian Fisheries Society Forum with individuals from the Network of Aquaculture Centers in Asia Pacific (NACA).

The CRSP further broadened its presence through participation in a discussion at the Patani Fisheries College about alternating tilapia culture with shrimp culture in coastal ponds. Lin also attended a workshop organized by the Ministry of Agriculture and Cooperatives. The workshop was organized in response to a request from the King of Thailand for assistance to farmers who recently lost their jobs in the city and returned to rural areas. AIT has volunteered to assist in the area of pond culture. Lin also met with the Deputy Director General of the Thai Department of Fisheries at AIT to discuss assistance for a training program on pond fertilization to provincial fisheries extension officers in Northeast Thailand.

CRSP scientists in Thailand collaborated with professionals of NACA to prepare a code of practices for mangrove conservation in addition to initiating collaboration in soils research with the Brackishwater Shrimp Culture Station in Ranot.

Publications

Cao, T.B., C.K. Lin, and H. Demaine, 1998. 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, 1998. 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. (in press).

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. (in press).

Presentations

Lin, C.K. and C. Limsuwan. Management strategies and approaches for water quality improvement in shrimp farming. Presented at 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 at the 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 at Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Yi, Y. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds. Presented at Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Conferences

American Fisheries Society Annual Meeting at Monterey, California, 24-28 August 1997. (Diana)

American Association for the Advancement of Science Meeting at Philadelphia, Pennsylvania, 12-17 February 1998. (Lin)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Diana, Lin, Yi)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Diana, Lin, Yi)

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

Eighth Work Plan, Thailand Research (TR1)
Final Report

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ABSTRACT

This experiment was designed to 1) assess effects of different turbidity reduction techniques on fish growth and water quality and 2) find a suitable approach for turbidity mitigation. It was conducted in 15 earthen ponds at the Asian Institute of Technology, Thailand, during October 1997 through April 1998. The five different treatments were: (A) control; (B) covering 50 cm of the pond edges starting from the top of pond dikes with black plastic to prevent turbidity from run-off; (C) covering pond bottoms with green manure (terrestrial weeds) to alter texture; (D) covering pond bottoms with netting material to prevent turbidity from fish disturbance; and (E) liming ponds biweekly with quick lime at a rate of 200 kg ha^{-1}. All ponds were fertilized weekly with chicken manure at a rate of 225 kg ha^{-1} (dry matter basis) supplemented with urea and triple super phosphorous (TSP) to provide 28 kg N ha^{-1} wk^{-1} and 7 kg P ha^{-1} wk^{-1}. Sex-reversed male Nile tilapia (*Oreochromis niloticus*) were stocked at 2 fish m^{-2} at a size of 15.0 ± 1.0 g. The liming treatment led to the best growth performance except for survival. The lowest survival and net fish yield occurred in the weed-covered treatment. With the exception of the weed-covered treatment, the different mitigation techniques did not result in significantly increased fish yield in the experiment conducted in the dry season. The significantly higher fish mortality in the weed-covered treatment was probably attributable to the low dissolved oxygen concentration due to decomposition of terrestrial weeds during the first month of the experiment. The bottoms covered by netting material prevented turbidity from fish disturbance, resulting in reduced phosphorus regeneration from pond muds but no reduced fish production. Compared with the control, the edge-covered treatment was not significantly different in fish growth performance. This treatment is expected to be more effective during the wet season. A similar experiment should be done during the wet season to further assess the proposed techniques for mitigating turbidity problems.

MANAGEMENT OF ORGANIC MATTER AND NUTRIENT REGENERATION IN POND BOTTOMS

Eighth Work Plan, Thailand Research 2 (TR2)
Final Report

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ABSTRACT

This report presents the results of two experiments, which were conducted in 12 earthen ponds at the Asian Institute of Technology, Thailand, from November 1997 through April 1998. The first experiment was conducted for 149 days to assess the effect of aerobic and anaerobic conditions of pond bottoms on organic matter decomposition and nutrient release and the effectiveness of common carp in removing organic matter from pond sediments and recycling nutrients for tilapia ponds. The experiment consisted of four treatments: (A) tilapia monoculture with water mixing; (B) tilapia monoculture without water mixing; (C) tilapia/carp polyculture with water mixing; and (D) tilapia/carp polyculture without water mixing. Sex-reversed male Nile tilapia were stocked at 2 fish m^{-2} at a size of 8 to 12 g in all ponds, and common carp fingerlings were stocked at 0.3 fish m^{-2} at a size of 13 to 17 g. All ponds were fertilized with chicken manure at the rate 1000 kg ha^{-1} wk^{-1} (dry matter basis) to create anaerobic pond bottoms. Aerobic pond bottoms in treatments A and C were created by fixing a submersible pump (0.5 kW) 30 cm above the bottom of each pond to mix surface and bottom water. The second experiment was conducted for 30 days in the same ponds used for experiment 1 to assess physical and chemical conditions during microbial decomposition of organic matter and the resultant nutrient release during pond drying. Six of the 12 ponds were refilled immediately after fish harvest and soil sampling, while the other six ponds were dried over a period of one month and then refilled. The polyculture of common carp and Nile tilapia was effective in recycling nutrients and might be effective in removal of organic matter if more common carp are added. Water mixing in the experiments caused greatly reduced phytoplankton growth in both mono- and polyculture ponds. Water mixing did not affect the growth of Nile tilapia in monoculture ponds, but significantly ($P < 0.05$) reduced the growth of both Nile tilapia and common carp in polyculture ponds. Results also showed that pond drying did not result in significant microbial decomposition of organic matter.

MANAGEMENT TO MINIMIZE THE ENVIRONMENTAL IMPACTS OF POND DRAINING: EFFECT OF HARVEST DRAINING TECHNIQUE ON WATER QUALITY AND FISH GROWTH

Eighth Work Plan, Thailand Research 3-2 (TR3-2)
Final Report

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ABSTRACT

An experiment was conducted to assess the effect of different harvest draining techniques of fish ponds on water quality and fish growth in subsequent culture cycles. Fifteen tilapia ponds of 200 m^2 were harvested using five different harvest draining techniques. After harvest, these ponds were stocked with Nile tilapia (*Oreochromis niloticus*) at 2 fish m^{-2}. Fish with an initial size of 11 to 13 g were cultured for 106 days in a fertilized pond system. Harvest draining techniques as treatments were: (A) ponds were not drained, and fish were harvested by seining using tea seed cake as an anesthetic toxicant; (B) ponds filled with canal water were completely drained after liming, and fish were harvested from a harvesting pit; (C) ponds filled with canal water were completely drained, and fish were harvested from a harvesting pit; (D) ponds filled with drainage water from harvest of adjacent ponds used in a previous experiment (equivalent to Treatment E of this study) were half-drained and seined twice, then completely drained to collect the remaining fish; and (E) ponds filled with canal water were half-drained and seined twice, then completely drained to collect the remaining fish. None of the treatment means of water quality parameters (dissolved oxygen, pH, Secchi disk depth, alkalinity, total ammonium nitrogen, nitrite nitrogen, nitrate-nitrite nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus, chlorophyll *a*, total suspended solids, and volatile suspended solids) were significantly different ($P > 0.05$) between treatments. Similarly, fish growth, net fish yield, and survival did not differ ($P > 0.05$) between treatments. Fish growth and net yield from undrained ponds (Treatment A) were 1.32 ± 0.15 g d^{-1} and 15.7 ± 4.2 kg ha^{-1} d^{-1}, respectively. Fish growth and net yield from ponds filled with drainage water of other ponds (Treatment D) were 1.11 ± 0.16 g d^{-1} and 17.3 ± 3.1 kg ha^{-1} d^{-1}. The results suggest that environmental impacts of pond draining can be minimized either by harvesting fish without draining or by draining pond water into empty ponds without affecting the water quality for fish growth.

HIGH-INPUT GREEN WATER ON-FARM TRIALS IN NORTHEAST THAILAND

Eighth Work Plan, Thailand Research 4 (TR4)
Final Report

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ABSTRACT

This report presents the results of high-input on-farm trials with farmers in Northeast Thailand. Based on AIT on-station trial results, technical recommendations for high-input green water culture were extended to 12 farmers through the Aquaculture Outreach Program (AOP). Pond size varied greatly among the project farmers, averaging 658 m^2. Measurements of water color indicated turbid water existed in most project farmers' ponds, which were poor in natural feed and unfavorable for fish growth. All the project farmers, upon receiving seed, started nursing fry in hapas in their ponds. The size of hapas varied greatly among farmers, averaging 5 m^3. The average number of fry released into a hapa for nursing was estimated to be 2,333, ranging from 800 to 4,000. The duration of nursing fry in hapas ranged from 30 to 57 days with an average of 41 days. Pig concentrate and rice bran (2:1) were recommended as supplementary feed for fry throughout nursing. On average, farmers fed 130 g of pig feed concentrate and 76 g of fine rice bran per day per 1000 fry. Density of fry during nursing, which was largely affected by the size of hapas, ranged between 93 and 556 m^{-3} with an average of 242 m^{-3}. The survival rate of the fry at the end of nursing in most of the farms was estimated to be 75%, with a range of 44 to 80%). Farmers were advised to stock 2 to 3 fish m^{-2} in ponds; actual stocking density was 3.1 fish m^{-2}. The culture period, recommended at six months, varied from four months for two farmers whose pond water level dropped rapidly after the cessation of the rainy season, to eight to eleven months for most farmers. Farmers were advised to apply fertilizers (urea and TSP) at weekly intervals at the rate of 4 kg N and 1 kg P ha^{-1} d^{-1}, respectively. Only two farmers reported that they applied urea at the recommended rate. Most farmers applied P at a higher rate than recommended. Despite AOP recommendations and support for the monoculture of sex-reversed tilapia for the on-farm trial, a number of farmers mixed other fish species in their pond. Total fish production was found to vary from one pond to another. Extrapolated yield (averaging 944 kg rai^{-1}, with a range of 292 to 1322 kg rai^{-1}) was higher than that expected on the basis of on-station trials (600 kg rai^{-1}). Virtually all project farmers experienced a substantial increase in fish yield, which was associated with a change in water color from turbid to green or dark green after application of urea and TSP. At the end of the trial, virtually all the participant farmers were very satisfied with the significant increase in fish production from their ponds. Average yields were nearly three times higher from high-input green water practices compared to previous years' yield without such practice. The average estimated gross margin (Baht 17,000 rai^{-1} in 7.5-mo culture period) in this trial was also higher than expected.

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

Eighth Work Plan, Feeds and Fertilizers Research 1 (FFR1T)
Progress Report

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ABSTRACT

Two experiments were conducted in eighteen 200-m^2 earthen ponds at the Asian Institute of Technology, Thailand, for 91 days from 4 June to 3 September 1998. The first experiment was designed to: 1) determine the optimal rate of nitrogen fertilization; 2) determine which of the nitrogen fertilization rates evaluated to produce Nile tilapia (*Oreochromis niloticus*) had the greatest profitability; and 3) develop a full-cost enterprise budget for the fertilization level that resulted in the greatest profitability. Treatment ponds with triplicates each were fertilized with TSP at a rate of 8 kg P ha^{-1} wk^{-1} and with urea at 0, 10, 20, and 30 kg N ha^{-1} wk^{-1}. Sex-reversed male Nile tilapia, 10.1 to 10.9 g in size, were stocked at 1,000 kg ha^{-1} in all ponds (10 fish m^{-2}). For the second experiment, sex-reversed male Nile tilapia were also stocked at 1,000 kg ha^{-1}, but with respective fish sizes of 4.6 to 4.8 g, 10.1 to 10.5 g, and 21.3 to 21.8 g in each of the three treatments which were conducted in triplicate ponds. These various fish sizes resulted in stocking densities of 22, 10, and 5 fish m^{-2} for each of the three treatments, respectively. Ponds were fertilized with urea and TSP at a rate of 30 kg N and 8 kg P ha^{-1} wk^{-1}. All ponds for both experiments received sodium bicarbonate weekly to attain and maintain the minimum alkalinity (75 mg l^{-1} as $CaCO_3$) based on weekly measurements of alkalinity in pond water. The experiments showed that higher nitrogen inputs generally resulted in better growth performance of Nile tilapia. Growth in the treatment without N inputs ceased before day 50, which was earlier than growth ceased in the treatments with varied inputs of N (around day 70). 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. Nile tilapia yield was highest in the treatment with 30 kg N ha^{-1} wk^{-1} (2,409.6 ± 46.4 kg ha^{-1}), intermediate in the treatments with 10 and 20 kg N ha^{-1} wk^{-1} (2,172.8 ± 153.8 and 1,935.2 ± 165.9 kg ha^{-1}, respectively), and lowest in the treatment without N inputs (1,221.2 ± 44.0 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$11.90 net return could be produced from a 200-m^2 pond in this treatment during a three-month culture period. All parameters of fish growth performance were significantly better in the treatments stocked with medium and large fish than in the treatment stocked with small fish. Survival rate was highest in the large-size treatment, intermediate in the medium-size treatment, and lowest in the small-size treatment. Individual fish growth rates were significantly higher in the treatment stocked with larger fish. However, the estimated fish biomass and yields were highest in the medium-size treatment, intermediate in the large-size treatment, and lowest in the small-size treatment.

PHILIPPINES PROJECT

Subcontract No. RD010A-11

Staff

University of Arizona, Tucson, Arizona

Kevin Fitzsimmons	US Principal Investigator, Project Leader
Gary Dickenson	Technician
Brent Skeen	Graduate Research Assistant (to December 1997)
Casey McKeon	Graduate Research Assistant (from January 1998)
Jake Dillard	Undergraduate Research Assistant (from April 1998)

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Antonio Circa	Host Country Principal Investigator (to 16 June 1998)
Ruben C. Sevilleja	Director, Freshwater Aquaculture Center (from 16 June 1998)
Eddie Boy T. Jimenez	Technician
Jose Pagaduan	Field Staff
Boy Tomines	Field Staff (to December 1997)
Ben Pagaduan	Field Staff

Cooperator:

Chino Valley High School, Chino, Arizona
David Pereda

Site Background

The PD/A CRSP has been active in the Philippines since the program's inception in 1982. Until the present time, research in the Philippines was reported as part of the Thailand work plan as the Philippines functioned as a companion site to the CRSP prime site in Thailand. More recently, a restricted Request for Proposals (RFP) was issued to find a lead US university for a prime site in the Philippines; however, owing to various delays, including a reissuance of the RFP, the prime site award was not made until well into the present reporting period.

While the search for a lead US university for the Philippines Prime Site 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 attempts to develop low-cost supplemental feeds by using agricultural by-products. The project will determine if agriculture by-products including rice bran or straw can be used in pelleted diets. Yeast and rice bran or composted straw will be tested as possible ingredients.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

- Development of low cost supplemental feeds for tilapia in pond and cage culture/PHR1. The report submitted for this study was a progress report.

Note: Philippines research conducted by the University of Arizona is proceeding under its original schedule and is described in the *Eighth Work Plan*.

Site Improvement

Laboratory facility enhancement occurred with the delivery of the pelleting equipment to the FAC. A pellet mill was purchased in Kansas and shipped to Manila. The FAC staff brought the mill to the feed lab and installed the equipment. The mill is operating as expected and the FAC has used it to create experimental feeds for the trials, for other experiments, and for some local sales to area tilapia farmers. The University of Arizona has assigned a second laptop computer to CLSU to use at the FAC and provided the facility with a submersible water pump as well as additional lab equipment.

Networking Activities

In the Philippines CRSP Principal Investigator Kevin Fitzsimmons and Education Development Component (EDC) Coordinator Marion McNamara met with the Dean of the Fisheries College, the Director of the FAC, and the Director of the Bureau of Fisheries and Aquatic Resources (BFAR) to discuss future goals for the development of research and education projects. CRSP participants also visited private and public hatcheries and grow-out operations in Central Luzon and the research facilities of BFAR, the International Center for Living Aquatic Resources Management (ICLARM), the Genetically Improved Farmed Tilapia (GIFT) program, and the Genetically Produced Male Tilapia (GMT) program. In a subsequent tour Fitzsimmons traveled to FAC to discuss the progress of PD/A CRSP experiments and visit additional aquaculture operations, which allowed for extensive discussions with professionals and producers from private and public hatcheries and several cage farm operations. Fitzsimmons also presented information at CLSU on aquaculture research taking place at the University of Arizona and discussed production, processing, and markets of the US tilapia industry.

PD/A CRSP researchers from the Philippines project were closely connected with the Fourth International Symposium on Tilapia Aquaculture (ISTA IV) in October 1997. Fitzsimmons was one of the chief organizers of the conference.

Host Country Principal Investigator Tony Circa attended the ISTA conference as part of a PD/A CRSP training/tour sponsored by the EDC. Circa (along with other new Host Country collaborators from Honduras, Peru, and Kenya) traveled to Oregon State University and to Auburn University in October 1997 under the auspices of the EDC to participate in a CRSP orientation training (for more detail, please see the report of the EDC).

Presentations

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.

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.

Conferences

Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997. (Circa, Dickenson, Fitzsimmons, Skeen)

PD/A CRSP Annual Meeting at Las Vegas, Nevada, 12-14 February 1998. (Circa, Fitzsimmons)

Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998. (Circa, Fitzsimmons)

Genetics in Aquaculture meeting at the Freshwater Aquaculture Center, Muñoz, Philippines, March 1998. (Circa, Fitzsimmons)

DEVELOPMENT OF LOW-COST SUPPLEMENTAL FEEDS FOR TILAPIA IN POND AND CAGE CULTURE

Eighth Work Plan, Philippines Research 1 (PHR1)
Progress Report

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ABSTRACT

Two feeding trials were conducted at the Central Luzon State University Freshwater Aquaculture Center in the Philippines to determine the viability of using yeast and composted rice straw as alternative protein sources for tilapia diets. In the first phase, the experimental diets were prepared using a meat grinder to make pellets and fed to tilapia in ponds. In the second phase, the diets were fed to tilapia in cages in a common pond. In both experiments, the fish fed the diet incorporating the composted straw demonstrated the highest growth rate. In the pond study, 1.5-g tilapia were stocked in fertilized ponds, allowed to grow for seven months, and then fed the experimental feed for three months. The fish grew to an average of 141.3, 134.6, and 106 g in the compost, yeast, and un-fed control ponds, respectively. The ponds also yielded fingerlings with an average biomass of 124.3, 101.0, and 57.2 kg per pond in the compost, yeast, and un-fed controls, respectively. In the second phase, the fish were stocked into hapa cages at an average size of 73.9 g. In three months the fish grew to average sizes of 162.6, 155.6, 148.8, and 146.6 g when fed the compost diet prepared on a meat grinder, compost diet from a pellet mill, yeast diet from a grinder, and yeast diet from a pellet mill, respectively. Based on the results of these trials we conclude that these low-cost supplemental feeds would increase the yield from ponds and the composted rice straw would be the better protein source for the replacement of fishmeal compared to the variety of yeast used in the diet.

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 (now 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 socioeconomic 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 facing farmers and commercial aquaculturists in the US and host countries.

August 1, 1998, 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 CRSP Grant in 1987, Host Country and US institutions renewed their Memoranda of Understanding. These Memoranda reflected the structural changes (i.e., the consolidation of the CRSP from seven countries to three) 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—OSU 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 at 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 1998

At the present time, Memoranda of Understanding are in place between the following participating CRSP institutions:

- International Center for Aquaculture and Aquatic Environments, Auburn University, and the Secretaría de Recursos Naturales, Republic of Honduras
- Southern Illinois University, Carbondale, and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana
- Oregon State University Fisheries and Wildlife Department and the Department of Fisheries, Ministry of Wildlife and Tourism, Kenya (the Department of Fisheries has since moved to the Ministry of Natural Resources)
- The University of Michigan and the Asian Institute of Technology, Thailand

Memoranda of Understanding are in process (or are being considered) between the following institutions:
- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico
- CRSP ME/Oregon State University and the International Center for Living Aquatic Resources Management
- CRSP ME/Oregon State University and Université Nationale du Rwanda

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 5.

APPENDIX 2. PROGRAM PARTICIPANTS

The Pond Dynamics/Aquaculture CRSP represents the joint efforts of more than 70 professional and support personnel from US universities. It also represents the collaborative efforts of over 75 scientists, technicians, and graduate students from project sites in five host countries. 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; Sociology; Data Management, Analysis, and Modeling; Sociology; Biotechnology; Agricultural Economics; Adult Education; and Research Administration.

The program's United States-based personnel is drawn from each of the participating institutions—Auburn University (AU), Oregon State University (OSU), Southern Illinois University, Carbondale (SIUC), The University of Michigan (UM), the University of Arkansas at Pine Bluff (UAPB), the University of Arizona (UA), the University of California at Davis (UCD), the University of Texas (UT), and the University of Oklahoma (UO). Host country staff participate in the CRSP though their involvement with:

Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras
Laboratoria de Calidad de Agua La Lujosa, Choluteca, Honduras
Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras
Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru
Universidad Nacional de la Amazonia Peruana, Iquitos, Peru
Fisheries Department, Nairobi, Kenya
Sagana Fish Farm, Sagana, Kenya
Asian Institute of Technology, Pathum Thani, Thailand
Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Cooperating institutions include:

Chino Valley High School, Chino, Arizona
Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico
Grupo Granjas Marinas, S.A., Choluteca, Honduras
Food and Agriculture Organization, Rome, Italy

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
Danielle Clair	Program Assistant
Clare LaFond	Financial Manager (to May 1998)
John Baker	Research Assistant (to July 1998)
Sayea Jenabzadeh	Office Support (to April 1998)
Julia Braun	Office Support (to May 1998)
Xena Cummings	Student Worker

*Most PMO staff are employed at less than full-time

ADVISORY BODIES

Board of Directors

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

Ex-Officio 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 (from 7/98)	University of Nebraska, Lincoln

Technical Committee	**Institution**	
Raul Piedrahita	Co-Chair	UCD
Bill Shelton	Co-Chair	UO

Material and Methods Subcommittee		*Research Area of Expertise*
Carole Engle	UAPB	Social and economic aspects
Karen Veverica	AU	Production optimization
Jim Szyper (to 2/98)	UH	Environmental effects
Doug Ernst (from 2/98)	OSU	Environmental effects

Technical Progress Subcommittee		
Joe Molnar	AU	Social and economic aspects
Shree Nath	OSU	Production optimization
Peter Edwards (to 3/98)	AIT	Environmental effects
Yang Yi (from 3/98)	AIT	Environmental effects

Work Plan and Budget Subcommittee		
John Bolte (to 2/98)	OSU	Environmental effects
Kevin Fitzsimmons (from 2/98)	UA	Environmental effects
Tony Circa	CLSU	Social and economic aspects
Bart Green	AU	Production optimization

External At-Large Member

Randy Brummett	ICLARM, Malawi

Research Support At-Large Member

Marion McNamara (from 2/98)	OSU

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	OSU
Brigitte Goetze	OSU

Expenditure of Funds

August 1, 1997 - October 31, 1998

Research Program	Institution	USAID (1) 8/98-10/98	USAID (1) Cumulative	Cost Share (2) 8/98-10/98	Cost Share (2) Cumulative	Total US Funds 8/98-10/98	Total US Funds Cumulative	Host Country Funds (3) 8/98-10/98	Host Country Funds (3) Cumulative
RESEARCH									
Global Research									
Pond Dynamics	Auburn University	35,983	113,981	8,996	29,889	44,979	143,870		
Reproduction Control	University of Oklahoma	47,040	117,280	12,790	31,194	59,830	148,474		
Reproduction Control	Auburn University	0	54,831	0	12,040	0	66,871		
Reproduction Control	Oregon State University	68,013	195,947	17,326	49,309	85,339	245,256		
Aquaculture Systems Modeling	University of California Davis	52,222	130,323	14,332	40,943	66,554	171,266		
Marketing and Economic Analysis	University of Arkansas, Pine Bluff	18,639	98,506	4,886	25,078	23,525	123,584		
Adoption/Diffusion	Auburn University	27,633	27,633	6,908	6,908	34,541	34,541		
Adoption/Diffusion	Auburn University	28,563	68,293	7,141	23,166	35,704	91,459		
Adoption/Diffusion	Auburn University	67,168	67,168	16,792	16,792	83,960	83,960		
Decision Support Systems	Oregon State University	40,863	195,444	10,668	49,710	51,531	245,154		
Regional Research									
Central America									
Honduras	University of Texas at Austin	0	19,767	0	4,066	0	23,833		
Honduras	Auburn University	139,526	597,582	34,882	102,317	174,408	699,899	67,758	112,758
Africa									
Kenya	Auburn University	67,586	322,106	16,897	72,388	84,483	394,494		
Kenya	University of Arkansas, Pine Bluff	5,886	17,386	1,472	6,005	7,358	23,391		
Kenya	Oregon State University	111,045	490,134	27,761	68,074	138,806	558,208	27,000	27,000
South America									
Peru	Southern Illinois University	85,302	180,756	41,930	74,061	127,232	254,817	58,531	58,531
Peru	University of Arkansas, Pine Bluff	12,042	12,042	4,288	4,288	16,330	16,330		
Asia									
Philippines	University of Arizona	0	69,833	0	20,908	0	90,741	500	500
Philippines	University of Hawaii	67,000	100,062	16,750	41,750	83,750	141,812		
Thailand	University of Michigan	98,990	366,263	24,748	68,422	123,738	434,685	26,000	52,000
Research Support									
Central Database Management	Oregon State University	57,083	156,390	14,271	42,082	71,354	198,472		
Education Development	Oregon State University	66,700	308,545	16,675	77,136	83,375	385,681		
Information Management & Networking	Oregon State University	257,824	706,390	64,556	176,773	322,380	883,163		
Subcontract Administration	Indirect on Subs < 25,000	13,000	99,410	0	0	13,000	99,410		
Research Subtotal		**1,368,108**	**4,516,072**	**364,069**	**1,043,299**	**1,732,177**	**5,559,371**	**179,789**	**250,789**
MANAGEMENT									
Program Management (4)									
Operations and Administration	OSU Management	340,000	1,230,000			340,000	1,230,000		
Advisory Groups	OSU Advisory	40,921	203,057			40,921	203,057		
Program Management Subtotal		**380,921**	**1,433,057**			**380,921**	**1,433,057**		
Total		**1,749,029**	**5,949,129**	**364,069**	**1,043,299**	**2,113,098**	**6,992,428**	**179,789**	**250,789**

Notes:
1. Includes funding received under three allocations from USAID and awarded for research under the Eighth and Ninth Work Plans.
2. Cost share includes commitments made in association with allocated funds in addition to cost share already accumulated.
3. Host country funds were not reported in all cases; however, these countries are typically contributing water, electricity, fish stock, and some amount of labor, supplies.
4. Cost sharing is not required for management operations.

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	PDR1	5/31/98	Progress
	Kohler	New Site Development and Characterization [1]	PR2	5/31/98	Final
	Bowman	New Site Development and Characterization	KR1	12/1/98	Abstract
	Diana	Effect of Mud Turbidity on Fertilization, and an Analysis of Techniques to Mitigate Turbidity Problems	TR1	7/31/98	Final
	Diana	Management of Organic Matter and Nutrient Regeneration in Pond Bottoms	TR2	7/31/98	Final
Feeds and Fertilizers	Green	Intensification of Tilapia Production: Effects of Feeding at Different Stocking Rate on Pond Water Quality	HR1	12/31/99	None
	Green	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (Honduras)	FFR1H	7/31/98	Final
	Bowman	Relative Contribution of Supplemental Feed and Inorganic Fertilizers in Semi-Intensive Tilapia Production	KR3	8/31/98	Progress
	Lochmann	Nutritional Contribution of Natural and Supplemental Foods for Nile Tilapia: Stable Carbon Isotope Analysis	KR3A	12/31/98	Progress
	Bowman	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (Kenya)	FFR1K	8/31/99	Progress
	Diana	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (Thailand)	FFR1T	1/31/99	Progress
	Fitzsimmons	Development of Low-Cost Supplemental Feeds for Tilapia in Pond and Cage Culture	PHR1	6/30/99	Progress
Reproduction Control	Phelps	Methods for Strain Variations in Sex Ratio Inheritance and Methods for Contribution from the Male and Female Genome to Sex Inheritance [2]	RCR1A & RCR1C	6/30/99 8/31/99	Progress
	Shelton	Nile Tilapia Gamete Management for Chromosome Manipulation *	RCR1B	6/30/99	Progress
	Phelps	Methods for Development of YY Lines of Male and Female *O. niloticus*	RCR1D	8/31/99	None
	Fitzpatrick	Steroid Immersion for Masculinization of Tilapia: Immersion of Tilapia Fry in MDHT	RCR2A	10/31/97	Final
	Fitzpatrick	Effect of Fish Density on Efficacy of Masculinization by Immersion in MDHT	RCR2B	6/30/98	Final
	Phelps	Masculinization of Tilapia Fry by Immersion in Trenbolone Acetate (TBA) at a Production Level *	RCR2C	3/31/98	Final
	Fitzpatrick	Detection of MT in Aquarium Water after Treatment with MT Food	RCR3A	3/31/98	Final
	Phelps	Detection of MT in Pond Water after Treatment with MT Food	RCR3B	4/30/99	Abstract
	Bowman	Strain Variations in Sex Ratio Inheritance	KR2	8/31/98	Abstract
Aquaculture Systems Modeling	Piedrahita	Model Evaluation and Application to the Ecological Analysis of Integrated Aquaculture/Agriculture Systems *	ASMR1A	9/30/98	Progress
	Piedrahita	Modeling of Temperature, Dissolved Oxygen, and Fish Growth Rate in Stratified Ponds Using Stochastic Input Variables *	ASMR1B	12/31/98	Progress
New Aquaculture Systems/ New Species	Kohler	Development of Sustainable Pond Aquaculture Practices for *Piaractus brachypomus* in the Peruvian Amazon *	PR1	5/31/98	Final

* Title of report is different than study title listed in the *Eighth Work Plan.*

[1] Study PR2 was carried out in lieu of the Global Experiment (FFR1), as work with tilapia in Peru is prohibited by the Peruvian government.

[2] Results of studies RCR1A and RCR1C were submitted as one report.

Eighth Work Plan Completion Dates (cont.)

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	HR2-1	9/30/98	Progress
	Ward	Analysis of Honduran Shrimp Farm Impacts on Channel Estuaries of the Gulf of Fonseca *	HR2-2	9/30/98	Progress
	Green	Influence of Daily Water Exchange Volume on Water Quality and Shrimp Production	HR3	5/31/98	Final
	Green	Water Exchange to Rectify Low Dissolved Oxygen	HR4	5/31/99	Abstract
	Diana	Management to Minimize the Environmental Impacts of Pond Draining: Effect of Harvest Draining Technique on Water Quality and Fish Growth *	TR3-2	7/31/98	Final

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	Economic and Social Returns to Technology and Investment and Risk Analysis of Pond Management Strategies [3]	MEAR1 & MEAR2	12/31/98	Progress
Adoption/ Diffusion	Molnar	Tilapia Producer Perceptions and Practices in Five PD/A CRSP Countries *	ADR1A	12/31/98	Progress
	Lovshin	The Influence of Fish Culture Technology, Extension Methodology, and Socioeconomics on Success of Fish Culture on Limited-Resource Farms	ADR2	6/30/99	Progress
	Bowman	Training	KR4	7/31/98	Final
	Bowman	Regional Outreach in Africa	KR5	7/31/98	Progress
	Diana	High-Input Green Water On-Farm Trials in Northeast Thailand *	TR4	7/31/98	Final
Decision Support Systems	Bolte	POND© Software Development and Refinement *[4]	DSSR1A, DSSR1B, & DSSR1C	4/30/98	Final
	Bolte	Macro-Level Agroecological Systems Analysis and Socioeconomics of Pond Aquaculture	DSSR1D	4/30/98	Final

* Title of report is different than study title listed in the *Eighth Work Plan*.
[3] Results of studies MEAR1 and MEAR2 were submitted as one report.
[4] Results of studies DSSR1A, DSSR1B, and DSSR1C were submitted as one report.

Appendix 5. 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 during this reporting period as well as those maintained by the Program Management Office. (Please see page 3 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
Bureau of Fisheries and Aquatic Resources, Manila, Philippines
Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt
Centro Internacional de Agricultura Tropica (CIAT), Cali, Colombia
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
    International Center for Living Aquatic Resources Management (ICLARM), Zomba, Malawi
    West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire
Cooperative for Relief and Assistance Everywhere (CARE), Atlanta, Georgia
Department of Fisheries, Udorn Thani, Thailand
Empresa Brasileira de Pesquisa Agropecuária (Embrapa), Brasilia, Brazil
Escuela Agrícola Panamericana (EAP), Zamorano, Honduras
Escuela de Agricultura de la Region Tropical Humeda (EARTH), San José, Costa Rica
European Union, Brussels, Belgium
Federación de Agroexportadores de Honduras (FPX), San Pedro Sula, Honduras
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
Institute of Agricultural and Food Information, Prague, Czech Republic
Institut Pertanian Bogor (IPB), Bogor, Indonesia
Integrated Pest Management CRSP, Blacksburg, Virginia
International Development Research Centre (IDRC), Ottawa, Canada
International Sorghum and Millet (INTSORMIL) CRSP, Lincoln, Nebraska
Land Tenure Center, Madison, Wisconsin
Marine Institute, Callao, Peru
Mekong River Commission, Phnom Penh, Cambodia
Microcredit Summit Campaign, Washington, DC
Ministry of Agricultural Development, Panama
National Agricultural Library, Washington, DC
National Inland Fisheries Institute (NIFI), Bangkok, Thailand
National Technical Information Services, (NTIS) Springfield, Virginia
Network of Aquaculture Centers in Asia Pacific (NACA), Bangkok, Thailand
North Central Regional Aquaculture Center (NCRAC), East Lansing, Michigan
Oceanic Institute, Waimanalo, Hawaii
Oregon Sea Grant, Corvallis, Oregon
Organization for African Unity, Addis Ababa, Ethiopia
    Inter-African Committee on Oceanography, Sea and Inland Fisheries
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
Small Ruminant CRSP, Davis, California
Soil Management CRSP, Honolulu, Hawaii
Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines
Southern African Development Community (SADC), Gaberone, Botswana
Special Program for African Agricultural Research (SPAAR), Washington, DC
Sustainable Agriculture and Natural Resources Management (SANREM) CRSP, Watkinsville, Georgia
Texas A&M University, College Station, Texas
The University of the Philippines in the Visayas, Iloilo, Philippines
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
Universidade de São Paulo, Brazil
Université Catholique de Louvain, Belgium
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam
University of Cantho, Vietnam
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

APPENDIX 6. 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, 4:157-168.

AUBURN UNIVERSITY

Publications and Reports

Alvarenga, H.R. and B.W. Green, 1985. Production of hybrid tilapia (*Tilapia nilotica* x *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* x *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* x) 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* x *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* x *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 saureus* 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.

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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, 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 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 acquisition 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.

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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) Nov. 1997.
Boyd, C.E., Workshop on water and soil quality in shrimp farming (2 days), Mazatlan, Mexico (41 participants) Jan. 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.
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, Philadelphia, Pennsylvania. This three-hour symposium featured presentations by shrimp farmers from Ecuador and Honduras, PD/A CRSP researchers Claude Boyd and Kwei Lin, Rural Sociologist Conner Bailey, and representatives of several environmental organizations, 1998.

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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.

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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)
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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)
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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)
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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)

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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, D.R. and R.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)

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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)

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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)

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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)

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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)

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APPENDIX 7. ACRONYMS

AAAS	American Association for the Advancement of Science
AFE-COHDEFOR	Administración Forestal del Estado—Corporación Hondureña de Desarrollo Forestal (State Forestry Administration—Honduran Corporation for Forestry Development)
AIARD	Association for International Agriculture and Rural Development
AIT	Asian Institute of Technology
ANDAH	Asociación Nacional de Acuicultores de Honduras (Honduran National Association of Aquaculturists)
AOP	Aquaculture Outreach Project
AU	Auburn University
BFAR	Bureau for Fisheries and Aquaculture Research
BOD	Board of Directors
CARE	Cooperative for Assistance and Relief Everywhere
CIAT	Centro Internacional de Agricultura Tropica (International Center of Tropical Agriculture)
CIESIN	Consortium of International Earth Science Information Networks
CIFAD	Consortium for International Fisheries and Aquaculture Development
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)
CRSP	Collaborative Research Support Program
CTU	Celsius Temperature Units
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
DOF	Department of Fisheries
DSS	Decision Support System
EAEN	East African Environmental Network
EAP	Escuela Agricola Panamericana (Panamerican Agriculture School)
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
FAC	Freshwater Aquaculture Center
FAO	Food and Agriculture Organization
FISA	Fisheries Society of Africa
FPX	Federación de Agroexportadores de Honduras (Honduran Federation of Export Producers)
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GMT	Genetically Produced Male Tilapia
GnRHa	Gonadotropin Releasing Hormone Analogue
HCG	Human Chorionic Gonadotropin
HTML	Hypertext Markup Language
ICLARM	International Center for Living Aquatic Resources Management
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
ISTA IV	Fourth International Symposium on Tilapia in Aquaculture
JCARD	Joint Committee on Agricultural and Research Development
LHRHa	Luteinizing Hormone Releasing Hormone Analogue
MDHT	17α-Methyldihydrotestosterone
ME	Management Entity
MOU	Memorandum of Understanding
MT	17α-Methyltestosterone
NACA	Network of Aquaculture Centers in Asia Pacific
NARP	National Agricultural Research Project
NASULGC	National Association of State Universities and Land Grant Colleges
NGO	Nongovernmental Organization
OAU/STRC	Organization of African Unity's Scientific, Technical, and Research Commission
OIRD	Office of International Research and Development
OSU	Oregon State University

PD/A CRSP	Pond Dynamics/Aquaculture Collaborative Research Support Program
PI	Principal Investigator
PL	Post-Larvae
PMO	Program Management Office
PRADEPESCA	Programa Regional de Apoyo al Desarrollo 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)
RFP	Request for Proposals
SDI	Sustainable Development Indicator
SIUC	Southern Illinois University, Carbondale
TAN	Total Ammonia Nitrogen
TBA	Trenbolone Acetate
TC	Technical Committee
TPSC	Technical Progress Subcommittee
TSP	Triple Superphosphate
UA	University of Arizona
UAPB	University of Arkansas at Pine Bluff
UCD	University of California, Davis
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)
UNIFEM	United Nations Development Fund for Women
UNR	Université Nationale du Rwanda (Rwandan National University)
UO	University of Oklahoma
URL	Universal Resource Locator
US	United States
USAID	United States Agency for International Development
UT	University of Texas
UV	Ultraviolet
WAS	World Aquaculture Society
WWW	World Wide Web