PD/A CRSP
Twelfth Annual Administrative Report

1 September 1993 to August 1994

Dedication

Since April of 1993, when the downing of President Juvenal Habyarimana's plane fanned the civil unrest in Rwanda into civil war, the PD/A CRSP has been deeply affected by the events taking place in Rwanda. An evacuation of U.S. citizens was effected almost immediately after the violence began. CRSP researchers Jean-Damascene Bucyanayandi, Lieven Verheust, and Anaclet Gatera were en route to Rwanda after the PD/A CRSP Annual Meeting, when their flight was re-routed to Bujumbura, Burundi. Although Research Associate Joyce (J-J) Newman was still in the U.S, her husband, as well as the spouses and families of the other researchers, had remained in Rwanda. Newman and Verheust's spouses were able to escape through Bujumbura, Burundi. Bucyanayandi and Gatera crossed back into Rwanda to find their families. Both men were killed. Bucyanayandi's wife and three children escaped.

Reports issuing from Rwanda since April have been sporadic and sketchy; nevertheless, we have pieced together enough information to know that other CRSP associates, such as Valens Ndoreyaho, and other research station workers met untimely and tragic ends.

We join their families and their country in mourning the loss of these talented individuals, who were promising, individually and collectively, to make great contributions to their communities, their country, and the world of aquaculture. We dedicate this annual report to their memory.

I. Introduction

Historical Overview

The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) is an international effort to develop aquacultural technology as a means of confronting food security problems in developing countries. The PD/A CRSP is funded by the U.S. Agency for International Development (USAID), under authority of the International Development and Food Assistance Act of 1975 (P.L. 94-161), and by the universities and institutions that participate in the CRSP. Oregon State University (OSU) is the Management Entity (ME) for the CRSP and has technical, administrative, and fiscal responsibility for program performance.

The CRSP is a cohesive program of research carried out in selected developing countries and the United States by teams of U.S. and host country scientists. The resources of U.S. and host country institutions are brought together to improve the efficiency of pond culture systems through sustainable aquaculture. The U.S. institutions participating in the program are Auburn University, the University of California at Davis, the University of Oklahoma, and the Consortium for International Fisheries and Aquaculture Development (CIFAD). CIFAD members include the University of Arkansas at Pine Bluff, the University of Hawaii, the University of Michigan, Michigan State University, and Oregon State University. Host country institutions with formal linkages to the CRSP through Memoranda of Understanding are the National University of Rwanda, Royal Thai Department of Fisheries, Asian Institute of Technology, Department of Renewable Natural Resources, Agricultural Research Center of Egypt, and Central Luzon State University of the Philippines. Numerous linkages are also maintained with other U.S. and host country governmental and non-governmental institutions, and with private companies and farmers.

CRSP activities were formally initiated on 1 September 1982 after several years of planning. From 1982 to 1987, CRSP projects involved the participation of government agencies and educational institutions in six host countries: Honduras, Indonesia, Panama, the Philippines, Rwanda, and Thailand. Funding constraints during 1986 and 1987 forced a reduction in operations. A reorganization plan was submitted in December 1986 to the Joint Committee on Agricultural Research and Development (JCARD) Panel on CRSPs and the AID Agricultural Sector Council Subcommittee. The plan, which went into effect on 1 September 1987, called for maintaining a presence in each of the USAID geographical areas originally selected. Three country sites were chosen: Rwanda, Thailand, and Panama. However, following that decision, political initiatives in Panama in 1987 made it necessary for the CRSP to leave Panama and return to Honduras. Largely through the efforts of Auburn University and through continuing financial commitments of the USAID Mission, the CRSP was welcomed back into Honduras in April 1988 and began experiments with the assistance of the Honduran Department of Renewable Natural Resources (RENARE) in August 1988.

New Challenges and Events

This year's many programmatic and technical accomplishments were overshadowed by the tragic events in Rwanda. Rwanda's civil war shook the world, and with it our CRSP. The tragedy brought about a sudden and devastating change to our program-the end of our Africa project site, and the death of many CRSP researchers and co-workers. The dedications at the beginning of this Annual Report are but a small sign of the sadness felt by each and every person in the CRSP, especially those who worked on the Rwanda project. In the face of adversity, many personal stories unfolded and are now becoming part of the fabric of our program. It is with this depth of experience and emotion that we embark upon a quest for a new African site.

New site selection, although not part of the past year's activities, will become a major undertaking in the year to come. Not only is the CRSP evaluating alternate sites in Africa, but it is looking forward to establishing a new site in South America. The initiation of new sites, however, depends on the funding received under the next five-year grant. The CRSP has been invited to submit a five-year continuation proposal to USAID. Recent external reviews have rated the program as exceptional and deserving of enhanced funding. New components of the program will target food security, information management, human resources development, and economic growth. The proposal was originally due in August 1994, but changes within USAID and BIFADEC have resulted in major delays. Consequently, the proposal will be a focus of the coming year's work.

Uncertainty within USAID has also been reflected in other ways within the CRSP. The PD/A CRSP received a 10% cut in its 1994-95 budget-less in absolute terms than the other CRSPs, three of which were cut greater than 40%. The CRSP grant, whose expected end date was 31 August 1995, was shortened by 4 months, to 30 April 1995. Funding and time constraints will therefore make the coming year a period of great challenge.

This past year was the "year of evaluations." The beginning of the period was marked by the culmination of the EEP Quinquennial Review (which took over a year to complete), and the undertaking of the USAID Internal Administrative Review. In addition, the Global Bureau commissioned Tropical Research and Development, a consulting firm, to evaluate all of the CRSPs. Their findings shed a positive light on the PD/A CRSP, especially in the areas of program management and overseas impacts. Finally, the Egypt project, a large informal buy-in grant under the CRSP, was evaluated by USAID/Cairo and USDA. The Egypt project received commendations and was recommended for an extension.

Continuing Activities

Global Experiment and Related Activities

With the completion of the first three cycles of standardized global experiments (1982-1987), the CRSP began focusing on the statistical interpretation of data that were collected at the original six project sites. The research program was successfully modified to reflect a reduction in sites without changing the overall emphasis of the CRSP. The global nature of the program therefore remains intact. Experimental protocol, as described in subsequent work plans, conforms to that of the original three cycles to allow comparison between sites over time. Field experiments blend program-oriented (see Global Experiment and Related Studies) and project-oriented (site-specific) considerations in response to the results of earlier experiments.

After years of discussion, the CRSP is moving ahead with plans to incorporate much of the CRSP global data base into the data base of the International Center for Living Aquatic Resource

Management (ICLARM), FISHBASE. This will further ensure safekeeping of important data that have been collected through ten years of CRSP experiments.

The CRSP passed another milestone with the completion of a new version of PONDCLASS, now called POND. POND offers a Microsoft Windows™-based decision support system for aquaculture pond management, with enhanced capacities such as economic forecasting and weather simulations. Prospective users of POND are completing a questionnaire; survey results are expected to be useful for improving the next version of the POND software. POND not only provides new technology for fish culturists but also serves as an excellent teaching tool for simulating pond responses to a variety of inputs. The software manual is now available in French; the Rwanda team translated the manual in a cooperative effort with the Data Analysis and Synthesis Team. A Spanish translation of the manual is in progress.

New Brackish Water Site

The termination of brackish water sites in Panama and the Philippines in 1987 focused the approach of the CRSP toward freshwater research.

Now, the CRSP's new brackish water site in Choluteca, Honduras, which opened last year, provides opportunities for studying environmentally and economically important brackish water systems. In accordance with the goals of the USAID Mission in Honduras, the CRSP is conducting research near the Gulf of Fonseca to evaluate environmental impacts and alternative production strategies associated with shrimp farming in that region. Closer collaboration among the PD/A CRSP and Honduran organizations, other CRSPs, and private aquaculture farms is being facilitated through the CRSP's involvement in this new site. CRSP research at the freshwater station in Comayagua, which continues to operate under host country supervision, now focuses on extending CRSP technologies.

Recent Additions to the CRSP Framework

The initiation of a new site in Egypt in October 1992 offered the CRSP an exciting opportunity to investigate pond management strategies in an arid climate. The Egypt project is now part of the family of PD/A CRSP projects, but is unique in that it is funded under a separate grant from USAID/Cairo and the National Agricultural Research Project of Egypt (USAID Grant No. 263-0152-G-00-2231-00). In addition to the mandatory Global Experiment, which is conducted at all CRSP sites, the Egypt project is credited with adding new research themes to the CRSP: polyculture, bioconversion, and biotechnology. Also, through the Egypt project, the CRSP has added new researchers to its list of cooperators and has expanded its institutional affiliations (new participants include the Central Laboratory of Aquaculture Research, Abbassa, and the University of Oklahoma). Longtime institutional members of the CRSP participating in the Egypt project are Oregon State University, Auburn University, University of Hawaii, University of Michigan, and the Asian Institute of Technology.

The Egypt Project presents one example of the CRSP's active pursuit of new opportunities. Because collaborative projects must benefit both the host countries and U.S., as well as fulfill overall CRSP goals, new opportunities are actually quite rare. Nevertheless, the CRSP has been successful in attracting new projects in four target areas: socioeconomics research, gender studies, on-farm studies, and outreach. Projects in these focus areas are showing their first results and are successfully adding a broader dimension to the CRSP experience. Natural resources management has always been a cornerstone of the CRSP; therefore, the continued efforts in this area are not new. What is new is the integration of natural resources work with sociocultural and economic dimensions of aquaculture. Many of the technical summaries contained in the Annual Technical Report of this Twelfth Annual Report present practical economic information in addition to the biological analyses that are the mainstay of this CRSP.

A global social sciences project, which began in June 1992, has US CRSP economists, biologists, and sociologists collaborating with researchers from the Philippines, Thailand, and Honduras in an examination of aquaculture technology adoption and diffusion. This project presents one of the CRSP's first attempts to fully fund a social sciences activity that cuts across a number of CRSP sites. However, continued funding constraints – this CRSP is funded on average at 40 percent of the other CRSPs – may again relegate social science research to be funded primarily through extramural support.

When BIFADEC originally designed the CRSPs, the mandate called for greater focus on research than on outreach. The PD/A CRSP, however, sees the partnership of these two types of activities as critical to achieving positive social impacts. Therefore, greater emphasis during the past year has been placed on farmer participatory research, on extending research information to end users, and on adopting a research strategy that is sustainable and appropriate. The CRSP project in Rwanda, for example, regularly assisted the USAID Mission with its natural resources projects and helped transfer CRSP technologies to Rwandan farmers. In Northeast Thailand, the CRSP is cooperating with scientists from other donor agencies in helping farmers help themselves. The direct input that farmers provide to the research process renders the results more relevant and cost-effective.

Leveraged Activities

This Twelfth Annual Report contains some summaries of studies that were only partially funded by the CRSP; CRSP funds were used as seed money to leverage support from other sources. For example, the funds for testing CRSP models on farms in the Philippines were matched by the University of Hawaii and Central Luzon State University. In addition to the many grants and cooperators affiliated with the CRSP project in Rwanda, the European Economic Community contributed funds to improve and expand the pond facilities at Rwasave Fish Culture Station. In previous years, funds allocated to a Women in Development study helped to leverage funds from a number of sources.

Other continuing studies include investigations in tropical pond soils, which have allowed us to facilitate linkages with other soils projects such as the TropSoils CRSP in Honduras; polyculture research using native species; and research on ecologically sound alternatives to therapeutic drugs used in fish culture.

Other "buy-in" activities include expanding traditional pond dynamics work to encompass a broader analysis of the effects of aquaculture on the environment, and a grant from USAID to support a workshop on integrating a social sciences perspective into mainline CRSP research.

Research Support Activities

The CRSP's direct involvement with farmers, educators, and other end users of CRSP technology is one way to actively extend information generated by the program. Other information is extended through the CRSP's numerous publications, which are aimed at both technical and non-technical audiences. The CRSP's recently initiated international effort to write a comprehensive book on the principles of pond dynamics also involves the aquaculture community at-large. This book will be a useful addition to aquaculture researchers' and students' libraries, and an effort is being made to make it available at an affordable price to people in less economically advanced countries. The book will update and expand on an earlier CRSP book, Principles and Practices of Pond Aquaculture, which is in its third printing.

The CRSP has benefited from its involvement in the CRSP Council, a group composed of USAID-funded Collaborative Research Support Programs, although full participation in this group extracts a high cost in terms of time and capital from the smaller CRSPs such as ourselves. Through the Council, the PD/A CRSP has participated over the years in presentations to Congress, the World Bank, USDA, USAID, JCARD, and environmental groups. One impact of this effort is increased public awareness of CRSP programs.

Many other technical and programmatic accomplishments are described in detail in this Twelfth Annual Administrative Report, which covers the period from 1 September 1993 to 31 August 1994. This report is divided into two volumes: Program Accomplishments and Technical Reports. Each section has been designed to stand on its own. Program Accomplishments encompasses all administrative, research, and outreach activities during the reporting period and includes sections on program history, personnel, financial status, administrative and management activities, abstracts of all technical experiments conducted during the past year, and non-research activities such as training, publications, and service. Technical Reports focuses on the research accomplishments of the program and contains full technical reports. (See Appendix B for the table of contents of the technical reports volume.)

II. Summary of Activities and Accomplishments

1 SEPTEMBER 1993 TO AUGUST 1994

Major accomplishments during this reporting period include the initiation of Seventh Work Plan studies at all sites. Studies scheduled under the Sixth Work Plan had been concluded in the previous period, except for one experiment, which had been exchanged with a Seventh Work Plan experiment. POND, the new decision-support system which allows facility managers to project economic returns of various management strategies, is now available to interested persons. A number of special Topics Research activities were completed. The CRSP also participated in two different evaluations. Honduras, Thailand, the DAST, and the Management Entity participated in the overall CRSP review. The Egypt project underwent a technical review and was subsequently granted an extension. As always, efforts to disseminate research results continued through a variety of avenues.

Overseas Research

Honduras

Seventh Work Plan experiments were initiated this year at the brackish water site at Choluteca and at the freshwater site at El Carao. Brackish water research focused on the environmental effects of shrimp farming on estuarine water quality and on the development of culture techniques to reduce environmental impact. Researchers demonstrated that riverine estuaries were associated with higher nutrient loads than gulf embayments. Non-riverine estuaries showed no seasonal variability; however, riverine estuaries showed seasonal variability, and exhibited higher nutrient concentrations in the dry season. A companion study found that shrimp producers could reduce the nutrient input into estuaries during the dry season by a modification in management practices. It was found that use of fertilizer in the dry season did not increase shrimp yield. Other input rates can also be reduced in the dry season because decreasing the feeding rate by up to 50% did not result in significantly reduced shrimp yield.

Global Experiment research was carried out at El Carao with scientists comparing different management regimes. The first treatment followed the fertilization recommendations obtained from the decision-support system PONDCLASS (the precursor to POND), and was compared with a second treatment which used total ammonia concentrations (TAN) as a fertilization guideline. A third treatment compared the effect of increasing the stocking rate from 2 to 3 fish/m^2. PONDCLASS recommendations led to excessive nitrogen fertilization, because primary productivity was constrained by a carbon limitation. The results for the TAN experiment were inconclusive. Almost identical fish yields were obtained with the two different stocking rates. However, individual fish size was smaller at the higher density which significantly reduces marketability of the tilapia.

A second freshwater study combined various ratios of tilapia and tambaqui in a polyculture experiment. A combination of 75% tilapia and 25% tambaqui' was found to give the best results. The Honduras team

also conducted two studies which were not part of the Sixth or Seventh Work Plan. Hormonal sex-reversal is a commonly practiced method to obtain monosex fish populations. Determination of the optimal water temperature regime for mass production of tilapia fry for hormonal sex-reversal was the goal of the first investigation. Using a threshold temperature of 15 degrees C, fry production did not occur below 140 degree-days; the upper boundary was given by 195 degree-days. In a companion study, researchers tried to determine if the administration of 17a-methyltestosterone improved the growth of treated fry and fingerlings. This side-effect has been reported in the literature for other species; however, after 150 days no significant differences were observed between treated and untreated fry in this experiment.

Rwanda

Rwanda CRSP personnel conducted five workshops in late 1993 and trained 60 extension agents of the National Fish Culture Service. The terrible civil war that has ravaged Rwanda since spring 1994 ended all research and extension activities in Rwanda. When the civil strife erupted, the Rwanda CRSP team was investigating the productivity difference of fed and non-fed ponds at different elevations; the determination of fish production relationships from existing farmer-generated data; and tilapia fry mass-production techniques. These developments necessitated the development of a new work plan for the Rwanda research group. Replacements have been developed for those experiments which were underway in Rwanda at the outbreak of open hostilities. All hope of regaining access to the Rwanda data has been lost. New studies have been initiated to determine the most effective lime requirement estimators for broadly different soil types; to investigate the effect of pond soil characteristics on phosphorus fixation and availability; to determine the effect of feed consumption, growth, and conversion efficiency of tilapia fry; and to examine the efficacy of sex reversal treatment as a function of water temperature. These studies are still in progress. Results from a study on the use of defatted rice-bran as fish feed show that rice-bran, an agricultural by-product, is a good and economic supplemental food source, especially when pelleted. Pellets are not only easier to handle than loose rice bran, they also reduce the amount of fertilizer applications needed to maintain pond fertility.

Thailand and the Philippines

Determination of optimal phosphorus fertilization rates was the aim of two studies conducted by Thailand and CRSP researchers. The first study investigated the relationship between phosphorous sediment concentrations and phosphorous fertilization rates. It was found that optimum phosphorous fertilization, which does not result in either under- or over-fertilization, can be obtained if the fertilization rate is based on the phosphorous saturation level of the sediment. The second study reported a quick method to estimate phosphorous saturation level in sediment by using sediment clay content as the key variable.

Supplemental feeding is often necessary for growing larger, more valuable tilapia. Several studies investigated aspects of this management technique. Results indicated that early supplemental feeding produced inefficient feed use, while a late starting date (after fish have reached 150 g) extended the growing period considerably. A companion study investigated the relationship between stocking density and carrying capacity under a supplemental feeding regime. Initial results indicated that growth rates were similar among treatments and that carrying capacity had not been reached. A third investigation, comparing the growth rate of tilapia under different input regimes, found that 90.3% of the variance in

growth could be explained by feed and fertilizer input, alkalinity, and total inorganic nitrogen concentration. Combinations of feed and fertilizer were most efficient in growing tilapia to 500 g.

Improved understanding of pond dynamics is key to optimizing production techniques. Carbon has been shown to be a limiting nutrient in previous PD/A CRSP research of tropical fish ponds. The Thailand research group worked on two studies to further investigate carbon dynamics. One study attempted to stabilize total alkalinity by adding carbonate as part of the fertilizer input. During the dry season, total alkalinity was stable in treatment ponds, but declined in control ponds. During the wet season, no treatment effect was observed. A second study, currently underway, will quantify the rates of exchange of carbon dioxide between pond water and the atmosphere and compare these rates with photosynthetic carbon uptake and respiratory release.

Most of the PD/A CRSP's work has been done in shallow ponds (approximately 1 m deep). However, there exists considerable potential for aquaculture in rain-fed irrigation reservoirs. These ponds would likely exhibit different characteristics which would require the development of new management strategies. The initial results of an analysis of the diel temperature and oxygen stratification in deep, rain-fed ponds in Thailand lends credence to this view. While the surface layer (up to 1 m deep) behaves much like a shallow pond, the water below this layer is isolated from the top layer and did not seem to mix during the experimental period.

Research conducted in the Philippines is a sub-project of the Thailand project. Two investigations are currently underway at the Freshwater Aquaculture Center. A comparison of the performance of different tilapia strains will provide the information necessary for development of a breeding program. The CRSP Philippine team is collaborating with ICLARM's "Genetic Improvement of Farmed Tilapia" (GIFT) project and with the research project of "Genetic Manipulations for Improved Tilapia" conducted by the Freshwater Aquaculture Center at Central Luzon State University and the University of Wales Swansea. Fish from both projects will be compared with the Chitralada strain, used in Thailand, and the unmanipulated strain used in the Philippines. The second study tests whether CRSP fertilizer guidelines will be socially acceptable and economically viable under Philippine conditions.

Egypt

The beginning of experiments in Egypt last year was delayed due to inclement weather and a resulting fish kill; therefore, most of the second year experiments (see CRSP Work Plan 7) were still underway by the end of this reporting period. In order to conclude the research, the end date of the Egypt project was extended to December 31, 1994. Summaries of activities conducted from September to December 1994 will be published in the Final Report of the Egypt Project.

Investigations at the Central Laboratory for Aquaculture Research (CLAR) in Abbassa, Egypt, focused on validating CRSP guidelines in an arid climate. Five different pond management strategies were tested and yielded significantly different results. The highest gross yields were obtained from the Fertilization then Feed treatment; the lowest yields were obtained from the Chemical Fertilization treatment. A companion study examined the economic returns obtained from each treatment. The highest net economic returns were obtained from the Fertilization then Feed treatment, while the Chemical Fertilization treatment resulted in the lowest returns. A third study compared the yield characteristics of Nile tilapia to those of

blue tilapia. Initial results indicate Nile tilapia performs better in every treatment than blue tilapia. A fourth investigation aims to determine the effect of stocking rate on Nile tilapia growth and yield. Initial results indicate no negative effects of the higher stocking rate on either growth or yield. The Egypt project team also initiated a study of Egyptian pond bottom soils to determine the role of pond soils in pond nutrient dynamics.

The Egypt Project added biotechnology research, a new line of inquiry in the family of CRSP studies. Several of the studies focused on the use of sex hormones, mainly 17a-methyltestosterone (MT), which is internationally used as a sex-reversing agent in aquaculture. The U.S. Food and Drug Administration (FDA) granted a "compassionate" Investigational New Animal Drug exemption (INAD) to allow research on the efficacy and safety of this drug. A field trial was started in July 1994 at the Central Laboratory for Aquaculture Research (CLAR) at Abbassa, Egypt. This research, conducted in the field at the CLAR, was devoted to both the development of a technology to mass produce tilapia fry for sex-reversal, and examining the effects of MT on treated fry. Initial results indicate both high efficacy and survival rates.

Other MT-related research was conducted at Oregon State University (OSU) and the University of Hawaii (UH). The OSU research team characterized a binding site for sex-reversing hormones in gonadal tissue of adult Nile tilapia, and also developed a receptor assay, a fast tool for screening the efficacy of newly developed sex inversion agents. Other research at OSU continues to follow this line of inquiry by studying gonadal development in tilapia. The OSU team is also developing a cryopreservation technique for sperm and determining if an alternative sex-reversal technique (immersion) might be safer than the currently used method (medicated feed).

Researchers at UH conducted a study on the separation of the sex-reversing effects of MT from the growth-promoting effects of this drug on two different species of tilapia. It was found that the growth rate of *Oreochromis aureus* was nearly twice the rate of *O. mossambicus* at each dose level, and in almost all treatments, MT-treated animals grew significantly better. A totally different approach to the generation of monosex tilapia has been applied by Auburn University researchers, who are working to develop a YY tilapia breeding program to generate monosex tilapia offspring that are not treated with hormones. So far, four possible YY supermales have been identified. However, males which produced more than 95% male progeny in the first mating did not consistently produce such frequencies of male offspring in consequent spawns.

Bioconversion and polyculture research, another focus of the Egypt Project, focuses on building a polyculture system suited to the conditions found in Egypt by utilizing currently unused pond system components such as aquatic weeds or snails as fish food. Initial results from the bioconversion experiments indicated the effectiveness of grass and black carp as control agents; however, considerable contamination of the treatment ponds with common carp and mullet restrict interpretation of these results. Polyculture experiments are still ongoing and no results were available by the end of this period.

Data Analysis and Synthesis

During this period, the OSU DAST team completed work of the decision-support system POND. POND was developed to provide the aquaculture community with a tool for rapidly analyzing warm water

aquaculture systems, and to assist in developing optimal management strategies. POND can be used to set up pond facilities with different configurations and/or management strategies. Facility managers can use POND to project possible future economic return for different management options. Approximately 80 copies of POND Version 2.0 have been distributed to a wide audience including extension agents, educators, producers, and researchers.

The University of California at Davis DAST team concentrated its efforts on further improving existing models of oxygen dynamics and developing new models for stratified ponds. Current understanding of oxygen dynamics is hampered by insufficient information about diel respiration patterns. To collect the missing information, a respirometer has been developed for use in aquaculture ponds. Field tests showed that respiration rates change substantially over diel periods, with the highest rates occurring in late afternoon. Model development for stratified ponds focused on water temperature behavior. A computer model using stochastic inputs of solar radiation, wind direction, and wind speed has been developed. Simulations carried out for Thailand ponds showed that surface temperatures exhibited the largest temperature fluctuations in response to stochastic inputs.

Central Data Base

A Central Data Base continues to be maintained by the CRSP for the storage and retrieval of standardized records from the research sites. At the individual sites, data on physical variables (e.g., solar radiation, temperature, and rainfall) and chemical variables (e.g., water and soil chemical characteristics) are collected concurrently with biological measurements (e.g., primary productivity, fish growth, and fish production). Whereas the resulting sets of data are useful for site-specific studies, the compilation of all the individual data sets into the Central Data Base provides opportunities for many kinds of global analyses. Detailed standardized records such as those found in the CRSP Central Data Base are rare in the aquaculture literature. All data from research activities conducted under the First through Fourth Work Plans are already in the Central Data Base, which has continued to expand through the inclusion of new data generated under the Fifth and Sixth Work Plans.

In response to a decision reached by the Management Entity and Board of Directors, with input from the Technical Committee, Central Data Base functions were transferred from the Program Management Office to the University of Hawaii at Hilo in May, 1993. As the quantity of data generated by CRSP research has increased, so have the storage requirements. Consequently, during this reporting period, the database has been consolidated and storage requirements have been reduced by approximately 50%. In order to increase speed, utility, and user-friendliness of the database, a new program, Foxpro™, has been implemented. An additional advantage of Foxpro™ is its ability to work with different platforms. A menu-driven interface for Macintosh and IBM-type computers is being developed. This allows the distribution of the entire database as a self-contained unit.

This new feature will greatly increase the utility of the Central Data Base to researchers outside those directly involved with the PD/A CRSP. The Central Data Base was designed to facilitate communications with other large data bases, such as the Tropsoils CRSP data base and ICLARM's FISHBASE, thereby creating opportunities for collaboration. Efforts continue to integrate the CRSP Central Data Base with ICLARM's FISHBASE. The Central Data Base can also serve as a storage and retrieval center for

standardized data from any research site. CRSP scientists as well as scientists in the aquaculture community at large may contribute to and access the data base. Data are available on computer diskettes or in print as Pond Dynamics/Aquaculture Collaborative Research Data Reports.

III. CRSP Research Program Background

At its inception, the Pond Dynamics/Aquaculture CRSP had a single, main theme-that of a common set of experiments to be implemented globally, following a standard experimental protocol. The Global Experiment, as it came to be called, was intended to facilitate comparative studies of aquaculture pond dynamics; such studies would help us begin to understand how and why ponds at different geographic locations function differently, and how the management of aquaculture ponds might be fine-tuned or adapted to different sets of environmental conditions to optimize production.

As CRSP research progressed, it became apparent that there were important additional needs to be addressed. To meet these additional needs, research components were added, so that in the past few years the main core of the program has included three components:

- The Global Experiment,
- Special Topics Research in Host Countries, and
- Data Analysis and Synthesis.

This main core of CRSP activities has been augmented by supplemental activities that are associated with the main components and complement them in unique ways. These supplemental activities have included socioeconomic studies, soil-water interactions research, the development of simple new techniques for the evaluation of pond conditions, and studies to develop improved techniques for fish reproduction.

The CRSP Research Program

The long-range goal of the CRSP is to increase the efficiency of pond culture systems. This goal has the benefits not only of increasing the availability of animal protein in less-developed countries, but also of improving the economic efficiency of aquacultural production in any country, including the U.S. A technical plan consistent with this goal was developed under a planning study funded by USAID in 1981. Under this planning study, the literature on state-of-the-art pond culture was reviewed and synthesized, resulting in the publication of the first edition of Principles and Practices of Pond Aquaculture, and overseas sites were surveyed to determine research needs and the potential for the establishment of research projects.

The technical work plan that evolved from the planning study involved the establishment of research projects at seven sites in six countries. Two brackish water and five freshwater research projects were begun at sites in Central America (Panama and Honduras), Africa (Rwanda), and Southeast Asia (Thailand, Indonesia, and the Philippines) in 1983. All of the sites were within a zone 15 degrees north or south of the equator and represented the three major tropical regions where advances in pond aquaculture would be most beneficial and most apt to succeed. Although subsequent changes (primarily in response to

funding constraints) in the CRSP program required that research be continued only at the sites in Thailand, Rwanda, and Honduras, those three major regions have continued to be represented. Since 1991 the CRSP program has been expanded by the initiation of a sub-project in the Philippines and the beginning of a completely new project in Egypt. The research conducted in Egypt greatly increased the scope of the program by adding an arid site to the program, which had previously included sites only in relatively humid areas. In 1993, research in brackish water environments was resumed with the addition of a coastal site in Honduras.

CRSP Work Plans

A Technical Committee has had the responsibility for developing technical work plans throughout the CRSPs history. The first three CRSP Work Plans, outlining annual research programs that were almost exclusively global in nature, covered activities from 1 September 1984 through 31 August 1987. The First Work Plan specified a standard procedure for the preparation and stocking of ponds, and the concept of a standard protocol for research at all sites has been maintained throughout the program. These standards have evolved into the CRSP's Handbook of Analytical Methods, which was completed and distributed to participants in 1992.

In response to the recommendations of the External Evaluation Panel during the first triennial review, work plans beginning with the Fourth Work Plan have been developed on a biennial basis to allow more time for the completion and evaluation of experiments before planning new ones. This change in the planning procedure is the logical outcome of the need to test hypotheses that develop directly from the results of previous CRSP experiments. Another significant change that began with the Fourth Work Plan is that site-specific studies have also been included. Although the global aspects of CRSP research are maintained by conducting similar experiments (referred to as the Global Experiment) at the various sites and by conducting these experiments in a standardized manner, other experiments are adjusted to more directly address the needs of aquaculture producers in the country or region in which the research is taking place.

The Fourth, Fifth, and Sixth Work Plans covered research conducted in two-year periods from 1987 through 1994. This reporting period constitutes the first year of activities conducted under the Seventh Work Plan, but it also includes some activities conducted under the Sixth Work Plan. During this reporting period, the Continuation Plan for the PD/A CRSP was the focus of efforts by the Technical Committee and the Management Office.

A. Global Experiment and Related Investigations

Validation of PD/A CRSP Pond Management Strategies

Work Plan 7, Egypt Study 1A

Bartholomew W. Green

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Zeinab El Nagdy and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

The objectives of this research were to quantify tilapia yields for established Pond Dynamics/Aquaculture Collaborative Research Support Program pond nutrient input strategies under climatic, edaphic, and water quality conditions found in Egypt and to compare these results to those obtained using traditional Egyptian management practices. Five treatments, each replicated four times, were tested in 0.1-ha earthen ponds. Treatments tested were: *Traditional Egyptian*, *Enhanced Egyptian*, *Feed Only*, *Fertilization then Feed*, and *Chemical Fertilization*. Ponds were stocked with 20,000 *Oreochromis niloticus*/ha; mixed-sex fish were stocked in Egyptian treatments and sex-reversed fish in all others. Experiment duration was 145 days. Nile tilapia gross yield differed significantly among treatments and ranged from 1,278 kg/ha (chemical fertilizer treatment) to 2,877 kg/ha (fertilization then feed treatment). Wild tilapia (*O. aureus*, *S. galilae*, *T. zilli*) invaded all ponds and contributed 81 to 686 kg/ha to total tilapia yield treatment means. Thus, total tilapia yield ranged from 1,407 to 3,537 kg/ha and represented from 78% to 96% of gross fish yield. Gross fish yields ranged from 1,526 to 4,074 kg/ha. Tilapia yields in the *Traditional Egyptian* and *Fertilizer then Feed* treatments was significantly greater than in the *Chemical Fertilizer* treatment. Tilapia are marketed in Egypt by size class as follows: 1st class - 1 to 5 fish/kg; 2nd class - 6 to 12 fish/kg; 3rd class - 13 to 25 fish/kg; and, 4th class - 26 to 40 fish/kg. Farm-gate price varies from LE. 7.85/kg 1st class tilapia to LE 1.75/kg 4th class tilapia. Greater yields of 1st and 2nd class tilapia were obtained where organic fertilization was used in combination with formulated feeds than where chemical fertilization alone or formulated feed alone were used. Results indicated that ponds stocked with young-of-year monosex tilapia and managed according to the tested systems were feasible in Egypt.

Yield Characteristics of Two Species of Tilapia under Two Different Pond Environments

Work Plan 7, Egypt Study 1B

Bartholomew W. Green

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Zeinab El Nagdy and Abdel R.E. Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

PD/A CRSP research designs have been based on use of Nile tilapia (*Oreochromis niloticus*) as the test species because this species was common to all research sites. In Egypt, Nile and blue (*O. aureus*) tilapia, both good culture species, are endemic. The objective of this experiment was to compare production characteristics and production economics of *O. niloticus* and *O. aureus* reared in ponds managed under two different nutrient input regimes. Eighteen 0.1-ha ponds at the Central Laboratory for Aquaculture Research, Abbassa, Abou Hammad, Sharkia, Egypt, were used for this study using a completely randomized design in 3 x 2 factorial arrangement, where factors were tilapia species (Nile, blue, or co-stocked) and pond nutrient input regime (chemical fertilization or fertilization then feed). Weekly applications of nitrogen at 25 kg/ha and phosphorus to maintain an N:P ratio of 4:1 were made in the *Chemical Fertilizer* treatment. In the *Fertilizer then Feed* treatment, chicken litter was applied weekly at 1,000 kg dry matter/ha for the first eight weeks followed by feed (25% protein commercial fish feed) only. Ponds were stocked with sex-reversed tilapia fingerlings on 1 July 1994 at a stocking rate of 20,000 fingerlings/ha. Ponds are scheduled to be harvested after completion of 150 days of grow-out. Based on seine samples and estimated fish biomass, and assuming 20,000 fish/ha, the average mean individual fish weight after 83 days of growth was calculated. The highest estimated biomass and average weight were obtained in the *Fertilizer then Feed* treatment for *O. niloticus* 3,027 kg/ha and 151.4 g/fish, respectively. The co-stocked *Chemical Fertilizer* treatment resulted in the lowest average weight/fish (70.8) and in the lowest estimated biomass (1,415 kg/ha).

Nutrient Input Management by the Computer Program, PONDCLASS, and by Concentration of a Key Nutrient

Work Plan 7, Honduras Study 4A

David R. Teichert-Coddington

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Herbert Ramos

National Fish Culture Research Center

El Carao, Comayagua, Honduras

Abstract

Three simultaneous experiments were carried out to verify the pond management software PONDCLASS, to regulate pond fertilization by total ammonia concentration, and to evaluate the effect of raising the fish stocking rate from 2 to 3/m^2. The control was equal in all studies; ponds were fertilized weekly with chicken litter at 250 kg dry matter/ha, urea to maintain weekly total nitrogen input at 28 kg/ha, and diammonium phosphate to supply 7 kg/ha total phosphorus input. Mean fish weight and production of the control treatment were 15% and 28% greater, respectively, than PONDCLASS means. Excessive nitrogen fertilization was recommended by PONDCLASS. Fish production was thought to be limited by primary productivity, which in turn was limited by carbon. The effectiveness of fertilizer input regulation by total ammonia was inconclusive because of poor treatment management. Increasing the tilapia stocking rate from 2 to 3/m^2 had no significant affect on fish production or water quality. The mean average fish weight of the control treatment was 41% greater than the mean average weight of fish from the higher density treatment.

Management of Carbon Dioxide Balance for Stability of Total Alkalinity and Phytoplankton Stocks in Fertilized Fish Ponds

Work Plan 7, Thailand Study 6

James P. Szyper

Hawaii Institute of Marine Biology

University of Hawaii at Manoa

Kaneohe, Hawaii, USA

Kevin D. Hopkins

College of Agriculture

University of Hawaii at Hilo

Hilo, Hawaii, USA

Abstract

Stability of phytoplankton stocks and photosynthetic activity is important to successful pond culture. Large phytoplankton stocks in fertilized ponds can be unstable, and low total alkalinity (TA) can limit photosynthesis in ponds and contribute to instability. It is important to understand management of TA because it can change substantially during growth cycles in ponds, even when soils are conditioned. This

experiment documented temporal trends of TA in 15 ponds, and quantified the effect of interim additions of soluble carbonate. For the CRSP Global Experiment, one of the five triplicated treatments consisted of inputs management using the PONDCLASS decision-support system software; another treatment consisted of regular inputs according to the specified control protocol of Work Plan 7.

The results of this experiment are currently undergoing analysis; results discussed here are preliminary. The five treatments produced no significant differences in final mean individual fish weights, survival, or net yields ($P > 0.05$, Single-factor ANOVA). Neither were there significant treatment differences in mean concentrations of chlorophyll *a* or daytime net primary production.

Management according to PONDCLASS produced yields with (numerically) greater efficiency than did treatments involving regular weekly fertilizer inputs in constant amounts, because similar yields were produced with less input. The net yields for all ponds, extrapolated to units of t/ha/y, ranged from 3.3 to 6.5. These are approximately double yields previously obtained at this site in the same season (wet) during earlier experiments, but are substantially less than yields obtained with these methods at a nearby site.

It is likely that rainfall affected the attempt to examine effects of soluble carbonate inputs. During the first 50 days, when no rain fell, alkalinity tended to decline during sampling intervals in all ponds, although concentrations were effectively stabilized in ponds receiving carbonate additions. After the first 50-day period the wet season began, and alkalinity showed little decline in ponds of any treatment. Daytime net primary production ranged (pond-by-pond) from -0.1 to 19.4 mg O_2 l/d, with a mean of 7.0 for the experiment, equivalent to 2.0 g C/m/d. Higher values have been observed on this site, particularly during seasons without rain and/or cloud cover.

If completed analyses show that addition of soluble carbonate is effective in stabilizing TA, such inputs can readily be incorporated into the PONDCLASS and POND software systems and into transferred CRSP protocols. This will effectively eliminate the potential for decreasing alkalinity due to photosynthetically-mediated pH dynamics during production cycles in ponds, leading to more stable blooms and production rates, and thus to more reliable fish production protocols.

B. Global Studies and Activities

Minding the Pond: Feeding, Fertilization, and Stocking Practices for Tilapia Production in Rwanda, Thailand, The Philippines and Honduras

Joseph J. Molnar, Terry R. Hanson, and Leonard L. Lovshin

Alabama Agricultural Experiment Station

International Center for Aquaculture

Auburn University, Alabama, USA

Abstract

This report provides basic descriptive information concerning the way aquaculture is practiced in four CRSP countries. It focuses on four central aspects of tilapia culture; pond management, feeding, fertilization, and stocking practices. Data were collected from tilapia growers: 121 active Rwanda fish farmers in eight local administrative districts (communes) during the winter and early spring of 1992; 51 active Honduran fish farmers in five of 15 Honduran departments during the fall 1993; 51 active Thai fish farmers in four of 75 Thai provinces during winter 1994; 56 Philippine fish farmers in four of 15 provinces on the main island of Luzon during winter 1994. In each country, the survey instrument was revised and adapted, then translated into the national language. More than 80 percent of the Rwandan farmers had but a single pond. In contrast, more than 70 percent of the Philippine and Honduran farmers had more than one pond. Most Honduran farmers had more that a hectare of ponds. More than half the Thai sample reported problems getting enough water to keep ponds full. A third of the Philippine farmers said so, as did a quarter of the Rwandans. Farmers in the four countries fed their tilapia a variety of different items reflecting differences in the intensity of aquaculture practice in each nation. Commercial feed was not used in Rwanda; two-thirds of the Hondurans did not use commercial feed; and about half the Philippine respondents did not use commercial feed. Thai farmers were most dependent on commercial inputs to raise their tilapia crops. They also used the most diverse variety of feeds, reflecting the high level of availability of different feed types and a greater willingness to use feeds for other animals for the fish as well. Honduran and Rwandan farmers were most likely to report inadequacies in feed availability on their farms. About seven percent of the Rwandan farmers said that they never had enough. Cattle and goats were most often reported in Rwanda, pigs in Honduras, and chickens in the Philippines, and ducks were more frequent on Thai farms. Given the pervasive use of integrated systems in Thailand, ponds are most frequently fertilized by animal manure in that country. Thai farmers also are more likely to apply lime to improve the alkaline balance of the pond and foster primary productivity. Rwandan farmers indicated the most passive approach to fish farming - about half said they visited every day. Philippine farmers spent the most time with their ponds when they visited them; Thai farmers the least. Fingerling availability was a problem for 30 percent of the Philippine respondents, less than 25 percent in Rwanda and Honduras, and a concern for only 4 percent in Thailand. Most farmers are growing but single crop of tilapia each year in Rwanda and Thailand. In Honduras, almost half reported two or more crops, but in the Philippines two-thirds obtained two crops per year. The data emanating from this study present a comparative perspective on tilapia culture in four CRSP countries. The similarities and differences suggest different patterns of technology utilization and need in each setting. The benefits of these understandings should help shape research directions and enhance the development impacts of CRSP technologies.

POND: A Decision Support System for Pond Aquaculture

John P. Bolte, Shree S. Nath, and Doug E. Ernst

Department of Bioresource Engineering

Oregon State University

Corvallis, Oregon, USA

Abstract

Decision support systems are a useful mechanism for synthesizing qualitative and quantitative knowledge into analysis tools that can easily be used by a diverse audience. A user-friendly decision support system (POND) which can be used to guide decision-making processes relevant to pond aquaculture management and planning has been developed. POND uses a combination of expertise, an economics package, and simulation models for analyzing pond aquaculture systems, either at the level of an individual pond or for an overall facility. This functionality is accomplished by the use of an object-oriented paradigm which enables the definition of objects responsible for certain tasks analogous to entities or experts in a real pond aquaculture facility (e.g., a fish culturist) responsible for monitoring fish growth). The economics package can be used to generate enterprise budgets, which account for fixed and variable costs, depreciation, interest, and income items. Users can examine various pond management strategies and generate enterprise budgets to assess the economic viability of such strategies.POND includes simulation models to describe the dynamics of fish growth, water temperature, carbon, nitrogen and phosphorus, phytoplankton, and zooplankton. These models are organized hierarchically into two levels to provide users with the capability of performing different kinds of analyses based on data availability and output resolution needs. The fish growth model accounts for the effects of fish weight, food availability, photoperiod, temperature, and dissolved oxygen and unionized ammonia concentrations, and has been calibrated for Nile tilapia. This model has been used to simulate PD/A CRSP experiments at different sites with favorable results. Simulation models that are used in POND to describe other state variables are briefly discussed.

C. Africa

Binding Sites for the Masculinizing Steroid Mibolerone in the Gonadal Tissue of Adult Nile Tilapia *(Oreochromis niloticus)*

Work Plan 7, Egypt Study 4C1

William L. Gale, Martin S. Fitzpatrick, and Carl B. Schreck

Oregon Cooperative Fisheries Research Unit

Department of Fisheries and Wildlife

Oregon State University

Corvallis, Oregon, USA

Abstract

A binding site in the gonadal tissue of adult Nile tilapia (*Oreochromis niloticus*) was characterized using the synthetic androgen mibolerone (17-hydroxy-7,17-dimethylestr-4-en-3-one). The binding site demonstrated high affinity (K*d* = 1.03 +/- 0.11 nM ; n=2) and low capacity (*Bmax* = 5.65 +/- 0.42 fmol/mg protein; n=2) for mibolerone binding. Furthermore, it was located in gonadal cytosol only. The binding site also demonstrated ligand specificity. Only steroids with sex inverting capabilities displaced tritiated mibolerone binding. The receptor assay developed for tilapia may represent an important tool for the screening of newly developed sex inversion agents.

Effects of Form of Defatted Rice Bran Offered on Nile Tilapia Production in Ponds

Peter W. Perschbacher and Rebecca Lochmann

Department of Agriculture

University of Arkansas

Pine Bluff, Arkansas, USA

Abstract

Mixed-sex Nile tilapia were stocked into each of six 0.04-ha earthen ponds at 2.3 fish/m^2. Ponds were fertilized as necessary to maintain concentrations of chlorophyll *a* at approximately 100 mg/m^3 and fish were fed defatted rice bran at 2% body weight per day, divided into two feedings. In half of the ponds fish were fed defatted rice bran as a loose product and in the remaining ponds fish were fed a pelleted form. Advanced largemouth bass fry were also stocked into all ponds at 0.15 fish/m^2 to reduce tilapia reproduction. After 169 days ponds were drained and fish harvested. Net yields of stocked tilapia and reproduction were not significantly different between treatments and averaged 6128 kg/ha and 6316 kg/ha on an annual basis in pellet and loose fed treatments, respectively. Stocked fish averaged 100 and 90 g, respectively. Stocked fish yield was 13% higher in pellet-fed ponds. Maximum feeding was 45 kg/ha/d. Bass yield averaged 159 and 136 kg/ha in loose and pellet-fed ponds, respectively, and the average sizes were 236 g and 198 g. Chlorophyll *a* averaged 87.5 and 115 mg/m^3 in loose and pellet-fed treatments, respectively. Fertilizer applications required were signifcantly different and averaged 15.3 and 23.0, respectively. Defatted rice bran appears to be a good and economic supplemental food source. Pellets have advantages over loose form in ease of handling. Pellets also reduced the number of fertilizer applications needed to maintain pond fertility, and it apparently promoted increased yields of large fish.

Effect of 17a-Methyltestosterone on the Growth of Two Tilapia Species, *Oreochromis aureus* and *Oreochromis mossambicus*, in Fresh Water

Work Plan 7, Egypt Study 4B1

N. Harold Richman III and E. Gordon Grau

Hawaii Institute of Marine Biology

University of Hawaii at Manoa

Kaneohe, Hawaii, USA

Abstract

We examined the effect of 17a-methyltestosterone (MT) on the growth of two tilapia species, *Oreochromis aureus* and *Oreochromis mossambicus*, reared in fresh water. The growth rate of *O. aureus* was nearly twice that of *O. mossambicus* at each dose level (0, 1, 10, and 25 mg of MT/kg of feed). With the exception of *O. aureus* treated with 1 mg of MT/kg of feed, MT treatment significantly increased ($p < 0.01$) growth in both species over control animals. In *O. mossambicus*, growth performance increased with increased levels of MT. By contrast, the 10 and 25 mg of MT/kg of feed treatments stimulated growth equally in *O. aureus*. The gonadosomatic index (GSI) was not significantly different between treatments within each species. It was, however, significantly lower ($p<0.0001$) in *O. aureus* than in *O. mossambicus*. Gonadal weights were not significantly different between species which suggests that the smaller GSI in *O. aureus* results, at least in part, from the larger somatic mass of the animals. In both species, the hepatosomatic index (HSI) and absolute liver weight tended to increase with increased levels of MT and were significantly greater ($p< 0.05$; $p < 0.01$) in the 25 mg of MT/kg of feed treatment groups than in controls. The male-to-female sex ratio was not significantly different from 1:1 in any treatment group in either species. Analyses of residual MT levels in the serum and muscle samples are ongoing.

Use of 17a-Methyltestosterone for Tilapia Sex Reversal

Work Plan 7, Egypt Study 4A2

Bartholomew W. Green

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Esam H. Rizkalla and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

The U.S. Food and Drug Administration granted a compassionate Investigational New Animal Drug (INAD) exemption to Auburn University, the American Tilapia Association, and a commercial feed producer to collect data to support a New Animal Drug Application for the use of 17a-methyltestosterone (MT) for sex reversal of newly-hatched tilapia. Implementation of a clinical field trial at research institutions and commercial tilapia production facilities throughout the United States and overseas was one activity contemplated under this INAD exemption. U.S. and Egyptian researchers involved with the Pond Dynamics/Aquaculture Collaborative Research Support Program participated in the field trial. The first trial was initiated on 10 to 12 July 1994 when Nile (*Oreochromis niloticus*) and blue (*O. aureus*) tilapia fry were stocked into treatment hapas. A second trial was initiated on 18 to 20 September 1994. Fry availability allowed for stocking of two hapas each for control and MT treatment per species. Fish in Trial I completed treatment on 8 to 11 August; sub-samples of control and treated fry were restocked into hapas for nursery growth. Trial II was in progress, with an expected treatment completion date of 16 to 18 October 1994. Upon completion of the Trial I treatment period, Nile tilapia averaged 0.67 and 0.60 g/fry and 32.0 and 31.3 mm/fry total length for the control and MT treatments, respectively. The mean final individual weight and length for blue tilapia were 0.36 and 0.34 g/fry, and 25.9 and 27.5 mm/fry for the control and MT treatments, respectively. Fry survival for the control and MT treatments averaged 66 and 84%, and 96 and 91% for Nile and blue tilapia, respectively.

Progeny Testing to Identify "YY" Male Tilapia

Ronald P. Phelps

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Abstract

Males from nine populations possibly containing males of a "YY" genotype were mated with normal females. The sex ratios of the offspring of 4 of the 49 matings examined in FY 94 suggest that four YY males were identified. Two males which produced > 95% male progeny in the first mating did not consistently produce high frequencies of males in later spawns. These results suggest that sex inheritance is not strictly a male-determined characteristic and increases the difficulty of breeding a form of *Oreochromis niloticus* that will consistently produce all-male progeny.

Bioconversion of Gastropods by Black Carp in Egyptian Fish Culture Ponds

Work Plan 7, Study 2B

William L. Shelton

Zoology Department

University of Oklahoma

Norman, Oklahoma, USA

Kevin D. Hopkins

College of Agriculture

University of Hawaii at Hilo

Hilo, Hawaii, USA

Ashraf Soliman and Abdel L. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

Bioconversion research focuses on the transformation of an underutilized resource into fish flesh, while simultaneously resolving or reducing a management problem. Snails are abundant in Egyptian aquatic systems; several species are also significantly related to human health problems. An experiment was conducted to evaluate the use of black carp (*Mylopharyngodon piceus*) as a biological control of snails. Ponds were prepared by hand cutting aquatic plants to near the soil surface in March/April. Supply problems delayed stocking which commenced in June. All ponds were contaminated with wild (unstocked) fish which is believed to have influenced the growth rate of black carp. Black carp grew least in ponds that were contaminated by common carp and mullet. Data analysis continues.

Bioconversion of Nuisance Aquatic Plants by Grass Carp in Egyptian Fish Culture Ponds

Work Plan 7, Study 2A

William L. Shelton

Zoology Department

University of Oklahoma

Norman, Oklahoma, USA

Kevin D. Hopkins

College of Agriculture

University of Hawaii at Hilo

Hilo, Hawaii, USA

Abdel R. Mostafa and Abdel L. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

Aquatic weeds are a management problem in Egyptian aquaculture. They also represent an underutilized resource. Grass carp, *Ctenopharyngodon idella,* is known to feed on several aquatic plants. An experiment was carried out to determine if grass carp could be used as a biological control of nuisance weeds in Egyptian pond aquaculture. Ponds were prepared in March/April. Macrophytes, primarily Typha and/or Phragmites were hand cut to near the soil surface. Ponds were refilled and the area of plant development was estimated visually by predominant species. Supply problems necessitated a delay of grass carp stocking, so that some plant regrowth had occurred. Initial data indicate that grass carp were effective in maintaining ponds virtually free of emergent vegetative regrowth. However, because of the delayed stocking grass carp were not able to completely control *Azolla and Certophyllum*. In several ponds these plants were able to develop and reach greater than 40% coverage.

Interaction of Grass Carp and Black Carp in Egyptian Fish Culture

Work Plan 7, Egypt Study 2C1

William L. Shelton

Zoology Department

University of Oklahoma

Norman, Oklahoma, USA

Kevin D. Hopkins

College of Agriculturev

University of Hawaii at Hilo

Hilo, Hawaii, USA

Ashraf Soliman and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

Bioconversion of plants by grass carp and of snails by black carp can be considered as separate components in a polyculture system, but they are also interrelated because the plants provide food an cover to snails and thus affect black carp predation. Gastropod production might diminish by virtue of grass carp feeding on plants, but is unclear to what extent the predation of black carp on snails is influenced by grass carp feeding. Abundant vegetation could provide protection for snails, so that their biomass might increase in the presence of black carp rather than being suppressed by predation. A study was conducted to investigate these relationships. Data are being analyzed.

D. Central America

Estuarine Water Quality and Sustainable Shrimp Culture in Honduras

Work Plan 7, Honduras Study 1

David R. Teichert-Coddington

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Abstract

Water quality was monitored weekly for more than a year at 13 sites in six shrimp-producing estuaries of Honduras bordering the Gulf of Fonseca. Water quality differences were noted among estuaries, along longitudinal transects of estuaries, and between rainy and dry seasons of the year. Estuaries influenced by rivers (riverine) were more fertile and had less capacity to assimilate greater waste loads than those not influenced by rivers. The Choluteca River discharged greater quantities of nitrogen and phosphorus to the Gulf than did the 11,000 ha of shrimp ponds currently under cultivation. Eutrophication of riverine estuaries increased with distance from the Gulf because of reduced water exchange with the Gulf. Eutrophication in riverine estuaries was greater during the dry season when freshwater inflow diminished. No seasonal differences were seen for gulf embayments. The shrimp industry could take immediate steps to constrain estuarine pollution and promote management techniques that reduce waste load discharge to estuaries. Inaction will probably result in production losses similar to other shrimp producing areas of the world.

Prepared as an invited paper for Special Session on Shrimp Culture, WAS '95, San Diego, California.

Varying the Proportion of *Colossoma macropomum* and *Oreochromis niloticus* in Polyculture

Work Plan 7, Honduras Study 4B

David R. Teichert-Coddington

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Herbert Ramos and Nelson Claros

National Fish Culture Research Center

El Carao, Comayagua, Honduras

Abstract

Tilapia (*Oreochromis niloticus*) and tambaquí (*Colossoma macropomum*) were co-stocked in tropical earthen ponds at proportions of 0, 25, 75, and 100% of each species. Fish were offered a 28% protein pellet. Total density was 3 fish/m^2. After 182 d, mean treatment production ranged from 2478 to 5120

kg/ha. Total production increased and feed efficiency decreased curvilinearly as the percentage of stocked tilapia increased. Feed efficiency ranged from 1.15 to 2.78. Total nitrogen and chlorophyll *a* decreased linearly as percentage of stocked tilapia increased, because of grazing by tilapia on phytoplankton. Mean tilapia and tambaquí weight ranged from 187 to 325 g and from 122 to 270 g, respectively. Tilapia mean weight decreased curvilinearly, and tambaquí mean weight increased linearly as the percentage of stocked tilapia increased. Tambaquí growth was thought to be hindered by relatively cool water temperatures. The best species mixture was 75% tilapia and 25% tambaquí.

Inorganic Fertilization and Feed Reduction in Commercial Production of *Penaeus vannamei* during Wet and Dry Seasons in Honduras

Work Plan 7, Honduras Study 3A

David Teichert-Coddington

Department of Fisheries and Allied Aquacultures,

Auburn University, Alabama, USA

Rigoberto Rodriguez

Granjas Marinas de Sn. Bernardo

Choluteca, Choluteca, Honduras

Abstract

Feed was offered to *Penaeus vannamei* at a standard rate, half the standard rate, half the standard rate in addition to inorganic fertilization, and inorganic fertilization for 8 weeks followed by the standard rate of feed. Shrimp were stocked at 7.5 fish/m^2 in earthen ponds. The study was repeated during wet and dry seasons. Yield, survival and mean shrimp size were 294%, 36%, and 177% greater during the wet than dry season. Mean wet season yield for the 1/2-ration and fertilizer treatment was significantly greater than the 1/2-ration treatment. Otherwise, there were no significant treatment differences in yield. Feed conversion was significantly lower in the normal-ration treatment than in the other treatments. Fertilization had no effect on shrimp production during the dry season despite increasing primary productivity. The standard feeding rate could be reduced by 50% during the dry season without reducing shrimp yields.

E. Southeast Asia

Timing of Supplemental Feeding for Tilapia Production

Work Plan 6, Thailand Study 7

James S. Diana

School of Natural Resources and Environment

University of Michigan

Ann Arbor, Michigan, USA

C. Kwei Lin and Yang Yi

Agricultural and Food Engineering Program

Asian Institute of Technology

Bangkok, Thailand

Abstract

The effect of timing of feed application on fish growth and yield was evaluated for Nile tilapia. Fish were stocked into 15 ponds on 15 January 1993 at 3 fish m^{-2}, and the ponds were grouped into 5 treatments. Each treatment differed by the average size that fish achieved before supplemental feeding began, with treatments at 50 g, 100 g, 150 g, 200 g, and 250 g. Fish were fed at satiation rates until they reached 500 g in average weight. All treatments showed a similar growth rate prior to feeding and a similar rate after feeding, regardless of when feeding was initiated. First supplemental feeding varied from 38-234 days after stocking, and harvest occurred after 236-328 total days of culture or 94-198 days of feeding. Yield varied from 10,420 to 28,178 kg ha^{-1} yr^{-1}. Fish growth (g d^{-1}) was correlated to days of culture, feed input, and chlorophyll *a* content ($R^2 = 0.889$, $p < 0.001$).

Stocking Density and Supplemental Feeding in Tropical Fish Ponds

Work Plan 6, Thailand Study 6

James S. Diana

School of Natural Resources and Environment

University of Michigan

Ann Arbor, Michigan, USA

C. Kwei Lin and Yang Yi

Agricultural and Food Engineering Program

Asian Institute of Technology

Bangkok, Thailand

Abstract

The relationship between density, complete feeding, and carrying capacity was examined for Nile tilapia. Nine ponds were subdivided into three treatments and stocked with fish on 11 November 1993. Treatments included fish stocked at 3, 4.5, or 6 per m^2. Fish were fed to satiation daily. Water chemistry and other parameters were monitored biweekly. Ponds were harvested on 15 July 1994 (242 days). Unfortunately, some ponds had few fish remaining at harvest, probably as a result of poaching. Growth rates were similar among treatments, and ponds with high biomass had no indication of limited water quality. Ponds also showed no evidence of having reached carrying capacity. Due to poaching problems this experiment will be redone with a higher stocking density.

Supplemental Feeding of Tilapia in Fertilized Ponds

James S. Diana

School of Natural Resources and Environment

University of Michigan

Ann Arbor, Michigan, USA

C. Kwei Lin

Agricultural and Food Engineering Program

Asian Institute of Technology

Bangkok, Thailand

Kitjar Jaiyen

Department of Fisheries

Ministry of Agriculture and Cooperatives

Kasetsart University Campus

Bangken, Bangkok, Thailand

Abstract

(Printed as submitted)

The addition of feed to fertilized fish ponds was evaluated by adding feed alone, feed plus fertilizer, or fertilizer alone to nine ponds stocked with Nile tilapia *Oreochromis niloticus*. Two experiments were conducted. The first had 500 fish per 250 m^2 pond in 3-treatments: ad-libitum feeding; fertilizer only; or fertilizer and ad-libitum feeding. The second experiment had 5 treatments with 750 fish per pond: ad-libitum feed only; fertilizer only; or 0.25, 0.50, and 0.75 satiation ration plus fertilizer. Ponds in Thailand were maintained for 155-162 d, during which chemical and physical properties were monitored. In experiment 1 tilapia growth was highest in feed only ponds, and lowest in fertilizer only ponds. Net yield did not differ significantly among treatments, due to variation in survival. In experiment 2, tilapia growth was lowest in fertilizer only ponds, intermediate in 0.25 ration ponds, and highest in 0.50, 0.75, and ad-libitum ponds. The latter treatments were not significantly different. Multiple regressions for each experiment indicated only 47-87% of the variance in growth was explained by feed and fertilizer input, while 52-89% of the variance in yield was explained by those factors. For both experiments combined, 90.3% of the variance in growth was explained by feed input, fertilizer input, alkalinity, and total inorganic nitrogen concentration. For yield, R^2 was 0.888 and the regression included feed input, pH, and number of low dissolved oxygen events. Experiment 1 appeared to approach carrying capacity near the end, while no reduction in growth occurred in experiment 2 at higher fish density and biomass. Reductions in growth in experiment 1 were not correlated with declining water quality late in the grow out. Combinations of feed and fertilizer were most efficient in growing tilapia to large size (500 g) compared to complete feeding or fertilizing alone.

Appeared in Journal of the World Aquaculture Society 25(4).

F.United States

Respiration Dynamics in Aquaculture Ponds

Work Plan 7, DAST Study 1

Philip Giovannini and Raul H. Piedrahita

Department of Biological and Agricultural Engineering

University of California, Davis

Davis, California, USA

Abstract

A respirometer has been developed for use in aquaculture ponds. The respirometer is designed to measure oxygen consumption rates in water samples that have been suddenly darkened. Rates of oxygen consumption are measured over 15 minute periods, and the process is repeated at 20 minute intervals, allowing for a 5 minute respirometer flushing and sample pumping period. The respirometer is connected to a data acquisition system and to a computer for automated data collection and analysis. Some results of tests carried out with the respirometer both in the laboratory and in the field are presented. The results show substantial changes in respiration rates over diel periods, with the highest rates occurring in the late afternoon. Rates decline rapidly after sunset and remain at much lower levels than during daylight hours. Limitations of the respirometer design are discussed, especially problems associated with fouling.

Stochastic Modeling of Temperature in Stratified Aquaculture Ponds

Work Plan 7, DAST Study 2

Cristiano dos Santos Neto and Raul H. Piedrahita

Department of Biological and Agricultural Engineering

University of California, Davis

Davis, California, USA

Abstract

A computer model for temperature simulations in stratified aquaculture ponds has been run with stochastic inputs. Stochastic inputs used are solar radiation, wind direction, and wind speed. Values for the stochastic inputs were obtained from synthetically generated series based on historical records obtained from the CRSP data base. The techniques used for obtaining the stochastic input values are described, as are the results of simulations carried out for Thailand ponds. Surface temperatures showed the largest fluctuations as a result of stochastic changes in the input parameters.

Calculation of pH in Fresh and Sea Water Aquaculture Systems

Raul H. Piedrahita

Department of Biological and Agricultural Engineering

University of California, Davis

Davis, California, USA

Aina Seland

SINTEF Norwegian Hydrotechnical Laboratory

Trondheim, Norway

Abstract

(Printed as submitted)

A procedure for the calculation of pH in fresh and salt waters has been developed. The method is based on a fourth-order polynomial relationship between hydrogen ion concentration and other (conservative) water quality parameters. The method avoids trial and error estimations and results in a direct calculation procedure that can be implemented in models developed in various modeling environments, such as spreadsheets, conventional programming languages (BASIC, C, FORTRAN, PASCAL, etc.), or specialized modeling languages (Extend(TM), Stella(TM)). The method developed is based on the solution of the full alkalinity-pH equation. Because of the need to simplify the equations to yield explicitly solvable polynomial equations, the accuracy of the solutions depends on the simplification made and varies with water properties. Three simplifications are tested based on a second-, a third-, and a fourth-order polynomial equation for hydrogen ion concentrations. The equations have been tested for salinities ranging from 0 to 35‰ (fresh to sea water), for temperatures ranging from 0 to 35°C, for total carbonate carbon of 0.1 and 5.0 mmol/l, and for total ammonia nitrogen of 0 and 10 mg/l. Approximations are most accurate in waters of high total carbonate carbon and low ammonia concentrations, where the fourth-order approximation yields results that are within 0.05 pH units for the full range of pH values tested (5 to 10).

Accepted for publication by Aquacultural Engineering.

G. Special Topics Research

Economic Analysis of Different Tilapia Pond Culture Systems in Egypt

Work Plan 7, Egypt Study 1A

Hussein A. Hebicha and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Bartholomew W. Green

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Abstract

Five different tilapia pond management strategies were evaluated for economic potential in 0.1-ha earthen ponds at the Central Laboratory for Aquaculture Research, Abbassa, Egypt. Pond management strategies were based on use of chemical fertilizer only, feed only, combination of organic fertilizer and feed, and combination of organic and chemical fertilizers and feed. Ponds were stocked with either mixed-sex or all-male populations of Nile tilapia. Yield and input data from 145-day pond trials were used to develop full-cost budgets for each management system. Net returns, values for production for major inputs, break-even prices and yields, and average rates of return to capital were estimated for each system based on a 2.1-ha production pond.

Net returns ranged from Egyptian pounds (L.E.) 19,102/2.1 ha for ponds stocked with all-male tilapia and receiving organic fertilizer and feed to L.E. 985/2.1 ha for ponds stocked with all-male tilapia and receiving chemical fertilizer only. The rates of return to capital for these two systems were 29.97% and 2.42%, respectively. Net returns to land and management for management systems that combined fertilization and feeding were, on average, 16.1 times the net returns for the extensive system. Management systems that combined fertilization and feeding also had the highest margins between average prices and break-even prices to cover total costs, which indicated reduced risks to farmers in the event of a decline in market prices. Sensitivity analyses indicated that combined fertilization-feeding systems maintained positive net returns if fish yield decreased by two standard errors and price decreased by 20%.

Effect of Stocking Rate on Growth and Yield of Nile Tilapia

Bartholomew W. Green

Department of Fisheries and Allied Aquaculture

Auburn University, Alabama, USA

Kevin Hopkins

College of Agriculture

University of Hawaii at Hilo

Hilo, Hawaii, USA

Zeinab El Nagdy and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

Nile tilapia are generally stocked at 20,000 fish/ha in semi-intensively managed production ponds. Nutrient inputs into these ponds include fertilizers and supplemental feeds; both natural pond productivity and supplemental feed contribute to fish growth. Often, pond carrying capacity and critical standing crop are not attained during the 5-month grow-out period, which indicates under-utilization of available pond nutrient resources. Knowledge of pond carrying capacity and density-dependent fish growth for a particular management system provides the ability to manipulate production management to improve efficiency and economic returns. The objective of this experiment was to quantify the growth and yield of Nile tilapia stocked at 30,000 and 40,000 fish/ha in production ponds.

This study was conducted at the Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt. Three replications of each treatment (stocking rates of 30,000 or 40,000 Nile tilapia/ha) were randomly assigned to 0.1-ha earthen ponds. Sex reversed Nile (Oreochromis niloticus) tilapia fry (mean weight: 0.5 g/fish) were stocked into ponds on 20 and 24 July 1994. Chicken litter was applied weekly at 1,000 kg dry matter/ha for the first eight weeks of the production cycle followed by feed (25% protein commercial fish feed) only. Average mean individual fish weights based on seine samples were 69.9 and 79.4 g/fish for the 30,000 and 40,000 fish/ha stocking rates, respectively. Estimated respective mean fish biomasses, assuming 100% survival at the effective stocking rates, were 2,098 and 3,178 kg/ha. Ponds are scheduled to be harvested after 150 days of grow-out.

Mass Production of Nile *(Oreochromis niloticus)* and Blue *(O. aureus)* Tilapia Fry

Bartholomew W. Green

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Esam H. Rizkalla and Abdel R. El Gamal

Central Laboratory for Aquaculture Research

Agricultural Research Center

Abbassa, Egypt

Abstract

A consistent, reliable supply of fingerlings of the desired species, sex, and size is critical to the success of any aquacultural enterprise. Of the four tilapia species endemic to Egypt, Nile and blue tilapia are considered better species for pond culture than *Sarotherodon galilae* and *Tilapia zilli*. Hormonal sex reversal is the most efficient means of mass production of monosex tilapia fingerlings at present. Newly hatched fry of 9- to 11-mm total length are given an androgen-treated feed during a 28-day period. Fry for sex reversal can be mass produced in earthen ponds, but water temperature can affect productivity. The objective of this research is to quantify production of Nile and blue tilapia fry in relation to water temperature in Egypt.

A total of 68 reproduction pond harvests have been completed since trials were initiated on 17 April 94. To date, 858,300 fry have been harvested; of these 659,000, or 79%, were suitable for sex reversal. The contributions of Nile and blue tilapia to these totals was approximately equal. The reproductive performance of Nile and blue tilapia appeared similar. Grading fry through a 3.2-mm square plastic mesh consistently yielded fry of uniform size and weight; fry passing the grader were within the size range (9- to 11-mm TL) desired for sex reversal.

Forty-nine sex reversal trials have been completed and 16 were in progress at the time of this report. The mean stocking rate of fry in 2-m^2 treatment hapas was 4,200 fry/m^2. Two hundred sixty-nine thousand Nile tilapia fry and 275,600 blue tilapia fry have been stocked into treatment hapas to date. After the 28-day androgen treatment period, fry averaged 23.8 mm total length. Overall mean survival has been 51% to date. Water quality deterioration, primarily due to high concentrations of ammonia caused by high feeding rates, was probably responsible for much of the fry mortality. Tank management was modified and survival improved. However, limited availability of water, because of equipment malfunction, continued to restrict the ability to manage water quality in tanks, even at moderate feed loading rates.

Growth of Control and Androgen-Treated Nile Tilapia, *Oreochromis niloticus* (L.), during Treatment, Nursery and Grow-Out Phases in Tropical Fish Ponds

B.W. Green and D.R. Teichert-Coddington

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Abstract

(Printed as submitted)

Masculinization of sexually undifferentiated tilapia fry is achieved by oral administration of the androgen 17a methyltestosterone (MT). An anabolic response to androgen treatment of tilapia has been reported. Growth of control and MT-treated tilapia was evaluated during consecutive treatment, nursery and grow-out phases under conditions approximating commercial, semi-intensive tilapia farms in Central America. *Oreochromis niloticus* (L.) fry were fed a 0 or 60 mg/kg MT diet for 28 days. Growth curves for control and MT-treated fish did not have significantly different slopes. Mean harvest fry weights were similar, averaging 0.1 g/fry for both treatments. Fry were subsequently stocked into 0.2-ha nursery ponds for 94 days of growth. Slopes of control and MT-treated fish growth curves were significantly different. Mean final individual weights did not differ significantly between treatments. Control fish did not deviate from the 1.1 male:female ratio, but MT-treated fish were 97% males. Control-male and MT-treated male fingerlings were stocked for grow-out into 0.1-ha organically fertilized earthen ponds. No significant difference in growth was observed between control and MT-treated fish. Mean gross yields after 150 days and mean final individual weights were similar for both treatments.

Published in Aquaculture and Fisheries Management 25:613-621.

Production of *Oreochromis niloticus* Fry for Hormonal Sex Reversal in Relation to Water Temperature

B.W. Green and D.R. Teichert-Coddington

Department of Fisheries and Allied Aquacultures

Auburn University, Alabama, USA

Abstract

(Printed as submitted)

Recently hatched tilapia 9 to 11 mm total length (TL) are preferred for hormonal sex reversal because they are most likely to be sexually undifferentiated. Thirty-three trials were conducted in Honduras between September 1998 (sic) and March 1990 to quantify the effect of water temperature on *Oreochromis niloticus* fry production in earthen ponds for hormonal sex reversal. Two 0.1-ha ponds were simultaneously stocked with brood fish in each trial; generally, one pond was harvested after 17 days, the other after 20 days (range 16 to 21 days). Fry production was evaluated in relation to degree-days from the threshold temperature of 15deg.C. Harvests averaged 86,000 fry/0.05 ha. A total of 4,897,000 fry were produced, of which 4,363,000 fry were of appropriate size for hormone treatment. No fry production occurred at less than 140 degree-days; fry production increased significantly with increased degree-days above this level. Above 195 degree-days percent of the population retained by a 3.2-mm vexar-mesh grader (too large for androgen treatment) increased significantly with increased degree-days. Fry retained by the grader averaged 14.2 mm TL, while fry not retained by the grader averaged 9.5 mm TL. No significant linear relationship between degree-days and number of fry not retained by the grader was observed between 140 and 280 degree-days. However, production appeared to peak at about 210 degree-days.

Published in Journal of Applied Ichthyology 9:230-236.

Phosphorus Fertilization Strategy in Fish Pond Based on Sediment Phosphorus Saturation Level

Madhav K. Shrestha and C. Kwei Lin

Agricultural and Food Engineering Program

Asian Institute of Technology

Bangkok, Thailand

Abstract

(Printed as submitted)

Two experiments were conducted to determine effective phosphorus (P) fertilization strategy in fish ponds in relation to sediment P saturation level. Experiment 1 was conducted in cement tanks with five levels of P saturated sediments (5%, 24%, 44%, 60% and 79%) and with three P-fertilization rates (0.2, 0.1 and 0.05 g/m^3/day, N:P ratio of 2:1, 4:1 and 8:1, respectively. Nile tilapia (*Oreochromis niloticus*) were cultured in those cement tanks for 57 days. Results showed that the mean concentration of soluble reactive phosphorus (SRP) in water column increased with increasing sediment P saturation and P fertilization rate. The maximum net fish yield (NFY), 4.2+/-0.3 g/m^3/day, was obtained at SRP concentration of 0.3 mg/L and higher concentrations did not increase fish yield. This level of SRP and NFY were attainable with P fertilization rate of 0.2, 0.1 and 0.05 g/m^3/day and N:P ratio of 2:1, 4:1 and 8:1 in ponds were the level of sediment P saturation was below 10%, above 45% and above 60%, respectively. Experiment 2 was conducted in earthen ponds to test and verify the P fertilization rate based

on cement tank experimental results. Three new and three old ponds with 8+/-1.7% and 88+/-7.3% sediment P saturated in top 5-cm mud were fertilized at a rate of 0.2 and 0.05 g/m^2/day and N:P ratio of 2:1 and 8:1, respectively. Nile tilapia were cultured at 2/m^2 for 85 days. The mean NFY obtained in new and old ponds were 1.73+/-0.08 and 2.24+/-0.32 g/m^2/day, respectively, which were not significantly different (P > 0.05). Results conclude that P fertilization rate should be based on P saturation level in mud to overcome the problem of under supply or over supply of P in fish pond.

Accepted for publication by Aquaculture.

Determination of Phosphorus Saturation Level in Relation to Clay Content in Pond Mud

Madhav K. Shrestha and C. Kwei Lin

Agricultural and Food Engineering Program

Asian Institute of Technology

Bangkok, Thailand

Abstract

(Printed as submitted)

An experiment was conducted to determine the amount of phosphorus (P) needed to saturate simulated fish pond sediments which were made up to contain six levels of clay at 0%, 30%, 41%, 64%, 73% and 81% by weight. A series of cylindrical cement tanks were filled to 20 cm depth with six sediment types and triple superphosphate (TSP) solution was added to reach P saturation in sediment. Results showed that all sediment types reached constant inorganic-P concentration in upper 5-cm after 12 weeks of TSP application, and P adsorption capacity of sediment increased with increasing clay content. Sediment P adsorption was slower and not significant (P > 0.05) below the 5-cm depth except that contained 0% clay. Regression analysis showed that rate and adsorption capacity of P in sediment are primarily governed by clay content and its dominant minerals. While organic-P and loosely bound-P are commonly deposited in sediment most inorganic P is absorbed by cations to form cation-P complex. The linear relationship between cation-P saturation level and percent clay in sediment is highly significant (r^2 0.34, P < 0.001) and therefore, the maximum adsorption capacity of cation-P in pond sediment can be calculated by Y = 0.019 X (Y = 100% saturation level mg-P/g soil: X = % clay in sediment). In practice the level of P saturation (%) in sediment can be calculated by the initial cation-P and clay content (%) in top 5-cm of pond mud using the equation: P saturation (%) = initial cation-P (mg/g soil) X 100/P adsorption capacity (mg/g soil).

Accepted for publication by Journal of Aquaculture Engineering.

V.Public Service and Project Development

The Pond Dynamics/Aquaculture CRSP relies on its on-site researchers to recognize opportunities to support local research institutions' training activities, and to find efficient ways to extend CRSP research results to the farmers. CRSP researchers in all countries

have capitalized on these opportunities, enabling the CRSP to increase its impact at little or no additional cost. Although ancillary to the Global Experiment and site-specific studies, these activities contribute to institution building and increased food production, thereby furthering the main strategic approach. These activities also help to promote international scientific linkages through the exchange of technical information. As a result, research capabilities have been substantially strengthened in every developing country in which the CRSP has been active. Some of these important contributions are described below.

Institution Building

The research activity of the CRSP has resulted in major improvements to the research infrastructure of collaborating host country institutions, both directly and by helping to attract other funding opportunities. In addition, CRSP scientists serve as advisors in the research programs of students at host-country universities and make contributions to curriculum development.

In Honduras, a CRSP-led, public-private joint venture continues to produce economic benefits while increasing the understanding of the water quality issues associated with the shrimp industry in southern Honduras. The CRSP works with the Ministry of Natural Resources, the National Association of Honduran Aquaculturist (ANDAH), the Panamerican Agriculture School (EAP), and the Federation of Producers and Exporters of Honduras (FPX) to study water quality issues that affect shrimp production and the estuarine environment surrounding the farms. The refurbishment of the laboratory in La Lujosa, near Choluteca, was made possible by the active participation of all the partners in this joint venture. The Ministry of Natural Resources provides the laboratory and office space at La Lujosa. ANDAH provides equipment and supplies for the lab, funded by a self-imposed assessment on shrimp exports. ANDAH members also provide ponds and inputs to conduct CRSP experiments. FPX extensionists assist in collecting data from their members and disseminating research information. Students under the direction of EAP conduct research in shrimp culture and water quality analysis. The laboratory was dedicated in the spring of 1993, and makes important contributions to research issues such as estuarine monitoring, pond fertilization, and shrimp feeding strategies, that will increase farmers' economic efficiency and minimize negative environmental impact.

Right up to the time of the forced evacuation from Rwanda, the laboratory at Rwasave was the premier water quality laboratory in East Africa, despite the on-going climate of civil unrest that seriously damaged national infrastructure and interfered with travel and communications. Prior to the evacuation, the fry production pond was renovated, including the addition of a catch basin to improve the capacity of the station to generate large numbers of fry for on-farm studies. Bridges were constructed over two sex-reversal ponds to facilitate the use of hapas in the sex-reversal process. The loss of this research facility will be felt not only in Rwanda, but throughout East Central Africa, which relied on the laboratory

for water quality and soil sample analysis, and on the expertise of the CRSP researchers for training and advice.

The CRSP continues to be an active partner in the establishment of research ponds at the Chaiyaphum Fisheries Station in northeast Thailand and at Phayao Station in northern Thailand.

In Egypt, the CRSP provided support for an overwintering facility and installed a second recirculating system. Ten round (100 m^2) earthen ponds were renovated for tilapia reproduction. The water inlet and outlet structures on experimental ponds were modified to exclude contamination with wild fish. The presence of CRSP researchers in Egypt significantly enlarges the institutional and professional network available to students, and strengthens Egyptian universities through these increased international linkages.

Education and Professional Development

Formal training programs have been infrequently (or rarely) funded by this CRSP; nevertheless, the involvement of students from host countries and the United States constitutes an important part of the CRSP's international outreach. Informal training activities such as short courses and workshops are frequently conducted. Since the beginning of the program, over 400 individuals have benefited from CRSP training activities.

Thailand and Philippines

The CRSP is involved in training as a component of several studies that help extend CRSP research to farm ponds throughout Thailand. The CRSP provides the research component for an adaptive management system. The on-farm studies help speed the extension of research to the farmers, and at the same time, use the farmers' concerns to help create the research agenda. In the Philippines, the regional verification of the CRSP fertilizer guidelines continues at the Freshwater Aquaculture Center at Central Luzon State University (FAC/CLSU).

Honduras

David Teichert-Coddington conducted a short course on water quality as part of a longer course on shrimp diseases organized by the Ministry of Natural Resources. In January, Teichert-Coddington played a key role in organizing a one-day conference on sustainable shrimp farming in Honduras. The conference was designed to educate the farming community on sustainable shrimp culture, and to elicit support for CRSP research relating to estuarine monitoring and water quality. Teichert-Coddington was instrumental in organizing a two-day regional conference, *Sustainable Development of the Gulf of Fonseca and its Watershed*. Three hundred farmers and researchers from Honduras, Nicaragua, and El Salvador attended. CRSP researchers Claude Boyd and C. Kwei Lin were invited speakers, addressing the environmental regulation of coastal aquaculture and environmental impacts of intensive shrimp farming in Thailand, respectively. Teichert-Coddington presented a talk on the relation between estuarine water quality and shrimp farm discharge in southern Honduras. In addition, Teichert-Coddington conducted a workshop on tilapia production techniques to Peace Corps volunteers.

Egypt

Academic advancement is the focus of the CRSP's professional development activities in Egypt. A total of ten students are supported by the Egypt project; six are working on advanced degrees, while four others conduct research at the University of Hawaii, at Auburn University, and at Oregon State University. The focal point of the CRSPs professional development activities in Egypt is the scholarly exchange program. Eleven scientists participated in this program during this reporting period: four at Auburn University, two at the University of Maryland, one at the Northwest Fisheries Science Center in Seattle, one at University of Hawaii, one at University of Oklahoma, and two at Oregon State University.

In addition to the Scholarly Exchange program, the CRSP has sponsored numerous workshops at the CLAR during this reporting period. C. Kwei Lin gave three seminars at CLAR in November 1993 when he visited Egypt to work on polyculture research protocol and on catfish hatchery techniques. Komonporn Tonguthai, Director of the Aquatic Animal Health Research Institute in Bangkok, also presented a seminar about diseases of cultured fish. The CRSP sponsored a field day at the CLAR in December 1993 to highlight project progress and results. In January, Ali Abdelghany and Bartholomew Green organized an in-service training for fifty Government of Egypt aquaculture/fisheries personnel. Shmuel Rothbard from the Gan Shmuel Fish Breeding Center, Israel, and CRSP visiting scientists Kevin Hopkins and William Shelton also participated in the workshop. Bartholomew Green and Esam Rizkallea conducted a one-day tilapia fingerling production workshop at CLAR, which was attended by fish farmers, extension personnel, university professors, and students. Green and Rizkalla lectured and then demonstrated reproduction pond harvest, broodfish handling, fry collection, handling and transport, and sex reversal treatment. Claude Boyd presented a two-day workshop at the CLAR on water quality management in aquaculture ponds. Martin Fitzpatrick presented seminars on the reproductive physiology of fishes, sex differentiation in tilapia, and induced breeding in fishes. He also conducted workshops on identifying the sex of tilapia fry and physiological sampling techniques.

Enthusiasm generated by such informal training and by exposure to activities at the CRSP research sites has led some students to pursue university degree programs, either at institutions in their own countries or at participating U.S. universities. Students have pursued degrees at seven overseas institutions and at all of the collaborating universities in the U.S. Prior to this reporting period over 111 degrees (B.S., M.S., and Ph.D.) were awarded, and during this period, another five were completed under the direction of CRSP researchers. In addition, over 78 theses have been completed under the direction of CRSP researchers. Theses completed during this period are:

Alcívar, V.A. 1994. Crecimiento de dos razas de tilapia *(Oreochromis sp.)* alimentadas con tres dietas de diferente nivel proteico. Thesis, Ingeniero Agronomo, Escuela Agricola Panamericana en El Zamorano, Honduras.

Havanont, V. 1994. Effect of Controlled Dissolved Oxygen Regimes on Growth of Sea Bass *(Lates calcarifer)*. M.S. thesis. Asian Institute of Technology.

Gonzalez, H.J. 1994. Cultivo de tilapia*(Oreochromis niloticus)*, carpa común *(Cyprinus carpio)*, y tambaquí *(Colossoma macropomum)* en jaulas. Thesis, Ingeniero Agronomo, Escuela Agricola Panamericana en El Zamorano, Honduras.

Keawchum, S. 1994. Impact of substrate and commercial bacteria on the growth performance of shrimp *(Penaeus monodon)* in intensive closed and open culture systems. M.S. thesis. Asian Institute of Technology.

La-ongual, T. 1994. Development of a Model of Phytoplankton Productivity in Fertile Ponds. M.S. thesis. Asian Institute of Technology.

Nguyen, M.N. 1994. Current status, constraints, and potential of shrimp seed production in Central Vietnam. M.S. thesis. Asian Institute of Technology.

Nyirahabimana, P. 1994. Gender Differences and Technology Adoption: The Effect of Household Pressures on the Practice of Fish Farming in Rwanda. M.S. thesis. Auburn University.

Shrestha, M. 1994. Dynamics and recovery of phosphorus in mud of fertilized fish ponds. Ph.D. thesis. Asian Institute of Technology.

Wang, C.Y. 1994. Preliminary trials for nursing of Chinese catfish *(Silurus asotus)* in cages in tilapia culture ponds. M.S. thesis. Asian Institute of Technology.

Yahiya, Y.S. 1994. Eutrophication problem in shrimp *(Peneaus monodon)* ponds and the biological control using Nile tilapia *(Oreochromis niloticus)*. M.S. thesis. Asian Institute of Technology.

The number of individuals involved in all forms of training, from non-degree activities through work on advanced degrees, has climbed to well over 400 since the beginning of the program. Most of the trainees have come from PD/A CRSP host countries (Egypt, Honduras, Indonesia, Panama, Philippines, Rwanda, Thailand, and U.S.A.); however, the benefits of CRSP-related training have extended well beyond the borders of the seven collaborating countries, as evidenced by the fact that participants have been drawn from at least 27 countries over the course of the program. Furthermore, the interdisciplinary nature of aquacultural research attracts students from a wide range of academic disciplines. Many participants take positions in schools, banks, agricultural research institutes, national parks services, development projects, and agricultural extension services, where they are able to increase public awareness of aquaculture's importance in food systems.

Linkages

CRSP linkages in Honduras have been strengthened and broadened with the inauguration of the brackish water site in Choluteca. The CRSP was able to add this site largely because of the enthusiastic collaboration of private organizations and government institutions. Among the collaborators are the Ministry of Natural Resources, the National Association of Honduran Aquaculturists, the Panamerican Agriculture School, and the Federation of Producers and Exporters of Honduras, all of whom make substantial contributions to the on-going operation of the project. In addition, CRSP researchers serve as consultants for Peace Corps volunteers, and Peace Corps volunteers have assisted with logistical arrangements for researchers involved with the social sciences project.

The CRSP continues to strengthen its ties with institutions in southeast Asia. In Thailand, CRSP researchers hold long- and short-term faculty appointments at the Asian Institute of Technology (AIT), and teach a variety of courses and seminars. AIT serves as a regional resource for technology development and dissemination in Southeast Asia, so CRSP researchers are able to form linkages with students and faculty from many countries. They also serve as advisors to the Thai government on aquaculture and fisheries related projects.

In the Philippines, CRSP ties with the International Center for Living Aquatic Resources Management (ICLARM) continue to grow. Current work plans call for the use of genetically selected tilapia from an ICLARM-sponsored project for field testing at the FAC/CLSU as part of the regional verification trials being conducted by the CRSP in the Philippines. Another collaborator, the FAC/CLSU-University of Wales Swansea Research Project on Genetic Manipulations for Improved Tilapia (GMIT), will provide genetically male tilapia (GMT) produced by breeding "YY supermales" with untreated females to provide all male tilapia for use in one treatment of the CRSP regional verification.

The Research Associate in Rwanda advised the USAID/Kigali Mission and the USAID Natural Resources Management Project on natural resource issues up until the time of evacuation. CRSP researchers also advised the Rwandan Ministry of Agriculture's Aquaculture Strategy Commission in establishing research priorities and in proposing suitable research and extension linkages. The CRSP made major contributions to the Rwasave station in constructing facilities and supporting extension personnel and publications.

Linkages between Egyptian and U.S. institutions were strengthened, and new linkages were developed. The University of Maryland and the Gan Shmuel Fish Breeding Center in Israel collaborated with CRSP research during this period.

Raul Piedrahita, Principal Investigator for the UCD/DAST, traveled to Scotland to participate in a meeting on Aquaculture and Water Resource Management, and in a workshop on the Economics of Waster Water Management in Aquaculture. The workshop was sponsored by the European Inland Fisheries Advisory Commission (EIFAC). In addition to the CRSP's numerous formal connections with host country institutions through Memoranda of Understanding, the CRSP maintains ties with numerous other organizations, including many commercial fish producers in the U.S. and in host countries. A partial list of informal CRSP linkages follows:

Al Azhar University, Egypt

American Tilapia Association, United States

Board for International Food and Agricultural Development and Economic Concerns

(BIFADEC), Washington, D.C.

Boy Scouts, Rwanda

Cairo University, Egypt

CARE, Honduras

Catholic University of Leuven (CUL), Belgium, Rwanda

Central Luzon State University, Freshwater Aquaculture Center, Philippines

Consultative Group on International Agricultural Research (CGIAR), Washington, D.C.

Department of Aquaculture (DINAAC), Panama

Department of Fisheries, Udorn Thani, Thailand

Department of Renewable Natural Resources (DIGEPESCA), Honduras

Eastern Fish Cultural Laboratory, Marion, Alabama

Escuela Agrícola Panamericana, (EAP) Honduras

European Economic Community

European Inland Fisheries Advisory Commission (EIFAC)

Fish Breeding Centre, Israel

Fish Culture Research Institute, Szarvas, Hungary

Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Freshwater Aquaculture Center (FAC), Philippines

Gan Shmuel Fish Breeding Center, Israel

General Authority for Fish Resource Development, Cairo, Egypt

Gondol Research Station, Ensenada, Mexico

Honduran Federation of Agricultural and Agroindustrial Producers and Exporters (FPX)

INTSORMIL CRSP, Honduras

Institut Pertanian Bogor (IPB), Indonesia

International Development Research Centre (IDRC) of Canada

International Rice Research Institute (IRRI), Philippines

International Center for Aquaculture (ICA), Auburn University, Alabama

International Center for Living Aquatic Resources Management (ICLARM), Philippines

J.F.K. Agricultural School, Honduras

Mariut Fish Farm, Egypt

Ministry of Agriculture, Agricultural Research Center, Egypt

National Agricultural Library, Washington, D.C.

National Agricultural Research Project (NARP), Egypt

National Association of Honduran Aquaculturists (ANDAH)

National Inland Fisheries Institute (NIFI), Thailand

National Marine Fisheries Service (NMFS), La Jolla, California

National Technical Information Services, (NTIS) Springfield, Virginia

North Central Regional Aquaculture Center (NCRAC), Michigan

Northwest Fisheries Sciences Center, Seattle, Washington Peace Corps: Honduras, Thailand, Burundi, Rwanda

Red Cross, Rwanda

Soil Management CRSP, Honduras

South East Asian Fisheries Development (SEAFDEC), Philippines

Sustainable Agriculture and Natural Resources Management (SANREM) CRSP

Special Program for African Agricultural Research (SPAAR), Washington, D.C.

The University of the Philippines in the Visayas

United States Department of Agriculture (USDA)

United States Fish and Wildlife Service

University of Arizona, Tucson, Arizona

University of Washington, Seattle, Washington

Western Regional Aquaculture Consortium (WRAC), Seattle, Washington

Zagazig University, Egypt

Project Development

With its extensive international network of researchers, the CRSP is well positioned to identify needed areas of research and opportunities for aquaculture development. Emerging themes in development and in aquaculture are being addressed by the CRSP. With worldwide attention now focused on sustainable development, the CRSP work in natural resource policy development and implementation in Rwanda and Honduras assumes greater importance. The CRSP has taken an active role in encouraging women in aquaculture, reflecting the recognition of women's pivotal role in agricultural production and family nutrition. A workshop at the Annual Meeting focused on integrating a gender dimension into future aquaculture research and development. The private sector in many countries has been able to capitalize on CRSP research. The models and guidelines developed by CRSP researchers are being used in directing on-farm trials, the "acid-test" of new techniques and technologies. Finally, recognizing that new technology does not operate in a vacuum but is part of a larger socioeconomic system, the CRSP is devoting more resources to integrating the social sciences into the core research. A project inaugurated during this reporting period is investigating the socioeconomic dimensions of aquaculture development in Honduras, Thailand, and the Philippines.

The PD/A CRSP is commited to extending aquaculture development to appropriate sites. The on-going Egypt project gives the program an opportunity to apply the CRSP technologies and methodologies in an arid climate. Investigations have begun to increase the number of CRSP sites to include new agroecological zones. Deputy Director Brigitte Goetze responded to an invitation from the Ministry of Agriculture in Eritrea to visit that country to review its potential as a CRSP site. The CRSP Request for Proposals for the Continuation Plan attracted collaborators with experience and linkages in South American countries, and a new sites tin Peru is tentatively being planned, contingent on funding. In the next reporting period, Director Hillary Egna and Rwanda Principal Investigator Wayne Seim will undertake a site visit to Kenya to evaluate its appropriateness as the CRSP Africa site.

The planning for the CRSP Continuation Plan beyond 1995 began in August 1993, and continued during this reporting period. The positive reviews of the PD/A CRSP by the External Evaluation Panel and by the all-CRSP review conducted by Tropical Research and Development have resulted in an invitation from USAID to submit a Continuation Proposal during the next reporting period. A strategic document is being prepared that includes an ecological perspective on aquaculture development.

Development of Sustainable Aquaculture Systems

Environmental concerns are motivating the creation of more sustainable agricultural systems worldwide, at the same time as aquaculture production is being recognized as vital to the world's food economy. Diminishing stocks of wild fish, coupled with increasing demand for fish worldwide, have driven up the value of aquaculture products, especially fish and shellfish, and aquaculture is projected to continue to fill an important niche as a food source and cash crop in developing countries. Pond production of animals and plants is a key component of integrated agricultural systems in several ways. Aquaculture ponds provide an efficient means of conserving water in areas where water supplies are limited. Further, effluent from ponds can be used for crop irrigation, thus avoiding pollution of natural waterways. Pond mud-often high in organic matter and rich in nutrients-can be partially removed and used as a fertile soil additive for

land crops. Aquaculture is easily integrated with other forms of agricultural production, such as chicken-fish and duck-fish operations. Farm by-products such as manures, grasses, inedible plant parts, and composts can be used as nutrient sources in aquaculture ponds. CRSP research at all sites continues to emphasize efficient utilization of these agricultural by-products to enhance production in ponds, and to contribute to sustainability by recycling farm materials.

In Egypt, researchers investigate the possibilities of using biological controls to solve pond management problems. Experiments are conducted to evaluate the ability of grass carp to control nuisance aquatic weeds. Black carp, a voracious snail predator, is being tested for its potential to reduce the snail population. Since snails are hosts to the parasite that causes bilharzia, a reduction in the snail population may reduce fish farmers' danger of contracting bilharzia. These studies are designed as building blocks in the development of a polyculture system unique to Egypt. Polyculture studies will be conducted during the second year of CRSP research in Egypt. In a second line of inquiry, CRSP researchers are comparing different management strategies (e.g. traditional Egyptian aquaculture practices) with CRSP management guidelines in an attempt to determine which strategies might work best under the arid conditions found in Egypt, thus guaranteeing the most efficient use of precious water and nutrients.

Biotechnology opens alternative avenues for the production of monosex tilapia. Research is being conducted in both Egypt and the U.S., focusing on the safe use of steroids with a special emphasis on minimizing impacts on humans, fish, and the environment.

In southern Honduras, CRSP researchers are making progress in developing efficient farming practices for shrimp farmers and in determining the carrying capacity of the Gulf of Fonseca. An understanding of the Gulf's carrying capacity will give development planners information needed to insure the protection the estuarine environment surrounding the gulf. Already, research results have shown farmers that they can reduce the percentage of protein in their shrimp feed without affecting yield, lowering both farmers' feed costs and the nutrient load in the estuary. Further research will continue to integrate environmental issues with production concerns.

Water quality concerns are also on the research agenda in Thailand. Experiments to determine the most efficient level of nutrient input help Thai farmers plan for optimal resource use without polluting ground and surface waters. CRSP researchers at all sites demonstrate a concern for the effects of aquacultural production on the wider environment.

Socioeconomic Studies

The CRSP has long recognized that social and economic factors play an important role in the development and adoption of aquaculture technologies and management strategies. Limited funding for this CRSP has constrained research in these areas, so that only small, site-specific studies could be conducted. Past socioeconomic research was limited to providing answers to specific questions, ranging from economic analyses of feeding strategies in Honduras to analysis of gender variables in Rwanda. However, CRSP researchers recognize the need to provide basic economic information to enable farmers to evaluate research recommendations in the light of financial profitability. On-going efforts are being made to include socioeconomic variables in core research.

- POND, the expert system for pond management developed by the OSU/DAST, now includes economic data. The user-friendly program runs on IBM-compatible personal computers, and supports pond manager decisions regarding variables such as fertilization and stocking strategies.
- In Honduras, brackishwater research has already had an economic impact. Studies showed that no significant difference occurred in shrimp production when a 20% protein feed was substituted for a 40% protein feed. This finding allows farmers to cut their feed costs substantially without affecting production.
- In Rwanda, enterprise budgets for fish production and production of 12 different crops commonly raised on Rwandan farms indicate that fish farming affords the greatest rate of return to both labor and capital. An unexpected result of this study showed that farmers enter aquaculture mainly to generate income, not as was thought, to have fish as an additional food item.
- In Thailand, feeding studies designed to determine the optimal time for initial application of supplemental feed in fertilized ponds help farmers make economically sound decisions regarding supplemental feeding by identifying the critical stages when the natural food supply is inadequate to support optimal fish production.

Socioeconomic studies will soon move from the periphery of the CRSP research agenda. Socioeconomic concerns are identified as one of the core themes in the new Continuation Proposal, and will be firmly integrated into the CRSP research agenda. The global social sciences project, "Socioeconomic Dimensions of Aquaculture Development: A Comparative Assessment of Financial Returns, Adoption Barriers, and Impacts of Tilapia Production Regimes," identifies the level and type of technology available to tilapia farmers in Honduras, Thailand, and the Philippines. The role played by CRSP technology in the evolution of tilapia production practice, and the relationship of these technologies to the larger research and technology development systems is articulated, and the economic context that shapes farmers' decisions concerning technology adoption is profiled. The results of the study will have implications for future research proposals, development policy, and farm-level decision-making about tilapia technology. Field work in Honduras, Thailand, and the Philippines was completed during this reporting period.

USAID sponsored a workshop at the 1994 Annual Meeting on integrating gender dimensions of development into the research agenda. The workshop offered CRSP researchers the opportunity to reframe research proposals to reflect social, economic, and cultural variables, in addition to physical, biological and chemical variables, that affect pond production systems.

Participation in International Scientific Meetings and Conferences

David Teichert-Coddington presented a talk on the "Relation between estuarine water quality and shrimp farm discharge in southern Honduras" at the *Sustainable Development of the Gulf of Fonseca and its Watershed* conference in Honduras. He also was invited to chair a section and present a paper at the regional conference on *Aquaculture Research in Central America* in Costa Rica, and presented a talk on water quality in shrimp ponds at the *Camaron '94* conference in Mazatlán, Mexico. This conference was

organized by Ralston Purina Feed Company for shrimp farmers and business people in Mexico and Central America.

Ali Abdelghany, Abdel R. El Gamal, Bartholomew Green, Hussein El Ghobashy, Fatma Hafez, Inrahim Shaker and Yasir Awad attended the World Aquaculture Society Conference and Expo '94 in New Orleans. Green presented two papers at the Water Quality/Fertilization session: "Water Budgets for Fish Ponds in the Dry Tropics" and "Chemical Budgets for Fish Ponds in the Dry Tropics."

Abdelghany also presented two posters at the Sixth International Symposium on Fish Nutrition and Feeding in Hobart, Tasmania: "Optimum ratio of animal to plant protein in formulated diets for Nile tilapia," and "Optimum protein requirements for Nile tilapia."

Jim Diana attended the annual American Fisheries Society meeting in Halifax, Nova Scotia.

Joseph Molnar presented a paper based on the CRSP survey data to the Annual Meeting of The Rural Sociological Society in Portland, Oregon.

William Shelton attended the Fifth International Symposium on Genetics in Aquaculture in Halifax, Nova Scotia, and presented a paper on "Ploidy Manipulation in Black Carp."

Hillary Egna, Brigitte Goetze, and Martin Fitzpatrick attended the two-day "Drugs in Aquaculture" workshop sponsored by the Food and Drug Administration (FDA) and United States Department of Agriculture (USDA) in Washington, DC.

Marion McNamara attended the Association of Women in Development in Washington, DC. She and Hillary Egna participated in the World Bank's International Centers week.

Raul Piedrahita traveled to Scotland to participate in a meeting on Aquaculture and Water Resource Management. He also participated in a workshop on the Economics of Waste Water Management in Aquaculture, sponsored by the European Inland Fisheries Advisory Commission (EIFAC).

VI. Program Management and Technical Guidance

The CRSP is organized to facilitate collaboration. Believing that mutually beneficial development strategies have the best chance of being sustainable over time, the CRSP's organizational structure facilitates collaboration among research, institutions, and countries. The Management Entity, located at Oregon State University, administers the program. The Management Entity subcontracts with Auburn University, the University of California at Davis, and the Consortium for International Fisheries and Aquaculture Development (CIFAD), a five-member consortium of universities. Members of CIFAD include: Michigan State University, Oregon State University, University of Arkansas at Pine Bluff, University of Hawaii, and The University of Michigan. The University of Oklahoma continued its association with the CRSP as part of the Egypt project. A Memorandum of Understanding (MOU) is

executed between the host country institution and the lead university for each project (e.g., an MOU is executed between the Asian Institute of Technology and The University of Michigan). An exception to this is the Egypt project where the Central Laboratory for Aquaculture Research of the Agricultural Research Center at Abbassa holds an MOU directly with the CRSP Management Entity.

This organizational structure gives the CRSP flexibility and the depth of expertise to respond effectively to new opportunities and challenges. CRSP efforts in Honduras have been successful in institutionalizing aquaculture research. Host country researchers at the freshwater site maintain day-to-day station operations. At the brackish water site, private sector collaborators help to fund research activities and take part in experiments. Linkages with these organizations, the result of ten years of research and training in Honduras, are further evidence of the efficacy of the CRSP in attracting local support for program activities. The Honduras project collaborates informally with experts from non-CRSP universities to evaluate water flux and waste assimilative capacity in estuaries.

The CRSP drew on its multi-disciplinary collaborative network to pioneer and refine a global project in socioeconomics. A study entitled "Socioeconomic Dimensions of Aquaculture Development: A Comparative Assessment of Financial Returns, Adoption Barriers, and Impacts of Tilapia Production Regimes," began in June. The study will identify the level and type of technology available to tilapia farmers in Honduras, Thailand, and the Philippines. Furthermore, the study will identify the role that CRSP technology has played in the evolution of tilapia production practices in these countries. The relationship of CRSP technologies to the larger research and technology development systems will be articulated, and the economic context that shapes farmers' decisions concerning technology adoption will be profiled. The implications for research management, development policy, and farm-level decision-making about tilapia technology will be useful for planners, researchers, and farmers. Field work on this project has been completed, and a final report will be forthcoming in the next reporting period.

As a result of exhaustive reviews conducted by the PD/A CRSP External Evaluation Panel and by the consulting firm Tropical Research & Development, the PD/A CRSP has been invited to submit a proposal for continuation of the CRSP from 1995 to 2000. The CRSP has used the strength of its collaborative network to plan for the next five years. The process began at the 1993 Annual Meeting, as areas of interest were identified and an RFP was issued. Proposals from new and continuing institutions were submitted for consideration. At the 1994 Annual Meeting, the process continued, as the Technical Committee identified specific research themes and charged the Technical Committee co-chairs Bryan Duncan and Kevin Hopkins to work with Program Director Hillary Egna to coordinate and write the Continuation Plan.

Management Entity

Oregon State University is the Management Entity (ME) for the Pond Dynamics/Aquaculture CRSP and is the primary grantee of USAID. The Program Management Office (PMO) is the operational component of the ME. The PMO is the link between USAID and the CRSP projects, which are subcontracted to Auburn University, the University of California at Davis, CIFAD, and the University of Oklahoma.

The Management Office is located in the Office of International Research and Development (OIRD) on the main campus of Oregon State University, in Corvallis, Oregon. OIRD provides accounting, purchasing, and travel support. The CRSP reports directly to the Vice Provost for Research and International Programs through the Director of the OIRD. Ties to the Department of Fisheries and Wildlife, and to the Department of Bioresource Engineering, are maintained through faculty appointments, academic interests, and research subcontracts.

During this reporting period, members of the Program Management Office included:

Hillary Egna, Director (1.0 FTE)

Brigitte Goetze, Deputy Director and Egypt Coordinator

(1.0 FTE - not funded on core CRSP funds)

Marion McNamara, Assistant Director (1.0 FTE - partially funded on core CRSP funds)

Naomi Weidner, Secretary (0.75 FTE - partially funded on core CRSP funds)

The Management Entity (ME) is responsible for:

- Receiving funds committed by USAID to the CRSP and assuming accountability for their use;
- Providing funds to the participating institutions, and ensuring complian with the terms of the grant;
- Providing a focal point for the interaction of the Technical Committee, Board of Directors, External Evaluation Panel, USAID staff, and BIFADEC/JCARD;
- Executing the decisions of the governing and advisory bodies;
- Spearheading program development efforts;
- Facilitating internal and external communications;
- Producing and distributing CRSP publications;
- Implementing the program; and
- Maintaining liaisons with overseas and domestic participants.

Specific accomplishments this year include:

- Preparation of CRSP budgets and subcontract modifications for extending funding and performance periods;
- Coordination of new administrative and contractual details for collaborative research projects in Thailand, the Philippines, Rwanda, Egypt, and Honduras;
- Site visit to Egypt to evaluate project progress and negotiate extension of project;
- Assistance with the Rwanda evacuation and project relocation;
- Coordination of planning and logistics for the review conducted for USAID by Tropical Research & Development, including providing background information and logistical support for travel and responding to the draft copy of their final report;
- Organization of the twelfth annual CRSP meeting in Hilo, Hawaii from 28 to 31 March 1994;
- Participation at Annual Meeting in Board and Technical Committee meetings;

- Development of questionnaires for evaluating the Annual and Technical Committee meetings;
- Assistance in processing travel clearances for all CRSP personnel and approvals for purchases of restricted goods for country projects;
- Coordination of travel schedules for U.S. researchers and Egyptia counterparts;
- Publication of research results in technical report series;
- Preparation, publication, and distribution of detailed quarterly reports summarizing technical and administrative progress;
- Training and supervising a graduate student intern working on an analysis of PD/A CRSP formal and informal training;
- Aided with equipment purchases for the CLAR;
- Developed a fact sheet about the Egypt project;
- Maintenance of the CRSP mailing list, which reaches approximately 300 people in 42 countries;
- Maintenance of the CRSP directory, which lists participants' addresses, telephone, fax and email number;
- Coordination of the Egyptian Scholarly Exchange Program, which brings Egyptian collaborators to U.S. aquaculture research institutions and facilities;
- Organization of and participation in Board Meetings and Technical Committee meetings;
- Maintenance of management informations systems to track projects;
- Collection of information about technology transfer and economic impact of various CRSP activities;
- Coordination, with Claude Boyd of Auburn University, of the new CRSP book *Dynamics of Pond Aquaculture*.

The PD/A CRSP maintains technical linkages with the Tropsoils and the SANREM CRSPs. Maintenance of programmatic linkages with all the CRSPs, increases the visibility of the PD/A CRSP and of aquaculture in general. The cost of participation in CRSP Council activities is disproportionately high for the PD/A CRSP, which is funded at a much lower level than other CRSPs and which is thus more financially strained by participation. The Management Office participated in the following CRSP Council Council Conference calls:

16 September 1993

7 October 1993

4 November 1993

2 December 1993

3 February 1994

16 March 1994

Three advisory groups, the Board of Directors (BOD), the Technical Committee (TC), and the External Evaluation Panel (EEP), support the management of the CRSP. These groups work closely with the PMO to guide the CRSP through policy decisions, budget allocations, research strategy, review, and evaluation.

The Board of Directors

As the primary policy-making body for the CRSP, the Board of Directors takes an active role in program guidance. The Board is composed of three members, one of whom is elected chair. Auburn University, the University of California at Davis, and CIFAD are each represented on the Board. In addition, the USAID Program Manager for the CRSP and the CRSP Director serve as ex-officio members. All Board members function in the objective interest of the CRSP regardless of their institutional affiliation. During this reporting period, the Board members were:

Dr. Robert Fridley, University of California at Davis, Chair;

Dr. Philip Helfrich, University of Hawaii (CIFAD institution);

Dr. R. Oneal Smitherman, Auburn University;

Mr. Harry Rea, NMFS, RSSA to R&D/AGR, ex-officio member;

Ms. Hillary Egna, Oregon State University, CRSP Director, ex-officio member.

The Board of Directors is responsible for:

- Review of program budgets and allocation of funds to research and Management;
- Recommendations to the Management Entity on budget allocations;
- Evaluation of the administrative and technical accomplishments of overseas research projects and U.S.-based research activities;
- Advice to the Management Entity on policy guidelines; and
- Review of the performance of the Program Director and Management Entity.

The Board of Directors convened once during this reporting period, in an extended meeting during the Annual Meeting (27 and 30 March 1994) in Hilo, Hawaii. Informal discussions are held regularly with the Board and approvals for some decisions are made through correspondence.

Specific accomplishments and recommendations made during this reporting period include:

- Approval of management and research budgets;
- Annual meeting agenda input and approval;
- Input on project monitoring by the Program Director and the BOD;
- Direction to the Technical Committee and PMO in developing the continuation proposal;
- Participation in the Twelfth Annual Program Meeting in March 1994;
- Participation in the review of proposals for the continuation plan.

Technical Committee

Researchers from U.S. universities and host country institutions comprise the Technical Committee, which advises the Management Entity on technical matters. The membership of the Technical Committee

is listed in Table 1 in alphabetic order, with institutional affiliations and subcommittee assignments. Voting privileges are accorded each institutional partner in each project receiving CRSP funds. Institutions holding a vote on the Technical Committee are listed in Table 2 by project. The CRSP Director and the USAID Project Manager serve as ex-officio members, and at-large members are appointed by the Board of Directors. Dr. Ted Batterson continues to serve as the At-large Technical Committee member. The Technical Committee has four standing subcommittees: Work Plans, Materials and Methods, Budgets, and Technical Progress. Special committees are convened as needed.

External Evaluation Panel

A committee of external aquaculture specialists periodically evaluates the accomplishments of the individual research projects and the overall program to ensure that research projects and the program remain focused, relevant, and cost-effective. The External Evaluation Panel (EEP) is responsible directly to USAID and BIFADEC for the review and evaluation of the technical progress of the CRSP. During this reporting period, Dr. Homer Buck, Illinois Natural History Survey (retired), rotated off the EEP, leaving Richard Neal, National Marine Fisheries Service (NMFS), and Roger Pullin, International Center for Living Aquatic Resources Management (ICLARM). A search is currently underway to find a third panel member.

The EEP evaluated all CRSP sites in 1992-93. During the current reporting period, the final report of the External Evaluation Panel was published.

The final report includes program responses to the findings and recommendations of the External Evaluation Panel.

CRSP Publications

CRSP publications are an important part of the CRSPs technology dissemination. A broad domestic and international audience receives our technical and program reports. Approximately 300 people in 42 countries now receive CRSP publications. Technical reports are issued through two series, *Collaborative Research Data Reports* and *CRSP Research Reports.* The goal of *CRSP Research Reports* is to publish all research produced by CRSP activities, with the exception of research related directly to the Global Experiment.

Collaborative Research Data Reports contain the results and data from the Global Experiment, along with interpretations of site-specific results. The first volume of *Collaborative Research Data Report* contains a description of sites and experimental protocols for the Global Experiment. Subsequent volumes focus on each research site separately by experimental cycle.

Other reports published by the CRSP Management Office include Annual Administrative Reports, Quarterly Reports, Program Grant Proposals, Work Plans, and CRSP Directories. *A Ten Year Summary of Activities in Honduras* was also published during this reporting period. The *Handbook of Analytical Methods* compiled by the Materials and Methods Committee of the Technical Committee and the *PONDCLASS Users' Guide* have also been published through the Management Office.

Principles and Practices of Pond Aquaculture was one of the founding documents of this CRSP. At the time of its production, this volume was state of the art and filled a neglected niche in the field of aquaculture. Since its publication in 1983, it has been one of the most requested of CRSP publications. But advances in pond aquaculture made by the CRSP and others require that this valuable resource be updated. A new volume that approaches aquaculture production as part of the larger agroecosystem is in progress, *Dynamics of Pond Aquaculture.* The Management Office has contracted with Lewis Publications to publish the book. CRSP researchers are collaborating in writing the sixteen chapters that make up the book, and that approach aquaculture production as part of the larger agroecosystem.

In addition to PD/A CRSP-produced publications, the Management Office contributes to USAID's program reviews, publications, and presentations. Administrative and technical reports prepared and disseminated during this reporting period are briefly described below and may be ordered from the Management Office. Technical reports that were not processed by the Management Office are listed in the Appendix.

Administrative Reports

Annual Administrative Report

Egna, H., J. Bowman, B. Goetze, and N. Weidner, eds. 1994. Eleventh Annual Technical Report 1993, Pond Dynamics/Aquaculture Collaborative Research Support Program. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 178 pp.

Egna, H. and M. McNamara. 1994. Eleventh Annual Administrative Report, Pond Dynamics/Aquaculture Collaborative Research Support Program. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 80 pp.

Quarterly Reports

Pond Dynamics/Aquaculture CRSP, Program Management Office. January 1994. Quarterly Report. October-December 1993. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 14 pp.

Pond Dynamics/Aquaculture CRSP, Program Management Office. April 1994. Quarterly Report. January-March 1994. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 15 pp.

Pond Dynamics/Aquaculture CRSP, Program Management Office. July 1994. Quarterly Report. April-June 1994. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 18 pp.

Pond Dynamics/Aquaculture CRSP, Program Management Office. October 1994. Quarterly Report. July-September 1994. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 16 pp.

Directory

The CRSP directory contains an organizational chart and the addresses of current CRSP members from USAID, BIFADEC, USAID Missions, the CRSP Council, the External Evaluation Committee, the Technical Committee, the Management Entity, the Board of Directors, and the Collaborative Research Projects. The chart is updated annually or semi-annually, as needed.

CRSP Directory. October 1993. Pond Dynamics/Aquaculture CRSP, Program Management Office. Office of International Research and Development, Oregon State University, Corvallis, Oregon.

CRSP Directory. May 1994. Pond Dynamics/Aquaculture CRSP, Program Management Office. Office of International Research and Development, Oregon State University, Corvallis, Oregon.

Newsletters

Aquanews, The Newsletter of the Pond Dynamics/Aquaculture Collaborative Research Support Program, is published quarterly. *Aquanews* serves to inform CRSP participants and others of program activities that are not of a technical nature. It contains information on project activities, meetings, travel of CRSP participants, and site visits. The following issues were published during this reporting period:

Aquanews, Winter 1993, Volume 9, Number 1. McNamara, M., ed. ISSN 1062-4996. PD/A CRSP Program Management Office, Office of International Research & Development, Snell Hall 400, Oregon State University, Corvallis, Oregon.

Aquanews, Spring 1994, Volume 9, Number 2. McNamara, M., ed. ISSN 1062-4996. PD/A CRSP Program Management Office, Office of International Research & Development, Snell Hall 400, Oregon State University, Corvallis, Oregon.

Aquanews, Summer 1994, Volume 9, Number 3. McNamara, M., ed. ISSN 1062-4996. PD/A CRSP Program Management Office, Office of International Research & Development, Snell Hall 400, Oregon State University, Corvallis, Oregon.

Aquanews, Fall 1994, Volume 9, Number 4. McNamara, M., ed. ISSN 1062-4996. PD/A CRSP Program Management Office, Office of International Research & Development, Snell Hall 400, Oregon State University, Corvallis, Oregon.

The Data Analysis and Synthesis Team publishes a newsletter with the goal of improving communication between the DAST and the Principal Investigators in the field. During this reporting period, DAST Newsletter Nos. 15 and 16 were produced and distributed.

Technical Reports

CRSP Research Reports

Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. 1993. The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L.). CRSP Research Report 93-56, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University,

Corvallis, Oregon, USA. [Originally published in *Aquaculture and Fisheries Management* 24:483-493, 1993.]

Boyd, C.E. and D. Teichert-Coddington. 1993. Relationship between wind speed and reaeration in small aquaculture ponds. CRSP Research Report 93-57, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquacultural Engineering* 11:121-131, 1992.]

Teichert-Coddington, D.R. and B.W. Green. 1993. Influence of daylight and incubation interval on water column respiration in tropical fish ponds. CRSP Research Report 93-58, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Hydrobiologia* 250: 159-165, 1993.]

Knud-Hansen, C.F. and A.K. Pautong. 1993. On the role of urea in pond fertilization. CRSP Research Report 93-59, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture* 11:273-283, 1993.]

Shrestha, M.K. and C.F. Knud-Hansen. 1994. Increasing attached microorganism biomass as a management strategy for Nile tilapia *(Oreochromis niloticus)* production. CRSP Research Report 94-60, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquacultural Engineering* 13:101-108, 1994.]

Springborn, R.R., A.L. Jensen, W.Y.B. Chang and C. Engle. 1994. Optimum harvest time in aquaculture: An application of economic principles to a Nile tilapia, *Oreochromis niloticus* (L.), growth model. CRSP Research Report 94-61, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture and Fisheries Management* 23:639-647, 1992.]

Hopkins, D.D. and D. Pauly. 1994. Instantaneous Mortalities and Multivariate Models: Applications to Tilapia Culture in Saline Water. CRSP Research Report 94-62, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Multivariate methods in aquaculture research: Case studies of tilapias in experimental and commercial systems.* M. Prein, G. Hulata, and D. Pauly (eds.). ICLARM Stud. Rev. 20, 1993.]

Green, B.W. and D.R. Teichert-Coddington. 1994. Production of *Oreochromis niloticus* fry for hormonal sex reversal in relation to water temperature. CRSP Research Report 94-63, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *J. Appl. Ichthyol* 9:230-236, 1993.]

Engle, C.R., M. Brewster, F. Hitayezu. 1994. An economic analysis of fish production in a subsistence agricultural economy: The case of Rwanda. CRSP Research Report 94-64, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *J. Aqua. Trop.* 8:151-165, 1993.]

Knud-Hansen, C.F. and T.R. Batterson. 1994. Effect of fertilization frequency on the production of Nile tilapia *(Oreochromis niloticus)*. CRSP Research Report 94-65, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture* 123:271-280, 1994.]

Teichert-Coddington, D.R., R. Rodriguez, and W. Toyofuku. 1994. Cause of cyclic variation in Honduran shrimp production. CRSP Research Report 94-66, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *World Aquaculture* 25(1):57-61, March 1994.]

Springborn, R.R., A.L. Jensen, and W.Y.B. Chang. 1994. A variable growth rate modification of von Bertalanffy's equation for aquaculture. CRSP Research Report 94-67, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture and Fisheries Management* 25:259-267, 1994.]

Diana, J.S., D.J. Dettweiler, and C.K. Lin. 1994. Effect of Nile tilapia *(Oreochromis niloticus)* on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. CRSP Research Report 94-68, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Canadian Journal of Fisheries and Aquatic Sciences* 48(2):183-190, 1991.]

Ayub, M., C.E. Boyd, and D. Teichert-Coddington. 1994. Effects of urea application, aeration, and drying on total carbon concentrations in pond bottom soils. CRSP Research Report 94-69, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *The Progressive Fish-Culturist* 55:210-213, 1993.]

Boyd, C.E. and D. Teichert-Coddington. 1994. Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds. CRSP Research Report 94-70, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Journal of the World Aquaculture Society* 25(3):210-213, 1994.]

Hopkins, K.D. 1994. Reporting fish growth: a review of the basics. CRSP Research Report 94-71, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Journal of the World Aquaculture Society* 23(3):173-179, 1992.]

Hopkins, K.D. and J.D. Bowman. 1994. A research methodology for integrated agriculture-aquaculture farming systems. CRSP Research Report 94-72, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in Jaw-Kai Wang, ed. *Techniques for Modern Aquaculture, Proceedings of an Agricultural Engineering Conference*, *21-23 June 1993. Spokane, Washington.* 89-98. American Society of Agricultural Engineers. St. Joseph, MO, USA.]

Diana, J.S., C.K. Lin, and K. Jaiyen. 1994. Supplemental feeding of tilapia in fertilized ponds. CRSP Research Report 94-73, Pond Dynamics/Aquaculture CRSP, Office of International Research &

Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Journal of the World Aquaculture Society* 25(4), 1994.]

Knud-Hansen, C.F. 1994. Pond history as a source of error in fish culture experiments: a quantitative assessment using covariate analysis. CRSP Research Report 94-74, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture* 105:21-36, 1992.]

Green, B.W. and D.R. Teichert-Coddington. 1994. Growth of control and androgen-treated Nile tilapia, *Oreochromis niloticus* (L.), during treatment, nursery and grow-out phases in tropical fish ponds. CRSP Research Report 94-75, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture and Fisheries Management* 25:613-621, 1994.]

Teichert-Coddington, D. and B. Green. 1994. Comparison of two techniques for determining community respiration in tropical fish ponds. CRSP Research Report 94-76, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture* 11:41-50, 1993.]

Teichert-Coddington, D. and B. Green. 1994. Tilapia yield improvement through maintenance of minimal oxygen concentrations in experimental grow-out ponds in Honduras. CRSP Research Report 94-77, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquaculture* 118:63-71, 1993.]

Teichert-Coddington, D.R., M. Peralta, and R.P. Phelps. 1994. Seepage reduction in tropical fish ponds using chicken litter. CRSP Research Report 94-78, Pond Dynamics/Aquaculture CRSP, Office of International Research & Development, Oregon State University, Corvallis, Oregon, USA. [Originally published in *Aquacultural Engineering* 8:147-154, 1989.]

Appendix A. List of Acronyms and Definitions

AID Agency for International Development

AIT Asian Institute of Technology, Thailand

ANOVA Analysis of Variance

AU Auburn University

Bmax number of binding sites

Baseline Data that information and data base in some sector or aspect of a developing country which is necessary to measure change in the future

BFAR Board for Food and Agriculture Research

BIFADEC Board for International Food and Agricultural Development and Economic Cooperation

Bilateral Programs assistance programs involving arrangements between a single developing country and a single donor country

Board of Directors an advisory body selected to assist, advise, and make policy recommendations

(for a CRSP) to the ME in the execution of a CRSP; members represent the interests of the CRSP

BW body weight

CGIAR Consultative Group on International Agricultural Research

CIFAD Consortium for International Fisheries and Aquaculture Development

Collaborating Institutions institutions which form a partnership arrangement with a lead participating U.S. institution to collaborate on a specific research project

CRSP Collaborative Research Support Program

d day

DAST Data Analysis and Synthesis Team

Data Analysis and Synthesis the process of compiling and analyzing information about pond culture systems from diverse sources into a coherent, usable format that can be applied to the development of predictive models and to the improvement of the efficiency of these systems

DE digestible energy

dNPP diel net primary productivity

DO dissolved oxygen

DOF Royal Thai Department of Fisheries

DP digestible protein

dR daytime respiration

EE 17a-ethynylestradiol

EEP External Evaluation Panel - senior scientists not involved in the CRSP and selected externally for their ability to evaluate objectively the scientific progress and relevance of a CRSP program on an ongoing basis

Experimental Protocol a detailed plan of a field experiment which specifies experimental methods, sampling schedules, data collection, etc.

Experimental Treatment fish cultural practices (e.g., fertilizer application, supplemental feeding, etc.) which modify the physical, chemical, and biological environment

Expert System a computerized compilation of knowledge that is used to make "intelligent" decisions about the management or status of a process or system

FAC Freshwater Aquaculture Center, Central Luzon State University, Philippines

FCR feed conversion ratio

FDA U.S. Food and Drug Administration

Field Experiments controlled fish production experiments in which quantitative responses to different levels of treatments are measured

FTE Full Time Equivalent

GFY gross fish yield

Global Experiment the overall plan of a CRSP for research on problems and constraints, global in nature, whose results are applicable and transferable regionally and globally (worldwide)

GOR Government of Rwanda

Grant Agreement the formal legal document which represents a binding agreement between AID and the ME institution for a CRSP; this is the legal document for the CRSP recognized as such by AID and the recipient institutions

Grant Proposal the formal document submitted by an ME to AID, proposing a CRSP for receiving a grant outlining the manner of implementation of the program and showing the budgetary requirements

Host Country (HC) a developing country in which a CRSP has formal activities

i.d. inner diameter

INAD Investigational New Animal Drug permit

INRP International Research Project

Institutional Development improvement in the capability of institutions in developing countries to conduct development programs for agriculture and other sectors, or for implementing educational/training, research, health, and other public programs. This may include improvements in physical facilities, equipment, furnishings, transportation, organization, but refers primarily to the development and training of a professional cadre.

JCARD Joint Committee on Agricultural Research and Development (formerly Joint Research Committee), BIFADEC

JRC Joint Research Council, USAID

LDC Lesser Developed Countries

Lps Lampiras, Honduran currency

Matching Requirement that sum of resources, financial or in-kind, which participating U.S. institutions must collectively contribute to a CRSP program as defined in the grant (also called "cost sharing")

mb mibolerone

ME Management Entity

MINAGRI Ministere de l'Agriculture, de l'Elevage, et de l'Environement (Ministry of Agriculture, Livestock and Environment)

Mission a formally organized USAID unit in a developing country led by a Mission Director or a country representative

MOU Memorandum of Understanding

MRTC Mariculture Research and Training Center, University of Hawaii

MSU Michigan State University

MT 17a-methyltestosterone

NFY net fish yield

NGO Non Government Organization

NIFI National Inland Fisheries Institute, Thailand

NMFS National Marine Fisheries Service

NPP net primary productivity

nR nighttime respiration

NRP National Research Project

OIRD Office of International Research and Development

OSU Oregon State University

PAR photosynthetically active radiation

Participating Institutions those institutions that participate in the CRSP under a formal agreement with the Management Entity which receives the AID grant

PD/A CRSP Pond Dynamics/Aquaculture Collaborative Research Support Program

PI Principal Investigators - scientists in charge of the research for a defined segment or a scientific discipline of a CRSP

PMO Program Management Office

PPC Program and Policy Coordination

Practices fish cultural activities related to design, management, and operation of pond culture systems

Predictive Models mathematical models used to simulate the processes occurring in pond systems; in the context of this CRSP, predictive models are used as analytical and management tools to improve the efficiency of pond systems

Principles the physical, chemical, and biological processes occurring in pond systems and their interactions

PVC polyvinyl chloride, common thermoplastic resin

RENARE Department of Renewable Natural Resources, Honduras. Now known as Dirección General de Pesca y Acuicultura, Honduras

R&D Bureau (R&D/AGR) (Formerly S&T/AGR Bureau of Science and Technology) central bureau of AID in Washington, charged with administering worldwide technical and research programs for the benefit of USAID-assisted countries

RWF Rwandan franc

SPN Service de Pisciculture Nationale (National Fish Culture Service)

SRP soluble reactive phosphorus

Subgrant Agreement a document representing a subagreement made between the ME and a participating institution under authority of the grant agreement by the ME and AID

TA total alkalinity

TAN total ammonia nitrogen

TC Technical Committee - a group of scientists participating in the research of the CRSP as PI's, selected to help guide the scientific aspects of the research program of a CRSP

TH total hardness

THB Baht, Thai currency

Title XII the Title XII Amendment to the International Development and Food Assistance Act of 1975 as passed by the United States Congress and subsequently amended

TSS total suspended solids

TVS total volatile solids

UAPB University of Arkansas at Pine Bluff

UCD University of California at Davis

UH University of Hawaii

UM University of Michigan

UNR Universite Nationale du Rwanda

UO University of Oklahoma

USAID United States Agency for International Development

USAID Project Officer an official AID employee designated to oversee a CRSP on behalf of AID

WID Women In Development

yr Year

Appendix B. Table of Contents for Twelfth Annual Technical Report

I. CRSP Research Program Background 1

II. Research Program Accomplishments 9

Global Experiment and Related Investigations 9

- Validation of PD/A CRSP Pond Management Strategies 12
  Yield Characteristics of Two Species of Tilapia under Two Different Pond Environments 18
  Nutrient Input Management by the Computer Program, PONDCLASS,
  and by Concentration of a Key Nutrient 20
  Management of Carbon Dioxide Balance for Stability of Total Alkalinity
  and Phytoplankton Stocks in Fertilized Fish Ponds 28

Technical Reports: Global Studies and Activities 33

- Minding the Pond: Feeding, Fertilization, and Stocking Practices for Tilapia Production in Rwanda, Thailand, The Philippines and Honduras 34
  Data Base Management 46
  POND: A Decision Support System for Pond Aquaculture 48

Technical Reports: Africa 68

- Binding Sites for the Masculinizing Steroid Mibolerone in the Gonadal Tissue of Adult Nile Tilapia (*Oreochromis niloticus*) 68
  Effects of Form of Defatted Rice Bran Offered on Nile Tilapia Production in Ponds 79
  Effect of 17alpha-Methyltestosterone on the Growth of Two Tilapia Species, *Oreochromis aureus*and *Oreochromis mossambicus*, in Fresh Water 84
  Use of 17alpha-Methyltestosterone for Tilapia Sex Reversal 91
  Progeny Testing to Identify "YY" Male Tilapia 94
  Bioconversion of Gastropods by Black Carp in Egyptian Fish Culture Ponds 97
  Bioconversion of Nuisance Aquatic Plants by Grass Carp in Egyptian Fish Culture Ponds 100
  Interaction of Grass Carp and Black Carp in Egyptian Fish Culture 103

Technical Reports: Central America 105

- Estuarine Water Quality and Sustainable Shrimp Culture in Honduras 105
  Varying the Proportion of *Colossoma macropomum* and
  Oreochromis niloticus in Polyculture 126
  Inorganic Fertilization and Feed Reduction in Commercial Production of *Penaeus vannamei* during Wet and Dry Seasons in Honduras 136

Technical Reports: Southeast Asia 147

- Timing of Supplemental Feeding for Tilapia Production 147
  Stocking Density and Supplemental Feeding in Tropical Fish Ponds 153
  Supplemental Feeding of Tilapia in Fertilized Ponds 156

Technical Reports: United States 157

- Data Analysis and Synthesis Team 158
  Respiration Dynamics in Aquaculture Ponds 159
  Stochastic Modeling of Temperature in Stratified Aquaculture Ponds 170
  Calculation of pH in Fresh and Sea Water Aquaculture Systems 179

Special Topics Research 180

Economic Analysis of Different Tilapia Pond Culture Systems in Egypt 181
Effect of Stocking Rate on Growth and Yield of Nile Tilapia 190
Mass Production of Nile (*Oreochromis niloticus*) and Blue (*O. aureus*) Tilapia Fry 192
Growth of Control and Androgen-Treated Nile Tilapia, *Oreochromis niloticus* (L.), during Treatment, Nursery and Grow-Out Phases in Tropical Fish Ponds 196
Production of *Oreochromis niloticus* Fry for Hormonal Sex Reversal in Relation to Water Temperature 197
Phosphorus Fertilization Strategy in Fish Pond Based on Sediment Phosphorus Saturation Level 198
Determination of Phosphorus Saturation Level in Relation to Clay Content in Pond Mud 199

Appendix

A. List of Acronyms and Definitions 201
B. Twelfth Annual Administrative Report, Table of Contents 207

Twelfth Annual Administrative Report Photos

Dedication Photo -- CRSP administrators, CRSP researchers and family.
Kigembe Rwanda

Central Laboratory for Agricultural Research
Egypt,
photo credit : H. Egna

Weighing fish
Ndorwa, Rwanda
photo credit : H. Egna

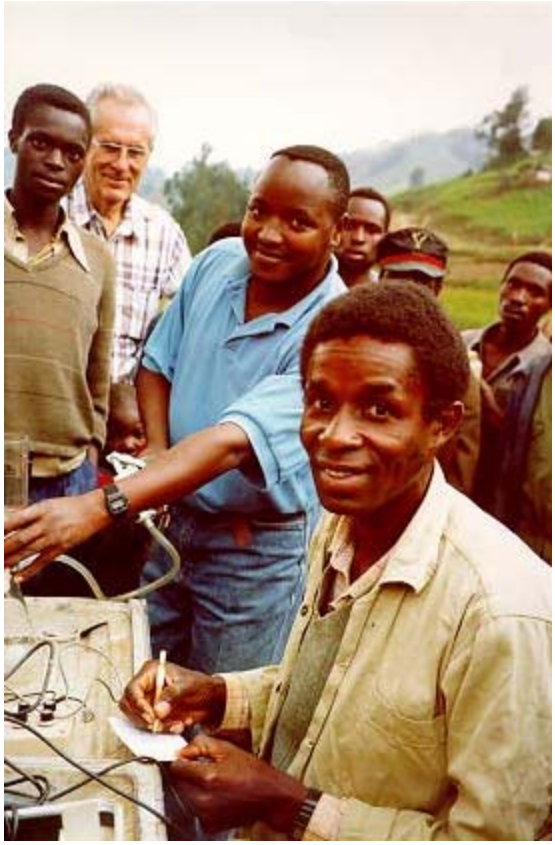
CRSP researchers taking water quality samples.
Ndorwa, Rwanda

Seining the tilapia pond
Rwanda
photo credit : H. Egna

Oregon State University Researcher gives a workshop on fish reproduction
Abbassa, Egypt,Central Laboratory for Aquaculture Research
photo credit : H. Egna

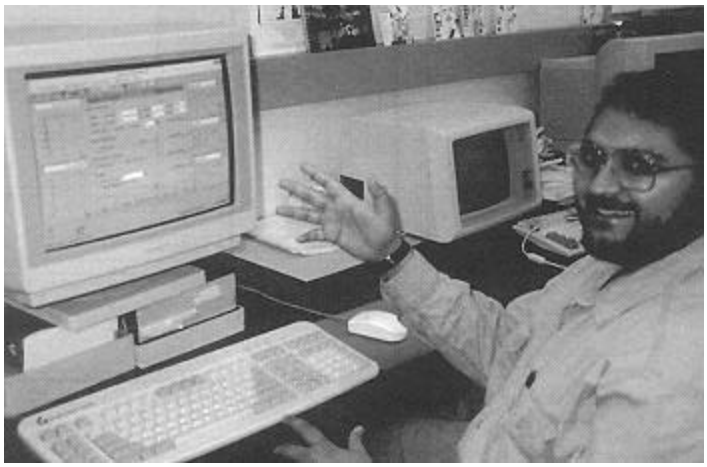
Central Laboratory for Aquaculture Research
Abbassa, Egypt,
photo credit : H.Egna

Small Boy Collecting Water at Fish Culture Station
Butare Rwanda
photo credit : W. Sein



CRSP researchers
Ndorwa, Rwanda,
photo credit : H. Egna

CRSP and Oregon State University group photo
San Diego, California, World Aquaculture Society Meeting



Oregon State University, Digital Analysis Synthesis Team, CRSP graduate student researcher
Corvallis, Oregon
photo credit : M. McNamara

Central Laboratory for Aquaculture Research
Egypt
photo credit : H Egna

Central Laboratory for Aquaculture Research
Abbassa, Egypt
photo credit : H. Egna