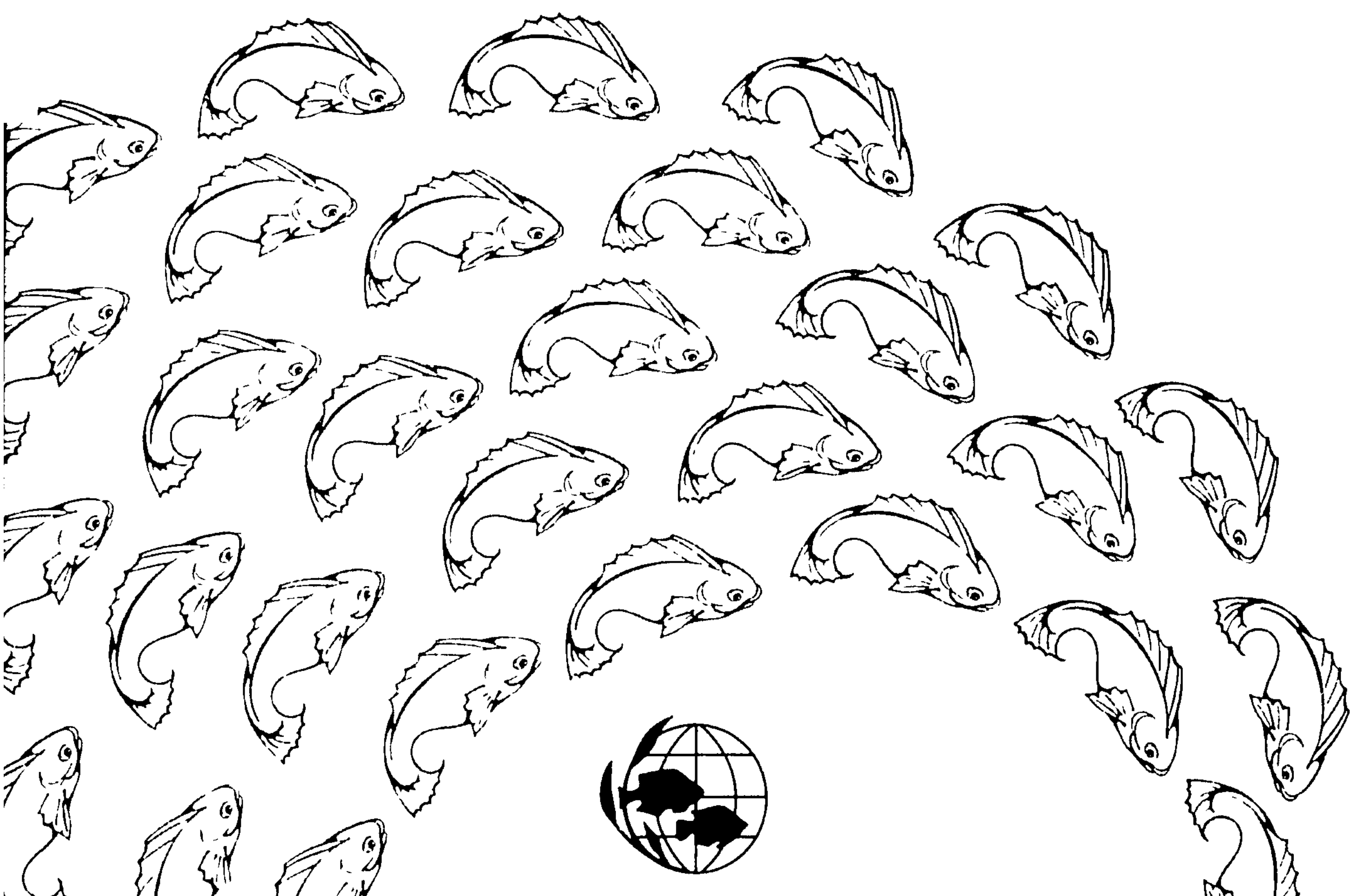
Title XII
Collaborative Research Support Program
Pond Dynamics/Aquaculture
Seventh Annual Administrative Report 1989



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TITLE XII
COLLABORATIVE RESEARCH SUPPORT PROGRAM

POND DYNAMICS/AQUACULTURE

SEVENTH ANNUAL ADMINISTRATIVE REPORT

(1 SEPTEMBER 1988 TO 31 AUGUST 1989)

May 1990

This administrative report addresses the management and technical accomplishments of the Pond Dynamics/Aquaculture Collaborative Research Support Program during the reporting period from 1 September 1988 to 31 August 1989. Program activities are funded in part by the United States Agency for International Development Grant Number: DAN-4023-G-SS-7066-00

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ACKNOWLEDGEMENTS

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INTRODUCTION

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 and nutritional problems. The program is supported in part by U S. Agency for International Development (AID) grants awarded in 1982 and 1987, under authority of the International Development and Food Assistance Act of 1975 (P.L. 94-161). Oregon State University is the Management Entity for the CRSP and has technical, administrative, and fiscal responsibility for the performance of grant provisions.

The PD/A CRSP is a cohesive program of research that is carried out in selected developing countries and the U.S by teams of U.S. and Host Country scientists. The U.S institutions participating in the program are Auburn University, the University of California at Davis, 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.

CRSP research activities were formally initiated on September 1, 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. Due to funding constraints during 1986 and 1987, the CRSP was faced with reducing its operations A plan for reorganization was submitted in December 1986 to the joint JCARD Panel on CRSP's and the USAID Agricultural Sector Council Subcommittee. The plan, which went into effect on September 1, 1987, called for maintaining a presence in each of the USAID geographical areas originally selected. Country sites were reduced to three: Rwanda, Thailand, and Panama. However, political initiatives in Panama in 1987 made it necessary for the CRSP to relocate to Honduras Largely through the efforts of Auburn University, the CRSP was welcomed back into Honduras in April 1988 and resumed experiments with the assistance of the Honduran Department of Renewable Natural Resources (RENARE) in August 1988.

With the completion of the first three cycles of standardized global experiments (1982-1987), the CRSP began to focus on the statistical interpretation of data that were collected at the six project sites. The 1987-1990 research program was modified successfully to reflect the reduction in sites without changing the overall emphasis of the CRSP. The global nature of the program remains intact; experimental protocol conforms to that of the previous three cycles. Field experiments blend program-oriented and project-oriented (site-specific) considerations in response to the results of the earlier experiments. Subsequent experiments will emphasize calibration and verification of predictive models under field conditions and field testing of pond management practices.

The second Triennial Review of the Pond Dynamics/Aquaculture CRSP was completed during this reporting period. The External Evaluation Panel, composed of eminent scientists in aquaculture, and an Internal Management Review team, consisting of staff from AID and BIFAD, participated in the CRSP Annual Meeting in Hawaii in January 1988. While there, they conducted interviews with Principal Investigators from the various projects, Program Management Office staff, and the Board of Directors. Members of the review teams visited former as well as present CRSP field sites throughout the winter and spring of 1988. The findings of the reviewers were discussed during the Seventh Annual Meeting in Davis, California on May 2-4, 1990. Generally, the reviewers found that the administrative and technical management of the Program was functioning well and that activities were carried out successfully given the limitations of the overall program budget.

The final report and recommendations of the Triennial Review were included in the proposal for continued funding through 1995, along with a response from the Program Management Office. The proposal (also called the 1990-1995 Continuation Plan) was presented in May 1989 and then revised and resubmitted in September 1989 to JCARD, BIFAD, and AID in Washington, D.C. The major changes in the September version were the inclusion of socioeconomic and on-farm studies, and a reduction in the proposed budget to reflect the present -- and probable --AID allocation (i.e., level-funded at $920,000 per annum). In order to reduce the budget, the Technical Committee, the Board of Directors, and the Management Office decided to remove several projects from the revised version of the proposal. However, these projects were included in the Appendix of the proposal to take advantage of future funding opportunities. The second presentation in September resulted in a recommendation to AID to fund the project at the full level (1 13 million per annum) should additional funds become available.

The Basic Ordering Agreement (BOA), a new financial instrument to facilitate buy-ins, was installed in the fall of 1989 In the face of continued funding constraints, AID has encouraged the CRSP's to expand activities by seeking funding from other sources. The Pond Dynamics/Aquaculture CRSP has received some funding of this type in past years but now plans to pursue these activities more routinely and seriously. Additional funding is particularly needed to conduct socioeconomic studies and to transfer technologies developed by our researchers A new economic study was initiated during this reporting period, and proposals have been submitted to expand this study into a fully-funded CRSP subproject. We expect to see the growth of this aspect of our program in the next few years.

The purpose of this report is to summarize technical accomplishments and program organization and management during the period from September 1, 1988 through August 31, 1989. The CRSP Global Experiment and the attendant analysis of data were the dominant activities during this reporting period. Notable progress also was made in the publication of CRSP research results.

SUMMARY OF ACTIVITIES AND ACCOMPLISHMENTS: 1 SEPTEMBER 1988 TO 31 AUGUST 1989

The major accomplishments of this reporting period included the completion of all research activities described in the CRSP Fourth Work Plan, further work on the development, calibration, and validation of models and expert systems, and continued efforts toward the dissemination of results and information.

Data Analysis and Synthesis

The University of Michigan component of the Data Analysis and Synthesis Team (DAST) continued to focus its efforts on the development of methods for analyzing fish growth and production and pond limnology. Statistical analyses of the Central Data Base were used to identify ecological relationships important for understanding limnology, and production models were developed to integrate the variables that are important to fish growth and yield. Several published numerical growth models were compared The most versatile of these, Von Bertalanffy's Growth Model, was modified to predict fish growth in aquaculture ponds more accurately. A multivariate statistical method to be used with Von Bertalanffy's model was developed for examining differences in growth patterns among sites, ponds, and treatments. Methods for identifying the factors responsible for growth reduction toward the end of production cycles and the differences among growth patterns at different geographical sites are still being developed.

Work on the validation and calibration of three mechanistic models described in previous reports continued at the University of California at Davis (UCD) Collaborative work with the University of Hawaii's Mariculture Research and Training Center and the Hawaii Institute of Marine Biology has provided additional data to be used in the model development process. The improved models will be useful in the analysis of new CRSP data sets and in the formulation of pond management guidelines. A new area of activity undertaken at UCD was the development of descriptive models, based on CRSP data, for the analysis of fish growth histories. Two models were evaluated and compared, one was selected for use in evaluating CRSP Cycle IV data.

At Oregon State University (OSU) work on our expert system, called PONDCLASS, has progressed well. The shell of the system is complete in two versions, for use on IBM and Macintosh personal computers. Computational algorithms are being developed for installation in the shell. Functional relationships that have already been developed for the algorithms include a nutrient requirement function and a water budget function When fully developed, PONDCLASS will advise users about the addition of nutrients to ponds in response to site-specific information that they provide regarding pond characteristics (chemical, physical, and biological) and local economic conditions. PONDCLASS will be a user-friendly, computerized version of the pond management guidelines, and will also serve as the source for the printed version, the Manual of Pond Management Guidelines.

Central Data Base

The Management Entity continues to maintain the CRSP Central Data Base 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 data sets 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 Central Data Base are rare in the aquaculture literature.

The Central Data Base has continued to grow through the inclusion of new data, generated under Work Plan IV, which has been transmitted from the research sites. New templates and "Instructions for Data Entry," created to reflect changes from previous work plans, were distributed to the CRSP participants.

The utility of the Central Data Base extends beyond the needs of the PD/A CRSP. The Central Data Base was designed to facilitate communication with other large databases, such as the Tropsoils CRSP data base, thereby creating opportunities for collaboration. It 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 in PD/A Collaborative Research Data Reports. During this reporting period information and/or data have been sent to researchers in India, Mexico, and the United States in response to requests for access to CRSP data.

Field Sites

Researchers in Rwanda (National University of Rwanda and Auburn University) continued to study the use of locally available organic materials as inputs for increasing fish production. Of seven methods of compost preparation tested, compost materials submerged in enclosures in the pond resulted in significantly greater production than any other method. The in-pond compost mixture containing the highest fraction of chicken manure (50%) resulted in the greatest production (1323 kg/ha/yr). A complementary study confirmed that the common practice of submerging compost materials in the pond is more effective than the alternative of broadcasting the materials over the pond surface.

Economic studies comparing pond operations above 1500 m with those below 1500 m were initiated by conducting personal interviews with 60 fish farmers. These studies will examine fish farming costs and returns and compare labor efficiency in ponds at different altitudes. Data analysis will be completed in the coming year.

Host Country Special Topics Research included a profitability study of integrated pig-tilapia culture, a study of plankton communities in ponds at the Rwasave Fish Culture Research Station, and experiments to establish procedures for sex reversal of tilapia fingerlings. All studies contributed to a better understanding of pond dynamics and to the development of improved production techniques for ponds in cooler parts of the tropics. An additional special research topic was an assessment of the impact of *Clarius gariepinus* stocks on other fishes in the Lake Ihema fishery through a study of its feeding habits and parasitism.

Research efforts in Honduras centered on tilapia production problems at the freshwater site at Comayagua and penaeid shrimp culture at the Granjas Marinas San Bernardo shrimp farm. At the El Carao station (Comayagua), researchers from the Honduran Department of Renewable

Natural Resources and Auburn University conducted a stocking density experiment using all-male fish, and found that although production increased with stocking density, the average weight of fish produced decreased with density. At the highest stocking density (two fish/m^2) production was 2499 kg/ha but average fish weight was only 148 g. In another experiment, various combinations of organic fertilizer (chicken litter) and a commercial feed were added to tilapia production ponds. Net incomes from the various treatments were not significantly different, even though the treatments with higher daily feed rations resulted in both greater production and greater mean weights of harvested fish. In a third study, which investigated the possible effects of hormones on fish growth, the growth of all-male tilapia was found to be similar throughout the treatment, nursery, and grow-out phases, whether or not hormones had been administered to the fish as fry. This indicated that the hormone used had no anabolic effect on fish growth.

At the Granjas Marinas San Bernardo farm the use of organic and inorganic fertilizers in shrimp production ponds was investigated. One study found that shrimp yields were not increased by the addition of inorganic fertilizer at any of the levels tested, and that the greatest economic return was obtained using no inorganic nutrient inputs. In another study, the use of chicken litter instead of commercial feed during the first four and eight weeks of production did not result in increased yield, indicating that chicken litter cannot be profitably substituted for feeds in the early phases of commercial shrimp production.

In Thailand, workers from the Asian Institute of Technology and the University of Michigan repeated a density experiment previously conducted using sex-reversed fish rather than hand-sexed fish. The results of the new experiment were similar to those previously reported: stocking density was inversely proportional to fish growth, but had little physical or chemical effect on the pond environment and did not affect fish yield within the range of densities tested. As expected, reproduction was greatly reduced when sex-reversed fish were stocked. An experiment to evaluate the effects of density on growth and maturation of tilapia was also conducted; the experimental phase was completed in September of 1989 and the analysis of results is underway.

At Ayutthaya, researchers from the National Inland Fisheries Institute (Royal Thai Department of Fisheries) and Michigan State University conducted an experiment to generate data for further development of a protocol for supplementing chicken manures (nitrogen-deficient) with nitrogen from inorganic sources. Increased fertilization rates under this regime were tested, and the highest rate of fertilization resulted in an average fish yield of 6071 kg/ha/yr, more than 1000 kg/ha/yr greater than normally expected for ponds receiving high rates of fertilization and supplemental feeds.

Information Dissemination

Ancillary to the Global Experiment, but still important to the overall goals of the CRSP, are activities geared toward country-specific research and extension needs. All U.S. staff overseas contribute some time to extension work such as training students and technicians, teaching short courses on aquaculture, conducting site-specific experiments, and working with local extension agents and farmers. These activities are described in the sections Project Development and Public Service, and Host Country Special Topics Research Reports.

During this reporting period, CRSP researchers and staff from the Program Management Office greatly broadened the contact of this CRSP with the world aquaculture community through dissemination and publication of research results. The rate at which results are being published in the scientific literature continues to climb. The CRSP now has a list of publications (including theses, reports, and presentations) that numbers over 300 and is distributed to a broad domestic and international audience Detail on our results and publications is presented throughout this report

CRSP RESEARCH PROGRAM BACKGROUND

The Pond Dynamics/Aquaculture CRSP has three components:

- the Global Experiment;
- a U S. research component composed of projects conducted by the Data Analysis and Synthesis Team as part of the Global Experiment and Special Topics Projects at participating U S. universities, and
- Special Topics Projects in Host Countries.

Under the initial phase of the Program (1981-1987) the Global Experiment and related data synthesis activities were the major focus of this CRSP and accounted for more than 90% of the total research program Special Topics Projects in the U.S and in Host Countries complemented the Global Experiment. Under the Continuation Plan (since 1987) increasing emphasis has been placed on site-specific research and the testing of hypotheses developed during the first three experimental cycles. These research activities, their purposes, and their present status are described in this section.

The Global CRSP Experiment

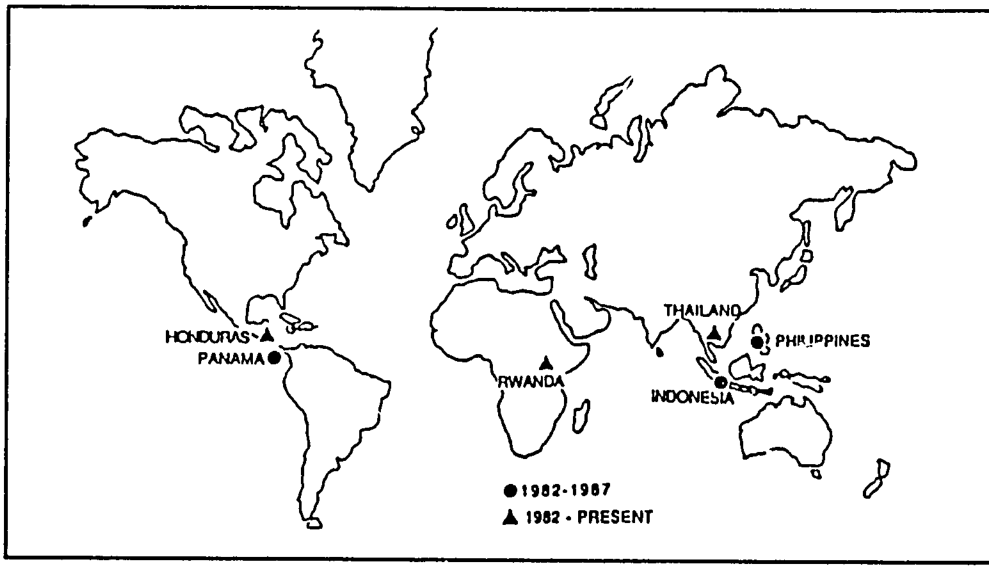
The long-range goal of the CRSP is to increase the availability of animal protein in less-developed countries through pond aquaculture The strategy adopted by the CRSP in pursuit of this goal is to undertake the basic research required to improve the efficiency of pond culture systems. A technical plan consistent with this strategy was developed under a planning study funded by USAID (Specific Support Grant AID/DSAN-G-0264). The technical plan reviewed and synthesized literature on state-of-the-art pond aquaculture and undertook overseas site visits to determine research needs and availability of local support in less-developed countries. The findings from these surveys were then translated into planning guidelines

In the course of the planning activities it become apparent that there are two important aspects of improving the efficiency of pond culture systems. First, there is a need to improve the technological reliability of pond production systems. Second, there is a need for economic optimization consistent with local conditions

The need for improved production technologies is manifest in the wide variation observed in the productivity of different pond systems. Pond aquaculture has been practiced for centuries as a highly developed art form and the literature is replete with reports about practices that have produced high yields However, when the same practices are applied to other ponds, the results are not reproducible It is clear that there are subtle differences regulating productivity from pond to pond, but the nature of this regulation remains obscure.

The need for rigorous economic analyses of pond aquaculture systems is typically encountered in attempting to formulate appropriate aquaculture development strategies, both in developing countries and in the U.S In order to determine if currently-used pond management practices are the most efficient approach to fish production, it is necessary to develop quantitative production functions to facilitate analyses of the various strategies or combinations thereof It is not presently possible to develop these functions without making numerous and often tenuous assumptions, because the dynamic mechanisms regulating the productivity of the ponds are poorly understood and the existing data base is inadequate The common denominator in improving production technologies on the one hand and facilitating economic analyses on the other, therefore, is clearly an improved understanding of pond dynamics

The Pond Dynamics/Aquaculture CRSP is unique relative to other CRSP's in several ways. The most visible difference is that it is funded at a substantially lower level than some CRSP's. A less-obvious difference is that whereas other CRSP's are composed of a cluster of related projects organized on disciplinary or geographical bases, this CRSP is organized around a single global experiment that involves all of its participants. Additionally, this CRSP is one of the few that was planned by the participating institutions.



Experimental Design

During the planning of this CRSP, it became apparent that the inadequacy of the existing pond aquaculture data base was a major constraint to improving the efficiency of pond culture systems. The abundant technical literature about pond aquaculture can provide general guidelines for the operation of pond culture systems. However, because of the lack of standardization in experimental design, data collection, and analysis, these reports cannot be statistically compared to one another and are consequently of limited utility for predicting the performance of pond culture systems. The approach taken by the CRSP to develop quantitative expressions to improve production technologies and facilitate economic analyses has been to develop a standardized data base that can be used to quantitatively evaluate pond performance over a broad range of environments.

The initial statistical design for the experiment involved monitoring environmental and fish production variables at seven geographical locations. The location of project sites was carefully selected to include a geographical cross-section of the world where advances in pond aquaculture would be most beneficial and apt to succeed Since September 1, 1987, the program has conducted experiments in only three of the countries originally selected, but continues to represent the three major regions of the tropics—Southeast Asia, Africa, and Latin America. All of the sites lie within a zone 15 degrees north or south of the equator. Observations specified in annual work plans are made on 12 or more ponds of similar size at each location. The variables observed, frequency of observation, and materials and methods are uniform for all locations.

Observations at each location are analyzed by the research team involved at that location. Data from all sites are also filed in a centralized CRSP data base, where they are accessible for analysis by the Data Analysis and Synthesis Team. Standard statistical methods are used to test hypotheses about correlations between variables and to evaluate the sources of variation within ponds, between ponds within locations, and between locations. Because of the relatively large number of locations and ponds at each location, the experimental design has substantial statistical power.

CRSP Work Plans

The CRSP technical plans are developed by the CRSP Technical Committee. For the first three cycles, each CRSP Work Plan represented a detailed experimental protocol for one experimental cycle. A cycle involved two series of observations of four to five months duration One set of observations was made during the dry season and the other during the wet season.

Five work plans have been developed to date. The rationale of the First Work Plan was to manage all ponds in exactly the same way to establish a detailed baseline of data on pond variables. The plan specified standardized methods for pond preparation and monitoring. It was developed at a meeting of CRSP participants in Davis, California on March 2-3, 1983.

The Work Plan for the second experimental cycle was developed at a meeting of CRSP participants in Atlanta, Georgia on April 10-12, 1984 At this meeting, participants reviewed accomplishments and discussed problems encountered during the first cycle of experiments They then developed a detailed plan for the second experimental cycle. In this experiment, the responses of ponds receiving organic fertilizers were compared to those of ponds receiving inorganic fertilizers.

The third cycle of pond dynamics experiments was developed by CRSP participants at their meeting in Honolulu, Hawaii on March 18-20, 1985 Based upon their experiences to date, Work Plan III was developed to compare the responses of ponds to varying levels of organic fertilizer.

The Fourth Work Plan was developed by the CRSP Technical Committee at their meeting in Portland, Oregon on February 25-26, 1987 CRSP participants reviewed the progress of the first three cycles of the Global Experiment Specific statistical hypotheses were formulated for research in Host Countries and the United States based upon results of previous experiments. New experiments were designed to allow the collection of standardized data for the CRSP Central Data Base. This work plan was further refined at the Technical Committee Meeting in Kona, Hawaii on January 11-14, 1988. As recommended by the External Evaluation Panel during the first Triennial Review, the Fourth Work Plan encompassed two years of experimental protocols rather than one. A biennial work plan was adopted because it avails greater opportunity for results to be analyzed before planning subsequent research

The Fifth Work Plan was developed during the CRSP Annual Meeting in Davis, California on May 1-4, 1989 Work Plan V follows the same approach as the Fourth Work Plan in that different, but related, experiments will be conducted at the various sites. The particular topics to be studied at each site were selected on the basis of the aquaculture research needs of each country. In addition to the research carried out at those sites and by participants in the U.S., experiments with farmer-cooperators in the host countries are planned. Like the Fourth Work Plan, the Fifth Work Plan encompasses two years of experimental protocols; activities specified in it will be undertaken between September 1, 1989 and August 31, 1991.

Data Management

Consistent with its long-term goal, the CRSP is working toward the development of practical pond management models to improve the efficiency of pond culture systems. The development of quantitative models is dependent upon the efficient management of standardized data.

Standardized data are tabulated at each research location in accordance with CRSP work plans. Project teams may conduct independent analyses of their data and publish results if they so desire. However, in all cases, the data are transmitted to a centralized CRSP Data Base maintained by the Management Entity. In this way, the entire data set is available to all CRSP participants, but especially to the CRSP Data Analysis and Synthesis Team (DAST). The DAST was appointed by the CRSP Board of Directors to accomplish data analysis, synthesis, and model development. The various activities of the DAST are supported as part of the U.S. Research Component.

The CRSP Central Data Base was brought completely up-to-date during the previous reporting period This consisted of the translation and verification of all data that were manually entered into personal computers at the seven field sites during the first three experimental cycles. Each site made approximately 90,000 observations per year of 96 variables. This amounted to over one-half million observations that were compiled and translated into standardized formats. During this reporting period, additional data from the fourth experimental cycle were added to the data base.

The current status of the data base facilitates communication with other large agricultural data bases. More importantly, it allows researchers worldwide ready access to data from the Global Experiment.

Second Year in A New Phase of The Global Experiment

During this reporting period, the CRSP continued the new phase of operations begun under the Continuation Plan. Under this plan, which covers CRSP operations from September 1, 1987 through August 31, 1990, research continues at three sites, in Rwanda, Honduras. and Thailand. These sites are representative of the three USAID geographical areas in which the CRSP conducts overseas research: Africa, Latin America, and Southeast Asia. In 1987 the CRSP was able to implement a reduction in the number of research sites without altering the overall emphasis of the program.

The continuation plan centers on a conceptual model of pond culture systems that was developed by CRSP scientists (Figure 1, p. 37). The model was used to identify more specific research needs for incorporation into future work plans. New experiments build on the results of previous CRSP research in a continuing effort to enhance the understanding of the dynamic processes that regulate the productivity of aquaculture ponds.

The Fourth Work Plan, which represents the new phase of research under the reorganization of the CRSP, was implemented on September 1, 1987, and continued through this reporting period. The CRSP Technical Committee refined this work plan during the year and expanded it to a biennial work plan. The Fifth Work Plan, developed during this reporting period, will emphasize the calibration and verification of predictive models under field conditions, and field testing of provisional pond management practices.

RESEARCH PROGRAM ACCOMPLISHMENTS

The Global Experiment

The global nature of the Pond Dynamics/Aquaculture CRSP is evident in the interrelationships among projects. The program consists of tightly knit research projects that share the long-term goal of increasing the availability of animal protein in less developed countries through pond aquaculture.

Project emphasis is placed on standardized experimental design and data collection. Standardization permits the comparison of data from diverse geographical locations. The experimental design involves monitoring environmental and fish production variables in 12 or more ponds at each of three geographical locations in accordance with standardized work plans.

The four cycles of the Global Experiment completed to date followed one another logically. While the main objective changed from cycle to cycle, consistency in experimental design allows the comparison of results between cycles. The global nature of the program will be preserved in the experimental cycles to come. The experimental protocol for the next cycles will remain consistent with that used in the Global Experiment. Furthermore, with the completion of the CRSP Central Data Base, the world aquaculture community may contribute to and begin to use the wealth of data amassed by the CRSP.

Results of the Global Experiment

The fifth year of the CRSP's Global Experiment, under the Fourth Work Plan, was successfully completed at each of the three research locations: Rwanda, Honduras, and Thailand. Cycle IV experiments at the freshwater sites in Rwanda, Thailand, and Honduras focused on the chemical, physical, and biological responses of ponds treated with varying rates of organic fertilizers. *Oreochromis niloticus* (*Tilapia nilotica*) was stocked at all freshwater sites. At the brackish water farm in Honduras (Granjas Marinas San Bernardo), the objective was to compare production resulting from standard management practices used at the farm with several alternative management schemes.

The Fourth Work Plan differs from previous work plans in that hypotheses about pond dynamics are tested in different field experiments at each research location. This procedure allows the CRSP to proceed rapidly through the testing process. The Global Experiment was further enhanced by addition of intensive sampling periods and diel studies *Standard Methods* (Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 1985) continued to be used for recommending materials and procedures for collecting data. Additional detail on the Fourth Work Plan is presented in Appendix A.

Central America: Honduras

Culture of Tilapia with Combinations of Chicken Litter and a Commercial Diet: Water Quality Considerations

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Introduction

Research on nutrient inputs versus tilapia production at El Carao over the past several years has led to a vastly improved understanding of aquaculture and the economics of aquaculture in Honduras. However, much work remains to be done on optimizing economic gain by mixing the use of low-cost manures with high-cost commercial feeds. The point in growth cycles at which it becomes of biological and economical benefit to start adding feeds, in addition to or in place of manure, is also of interest.

Previous CRSP research indicates that plankton populations cyclically increase and decrease, and that the frequency and amplitude of this cycling is probably related to quantity of nutrient input. Since oxygen dynamics are integrally bound to plankton dynamics, more intensive study of plankton cycling may contribute to solutions of oxygen management problems in ponds. However, the frequency of water sampling has not yet been sufficient to adequately document the cycles. Frequency of water sampling can usually be increased only if fewer ponds are sampled. Thus, more frequent sampling of fewer ponds may yield a more complete picture of pond dynamics.

The objectives of this experiment were: to document cyclical changes in water chemistry and biology and to correlate one with the other; to set up a data-logging system on the pond bank; and to refine tilapia production systems based on the costs of feed and chicken litter inputs.

Materials and Methods

Oreochromis niloticus fingerlings (18 g) were stocked into 12 earthen ponds (0.1 ha) at 1 fish/m^2. Three replications of four treatments were randomly assigned to the ponds. Treatments were chicken litter only or chicken litter plus feed (23% crude protein) at 0.5, 1.0, or 2.0% of fish biomass. Chicken litter was applied to ponds at 500 kg/ha/wk, total solids (TS). Feed was offered to fish six days per week, and quantities were adjusted weekly based on projected growth between monthly samples of fish weight.

Chlorophyll *a* and primary productivity (24-hour diurnal oxygen curve method) were measured in all ponds once per week. During oxygen diurnals, oxygen was measured at 0, 25, 50, and 75 cm depth at 0600, 1000, 1430, and 1800 hours, and again the following day at 0600 hours. Total alkalinity and total hardness were measured in all ponds once per month. Total suspended and volatile solids were measured in ponds receiving only chicken litter once per month to coincide with the oxygen diurnal.

Two ponds each from treatments receiving chicken litter only and chicken litter plus feed at 2.0% body weight were measured twice a week for chlorophyll *a*, filterable orthophosphates, total phosphorus, total ammonia nitrogen, pH, primary productivity (diurnal oxygen curve method), and zooplankton density. Zooplankton were filtered from 14 liters of water using an 80-µ mesh net, and were enumerated by the following categories: copepods, cladocerans, rotifers, and nauplii. Zooplankton were counted in duplicate 1-ml samples placed in a Sedgewick-Rafter cell. All water quality variables were analyzed in samples of water combined from 75-cm column subsamples taken from a transect of the pond between 0630 and 0730 hrs.

Wind speed, solar radiation, rainfall, and evaporation were measured daily. Wind speed was measured at 15-minute intervals on days when diurnal oxygen concentrations were measured.

A data-logging system was installed on the pond bank to sample the four ponds described above for oxygen, pH, and temperature every hour, 24 hours-a-day. Water was sampled from ponds via pumps placed at three depths in each pond Water was delivered to a central sampling chamber where sensors connected to a computer were located. Also tested was a system using one pump to deliver a single sample of water taken from six depths simultaneously.

The effects of the treatments on fish production, profitability, and water quality variables were analyzed with a one-way ANOVA. Variables measured frequently in the four ponds were subjected to graphical and regression analyses to document plankton cycling and to correlate this cycling with other water quality and climatic variables. For some graphs, values within each variable column, by pond, were standardized by the following equation. (value-mean)/SD. Differences were declared significant at an alpha level of 0 05. The experiment began on 11 August 1988 and was terminated 132 days later on 20 December 1988.

Results

The mean weights of harvested fish were 132, 136, 162, and 170 g for the 0, 0.5, 1.0, and 2.0% feed treatments, respectively. Mean production was 1234, 1261, 1473, and 1604 kg/ha, respectively. Net daily yield ranged between 8 0 and 10.8 kg/ha. Mean fish weights and production for the two highest feed treatments (1 and 2%) were significantly higher than for the two lowest treatments. However, net income was not different among treatments due to higher costs in the treatments with high feed rations. Mean net incomes (Lempira/ha) were 4784 4556, 5073, and 4726, respectively, for the four treatments. Fish production was low compared to other years at El Carao, especially considering that fish were given a concentrated diet in addition to the fertilization of the ponds.

Feeding fish with supplemental diets did not produce significant differences in water quality compared to ponds which received only chicken litter. Frequent measurements of water quality in four ponds indicated that variation of concentrations with time was sometimes great, and that variation was not correlated in ponds of the same treatments. This illustrates how great a problem it is to obtain a representative sample of a dynamic variable and—a greater problem yet—to interpret the meaning of averages composed of samples from various ponds. Data analyses indicated that large vacillations in climatic variables such as solar radiation, water temperature, and rainfall measurably influenced zooplankton and primary productivity variables; a secondary impact on inorganic variables was sometimes observed.

As in former years, phosphorus increased during the season and was always high. High phosphorus concentrations indicated that phosphorus was not a limiting nutrient to plankton growth, and did not cause changes in phytoplankton populations.

Total ammonia nitrogen was low in all ponds most of the season. Total ammonia was high only when plant biomass declined rapidly, for example, during a plankton die-off. This indicated that nitrogen, released during decomposition of nitrogen-poor chicken litter (low N:C ratio), was consumed immediately by plant material. It also indicated that the application of nitrogen fertilizers in addition to chicken litter stimulated phytoplankton productivity.

Chlorophyll *a* concentrations showed distinct patterns common to all ponds during the season, which indicated that climate was the determining factor. Primary production tended to increase from the start of the season to the end, but did not exhibit many of the seasonal patterns observed in chlorophyll *a*. Daily community respiration was always greater than gross primary production, indicating that the ponds consumed more oxygen than they produced.

Copepods were the dominant zooplankton during the season, followed by rotifers and lastly by cladocerans. Cladocerans are not generally abundant in tilapia ponds since they are easy prey for the tilapia due to their relatively large size and lack of mobility. Copepods are mobile and can evade tilapia. Rotifer populations were large only when copepod populations were small, and a reduction in copepods always preceded an increase in rotifers. This indicates that copepods were directly influencing rotifers, probably through predation.

Stepwise regression analyses were performed to help explain interrelationships among variables. Data were sometimes transformed to daily differences by subtracting the concentration measured on one day from that measured the day before. For analytical purposes, data were divided into observations made during the period of heaviest rainfall (first 71 days) and those made during the rest of the season (days 72-135). Regression analyses were performed on chlorophyll *a* vs zooplankton, water temperature, solar radiation, and rainfall. When the model included data from the whole season, only rotifer abundance was significantly correlated with chlorophyll *a*: $Y = -7.76x + 16.5$, $r^2 = .05$, $n = 122$; where x = ln(rotifers/ml) and Y = chlorophyll *a*. During the first 71 days, $Y = 15.6x_1 - 14.6x_2 + 15.2$, $r^2 = 0.20$, $n = 58$; where x_1 = water temperature (°C) and x_2 = rainfall (cm). During the last part of the season, $Y = -12.9x_1 - 8.2x_2 + 13.2$, $r^2 = 0.14$, $n = 68$; where x_1 = ln(rotifers/ml) and x_2 = water temperature (°C). Thus, at the first of the season during the heavy rains, when there was little increase in rotifer abundance, higher water temperature and lower rainfall resulted in higher measures of chlorophyll *a*. It is probable that water temperature did not directly affect chlorophyll *a* but that it was correlated with other factors, such as solar radiation and zooplankton, that could directly affect concentrations. Rainfall lowered chlorophyll *a* by dilution. During long periods of rainfall, ponds overflow and are maintained at higher levels than during periods of sporadic rainfall. Later in the season when the weather was drier and relatively more stable, variation in chlorophyll *a* was negatively correlated to both rotifer abundance and water temperature. Large rotifer populations can decrease chlorophyll *a* through grazing, and low water temperatures can lead to increased chlorophyll *a* by decreasing the grazing activity of tilapia. Large fluctuations in chlorophyll *a*, rotifers, and water temperature were observed during the last part of the season.

Variation in net primary productivity (NPP) during the study was positively correlated with solar radiation and total copepods. The model was $Y = .001x_1 + .106x_2 + .19$, $r^2 = 0.24$, $n = 106$; where x_1 = total copepods/L, x_2 = solar radiation (E/m²/d) and Y = NPP. During the first 71 days, $Y = -.265x_1 + .057x_2 + .38$, $r^2 = .17$, $n = 54$; where x_1 = ln(rotifers/L) and x_2= solar radiation (E/m²/d). For days 72 to 135, $Y = .001x_1 + .165x_2 - .11$, $r^2 = .39$, $n = 52$; where x_1 = total copepods/L and x_2 = solar radiation (E/m²/d). Solar radiation positively influenced NPP since it was the source of energy. Solar radiation was the single best correlator with NPP in all models. Copepods positively but indirectly affect NPP by preying on the planktivorous rotifers and cladocerans. When copepod populations were high, the phytoplankton grazers (rotifers and cladocerans) were low.

Installation and function of a pondside data-logging system was successful. The use of a pump-operated, water column sampler yielded oxygen, pH, and temperature data that was equal or similar to the average of data taken independently from three depths. The column sampler yielded lower numbers only during periods of intense oxygen production in highly fertile ponds when plankton stratification occurred near the surface of the ponds. In this case, the column sampler, with inlets at six different depths, probably produced data more reflective of the true column average. Three independent pumps were set at depths of 5, 35, and 70 cm. Computer-assisted sampling of ponds can probably be made much simpler, by using 66% fewer pumps and associated tubing, and by using a column sampler such as the one described. Potential problems to be solved in the practical use of data loggers are the frequency of sampling, the types of data to be measured, conversion of large quantities of data into usable forms, and the manipulation and statistical analysis of enormous data bases. Well-conceived uses for the end product (good research objectives) and the use of tools such as column samplers can resolve some of these difficulties.

Effects of Fish Density on Productivity, Economics, and Water Quality of Organically Fertilized Aquaculture Ponds

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Introduction

Previous studies indicate that plankton and oxygen dynamics are measurably affected by the density of planktivorous fish. However, no known studies have been specifically designed to quantify these effects in ponds. Moreover, planktivorous fish would presumably have more influence on plankton dynamics in organically fertilized ponds, where concentrated diets are not being used, than would non-planktivorous fish. Such systems are used more extensively in the tropical world than in the temperate zones, so the influence of fish density on plankton dynamics is more appropriately studied in the tropics The objectives of this experiment are: to analyze the effects of fish density on oxygen dynamics and the dynamics of plankton populations; to document and correlate cyclical changes in water chemistry and biology, and to refine tilapia production systems based on the costs of chicken litter inputs.

Materials and Methods

Three stocking densities of fish, each replicated four times, were tested in earthen ponds of 1,000 m^2. Male *Oreochromis niloticus* (tilapia) fingerlings (30 g) were stocked in ponds on 3 February 1989 at densities of 0.25, 1, or 2 fish/m^2. Male fish were produced through treatment with methyltestosterone. Guapote tigre, *Cichlasoma managuense*, fingerlings were stocked at 1/20 the density of tilapia to control reproduction. All ponds were fertilized weekly with chicken litter at 750 kg/ha, total solids. Fish were sampled at monthly intervals and were harvested on 3 July 1989 after 150 days.

Chlorophyll *a*, zooplankton density, Kjeldahl nitrogen, total ammonia nitrogen, pH, total phosphorus, and filterable orthophosphates were measured three times a week, and total hardness and total alkalinity were measured monthly in two ponds of each treatment. Primary productivity was measured daily using the 24-hr diurnal oxygen curve method Oxygen and temperature were measured hourly by use of a pond-side data logger, and a pump-operated column sampler that obtained water from six depths between 0 and 75 cm. Wind speed and solar radiation were also recorded hourly. Water was chemically analyzed according to *Standard Methods* (APHA). Zooplankton were filtered from 14 liters of water using an 80-μ mesh net, and were enumerated according to major groups: copepods, cladocerans, rotifers, and nauplii. Differences among treatment means, and treatment-by-time interactions were analyzed with repeated measures ANOVA Relationships among chemical, physical, and biological variables were investigated by regression and graphical analyses. Differences were declared significant at an alpha level of 0.05.

Results

Tilapia production and average fish weight for low, medium, and high fish densities were 1029, 2057, and 2499 kg/ha, and 368, 232, and 148g, respectively. Differences among treatments were significant. Production increased with density according to the model, $y = 577.1 + .217x - 6.08E\text{-}6x^2$, R =.995, n = 12, where y = fish production (kg/ha) and x = number of fish/ha at harvest. The average weight of fish decreased with increasing density according to the model, $y = 424.5 - 0.29x + 7.5E\text{-}7x^2$, R = 988, n = 12, where y = average fish weight (g) and x = number of fish/ha at harvest. The increase in fish weight was linear over time for all treatments. Production of fish at the medium density was nearly equal to that predicted (2098 kg/ha) by a model relating fish production to chicken litter input that was developed during Cycle III Economic analyses of production have not been completed

Analyses involving water quality and primary productivity also have not been completed, although some trends are evident There were no treatment differences for total ammonia nitrogen (TAN), filterable orthophosphates (FOP), total phosphorus (TP), or chlorophyll *a* (CHL), nor were there treatment-by-time interactions for TAN or FOP. There was a significant treatment-by-time interaction for TP and CHL After mid-season, CHL in the high treatment became significantly higher than in the other two treatments During the same period, TP in the high treatment became lower than in the other two treatments. It appears that high densities of fish affect primary productivity after fish size or fish biomass has reached a certain threshold. Analyses of primary productivity and zooplankton populations will cast more light on the subject.

Lack of Response of Shrimp Yield to Different Rates of Inorganic Fertilization in Grow-out Ponds

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The objective of this experiment was to quantify penaeid shrimp yield at four different rates of chemical fertilization. Twelve earthen ponds (2.2 to 3.0 ha) located at Granjas Marinas San Bernardo S A , Choluteca, Honduras, were stocked with juvenile shrimp, *Penaeus vannamei*, (average weight = 1.5 g) at 2.5 juveniles/m² on 22 December 1988. Four management strategies were tested using a completely randomized design. no nutrient input; 2 24 kg nitrogen and 2.24 kg phosphorus (P_2O_5)/ha per week; 4 48 kg nitrogen and 4.48 kg phosphorus (P_2O_5)/ha per week; and 8.96 kg nitrogen and 8 96 kg phosphorus (P_2O_5)/ha per week Each treatment was replicated in three ponds

Inorganic fertilization of the grow-out ponds did not increase shrimp yield. Mean shrimp yields (mean ± SE) for the 112-day culture period were 278 ± 22, 228 ± 13, 237 ± 17, and 224 ± 9 kg/ha for the 0, 2, 4, and 8 kg N and P_2O_5/ha per week treatments, respectively. Yields of tails averaged 63% of total yield across all treatments. No significant differences among shrimp yields were detected because of high variations in yield resulting from variable survival. Harvested shrimp were small, averaging 9 to 10 g; no significant differences in shrimp weight were observed. Input costs increased with increasing fertilization rate; however, income was similar for all fertilization rates. The greatest economic return was obtained using no nutrient inputs.

Absence of an Anabolic Effect on Growth of Hormonally Sex-Reversed *Oreochromis niloticus* in Earthen Ponds

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Introduction

Hormonal sex-reversal of tilapia is generally accomplished using the synthetic androgen, 17-α methyltestosterone. The hormone has both androgenic and anabolic qualities. The androgenic effect is evident from the mass production of male tilapia fingerlings through hormonal (methyltestosterone) sex-reversal However, conflicting research results regarding the anabolic effects of this hormone have been reported. All of the reported research involved fish that had been sex-reversed during one year, overwintered indoors, and used in grow-out trials the following growing season. It is not known how the overwintering process influences subsequent growth. In the tropics, where tilapia are cultured year-round, the presence of an anabolic effect would be an additional benefit of the use of hormonally sex-reversed fish. The objective of this study was to determine if the growth of hormonally sex-reversed fish (phenotypic males; genotypic males and females) and untreated fish (phenotypic males; genotypic males) was similar during the hormone treatment phase, the nursery phase, and the grow-out phase.

Materials and Methods

Two 0.05-ha earthen ponds were stocked with *Oreochromis niloticus* brood fish (244 females and 114 males) on 14 September 1988, and harvested on 30 September 1988. Fry were graded through a 3.2-mm mesh grader to remove those greater than 14 mm in total length. Fry were stocked into hapas at a rate of 4500 fry/m² on 30 September 1988. Treatments (hormone treatment and controls) were randomly assigned to each of 12 hapas. Synthetic methyltestosterone was incorporated into ground feed at a rate of 60 mg/kg feed Ground feed for the control fish was treated with a similar quantity of alcohol without dissolved hormone All hapas were harvested on 28 October 1988, fry were stocked into nursery ponds the same day at a density of 125,000 fry/ha. Two 0 2-ha nursery ponds were used for each treatment Fish were fed five days per week. Feed was initially offered at 10% of the fish biomass per day, the ration was decreased progressively to 5% of biomass per day by the end of the nursery phase. Ponds were fertilized with 1000 kg/ha chicken litter (total solids) every two weeks. Nursery ponds were harvested on 30 January 1989. Both treated and untreated fingerlings were examined to separate male from female fish. Grow-out treatments were randomly assigned to twelve 0 1-ha ponds, and fish (average weight 28.7 g) were stocked on 3 February 1989. An average of 10,800 tilapia/ha were stocked Guapote tigre

(*Cichlasoma managuense*) fingerlings were stocked at 1/20 the density of the tilapia to control reproduction. All ponds were fertilized weekly with chicken litter at 750 kg/ha, total solids. Fish were sampled at monthly intervals and harvested on 3 July 1989 after 150 days. Treatment means for each phase of the experiment were analyzed using the t-test. The level of significance was set at $p \leq 0.05$.

Results

Fry stocked into all hapas were similar in size (0.009 g/fry) After the 28-day hapa phase, fry in the control group averaged 0.096 ± 0.009 g (mean ± SE), which was similar to those in the hormone treatment (0.083 ± 0.007 g). No difference in fry survival was observed during the hapa phase; mean survival was 85.4 ± 7.1% and 84.2 ± 6.5% in the hormone treatment and control, respectively.

No significant differences were observed between the mean total yields of nursery phase treatments. Mean total yields were 1548 ± 160 kg/ha and 1613 ± 220 kg/ha for the control and hormone treatments, respectively. Fish survival during the nursery phase averaged 53.8 ± 1.25% and 48.0 ± 4.02%, respectively. At harvest, control fish averaged 22.5 ± 1.81 g, which was not different from the 26 2 ± 1.40 g/fish of the hormone treatment. However, the control population contained both male and female fish, the latter of which grew less rapidly. Females were 29 to 32% smaller than males in the control group, although no significant differences were observed. No significant difference was observed when growth of males was compared Males averaged 29.5 ± 2.6 g and 29.7 ± 1 6 g in the control and hormone treatments, respectively. The control treatment averaged 51.3% males, compared to 96 8% males in the hormone treatment

After 150 days of grow-out, the mean total yield of the control treatment (1709 ± 280 kg/ha) was not significantly different from that of the hormone treatment (1922 ± 277 kg/ha). Fish survival was similar in both treatments, and averaged 79.2 ± 4.61% and 88.7 ± 1.96% for the control and hormone treatments, respectively. At harvest, fish weight averaged 249.1 ± 37.94 g and 253.8 ± 43 37 g for the control and hormone treatments, respectively. Tilapia yield was nearly equal to that predicted (2098 kg/ha) by a model developed during Cycle III that related fish yield to chicken litter input

The androgenic effect of methyltestosterone was clearly demonstrated. Routine production of tilapia fingerling populations composed of 97% or greater males is feasible using 17-α methyltestosterone. There was no clear demonstration of any anabolic effect of this hormone on tilapia growth, either during the hormone treatment or post-treatment periods, from hatching to nine months of age.

Chicken Litter Applied at Low Rates Cannot Be Profitably Substituted For Feed In The Commercial Production of Penaeid Shrimp in Honduras

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The objective of this experiment was to determine the effects on penaeid shrimp production of substituting chicken litter for feed during the first four and eight weeks of culture. Twelve earthen ponds (2.2 to 3.0 ha) located at Granjas Marinas San Bernardo S.A., Honduras, were stocked with juvenile shrimp (average weight = 0.8 g) at five juveniles/m² on 7 September 1988. Four management strategies were tested: the standard Granjas Marinas protocol of chicken litter (60 kg/ha/wk, total solids) plus feed during the first eight weeks (STD); feed only (FEED); chicken litter during the first four weeks followed by feed only (4WK), and chicken litter during the first eight weeks followed by feed only (8WK) Each treatment was replicated in three ponds

Harvest results, after 99 days of growth, indicated that shrimp yield was not increased by manuring at the rate used during the first eight weeks when the shrimp were given commercial feed, and that low levels of chicken litter could not be profitably substituted for feed. Mean weights of shrimp from STD (14 1 g) and FEED (14 4 g) treatments were 13 to 16% larger than those of 4WK (12.2 g) and 8WK (12 1 g) treatments Mean yields from STD (518 kg/ha) and FEED (508 kg/ha) were 7 to 41% greater than those of 4WK (476 kg/ha) and 8WK (368 kg/ha) treatments, but the differences were not significant due to variations in production stemming from variable survival. Total nutrient costs for STD and FEED treatments were significantly greater than 4WK and 8WK treatments due to greater use of feed. Net incomes for STD and FEED treatments were 27 to 58% greater than those of 4WK and 8WK treatments, because of higher production and the higher value of larger shrimp.

Status of the University of Hawaii's Contribution to the Honduras Project

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James Szyper and Kevin Hopkins were selected as Principal Investigators (PI's) for the University of Hawaii (UH) component in Honduras and began work early in 1989 James Szyper visited the research sites in Honduras in March 1989, and met with host country researchers and administrators, Auburn University's in-country researchers, and USAID mission personnel. Project needs and potential UH contributions to the project were assessed and possibilities for the comparison of results obtained at the Honduras and Thailand sites were discussed The UH component provided badly-needed backup equipment for the automated water-quality monitoring system in use at the main research site The PI's contributed to drafts and revisions of materials for the Continuation Plan submitted by the PD/A CRSP and accepted by USAID. Both PI's attended the CRSP meeting in Davis, California, in May, 1989

Tilapia Production in Rwandan Ponds is Influenced by Composting Method

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Introduction and Objectives

The method used in composting influences the physicochemical properties of compost and should therefore be an important factor to consider when adding composts to fish ponds. Composts processed aerobically on land, in covered earthen pits, and submerged within the ponds were used as inputs to determine pond productivity for *Oreochromis niloticus*.

The objectives of this study were: 1) to determine pond productivity for tilapia in response to composting methods and manure/plant ratios of inputs and 2) to investigate pond processes in relation to input characteristics.

Materials and Methods

The experiment was conducted for 165 days, and used 21 ponds for seven treatments applied in triplicate. Fish weighing about 40 grams were stocked at 1 fish/m^2. The compost input for each pond was 500 kg/ha/wk, based on the dry weight of ingredients at the start of composting Ponds were fertilized with one of the following: aerobic compost (AE) composed of 80% grass and 20% chicken manure; AE composed of 100% grass; covered-pit compost (AN) composed of 80% grass and 20% manure; AN composed of 100% grass; and in-pond compost (IP) composed of either 50, 80, or 100% grass AE and AN composts were prepared previously and broadcast weekly. IP compost was prepared in the ponds by submerging the compost materials in corner enclosures on a weekly basis.

Compost inputs were analyzed bi-weekly for organic carbon, percent dry weight, Kjeldahl-N, nitrate, potassium, and phosphorus. Water quality parameters were measured three times during the experiment. Climatic data were collected daily.

Results

Net production of *Oreochromis niloticus* in ponds receiving in-pond composting (IP) was significantly greater than in ponds receiving aerobic (AE) or covered-pit (AN) compost having the same percentage of grass. Net production for the IP treatment at 50%, 80%, and 100% grass was 1323, 1030 and 817 kg/ha/yr, respectively. Ponds that received AE compost composed of 80% grass produced at 748 kg/ha/yr and ponds that received AN compost with 80% grass produced tilapia at only 613 kg/ha/yr

Ponds receiving IP compost exhibited very low minimum dissolved oxygen concentrations (less than 1 mg/L) For all ponds, rotifers dominated the zooplankton, and hydra were sometimes abundant. Euglenoids were the most common phytoplankter

Greater fish production in IP ponds may have resulted from losses of organic carbon and nitrogen during AE composting and from the production of refractory organic compounds during AN and AE composting. Increasing the chicken manure component of composts with respect to grasses improved tilapia production.

Anticipated Benefits

This experiment indicates that in-pond composting is a more effective method of fertilizing tilapia ponds than on-land or covered-pit composting. The results of these experiments provide a basis for understanding pond responses, which can lead to enhanced fish productivity in the cooler environment of highland Africa.

Fertilizer Input Method Influences Pond Productivity

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Introduction and Objectives

This experiment was designed to test the influence of two methods of organic input addition on the production of *Oreochromis niloticus*. The current practice in Rwanda, as recommended by the National Fish Culture Service, is to add plant material or manures to the pond in enclosures rather than to broadcast such material over the pond surface. This recommendation was not based on research results and the advantage of using enclosures in Rwanda was only assumed. Additionally, in a previous Rwanda CRSP experiment that compared in-pond and on-land composting, the compost processed on land was broadcast on the pond surface but material composted in the pond was added to corner enclosures. The distribution method as well as the type of compost may have influenced fish production The objective of this experiment was to examine the basis for the recommended practices in Rwanda by testing this possibility. An additional objective was to gain insight into carryover effects and variability in pond productivity by comparing the production of individual ponds in this experiment with that of the previous experiment.

Materials and Methods

The experiment was conducted for 92 days. Nine ponds were used for each of two treatments. *Oreochromis niloticus* fingerlings with an average weight of 86.6 g were stocked at 0.43 fish/m² after being hand-selected to eliminate females All ponds received 500 kg/ha/wk dry weight of grasses. In nine of the 18 ponds, the compost was broadcast onto the surface of the ponds by hand on a weekly basis (treatment BRD) In the remaining nine ponds, the compost was added to corner enclosures (treatment ENC).

Water temperature, pH, and dissolved oxygen were measured weekly near the surface, at mid depth, and near the bottom of the ponds. Alkalinity was measured three times and hardness twice during the experiment. Chlorophyll *a* was measured every other week Pond soils were analyzed for organic carbon, nitrogen, and phosphorus prior to pond filling and following pond draining.

Results

Net fish production was low in all ponds, as expected for this type of compost. Fish production was significantly higher in the ponds receiving compost materials in enclosures (773 kg/ha/yr, SD 192.3) than in ponds in which the compost material was broadcast on the surface (520 kg/ha/yr, SD 145.4).

Anticipated Benefits

This experiment substantiates the recommendations of the National Fish Culture Program and justifies the continued use of enclosures by rural farmers Concentrating compost materials in enclosures apparently enhances microbial decomposition in water, as it is known to do on land.

Sex Reversal of *Oreochromis niloticus* Fry in a Relatively Cool Environment Using Two Different Hormones

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Introduction

Previous research by the Pond Dynamics/Aquaculture CRSP at the Rwasave Station in Rwanda was conducted using hand-sexed male *Oreochromis niloticus* fingerlings. Although hand sexing efficiency has risen from about 85% in 1985 to over 99% in 1989, monosex tilapia culture using males selected by hand has disadvantages. Small females that are removed are sold for only 60FRw/kg whereas fish weighing over 200 g sell for 180FRw/kg (80FRw=$1). Additional pond area is used to grow fry to sexable size, and efforts to produce sufficient numbers of fry for hand sexing often result in stunting Hormone-induced sex reversal has proved to alleviate some of these problems in other regions, but specific methods of sex-reversal appropriate for the cooler environment of hignland Africa have not been developed.

Objectives

This study has four objectives· to determine tilapia fry growth rates in Rwanda; to compare the efficacy of methyltestosterone with that of testosterone proprionate, which is available locally; to determine the appropriate treatment duration; and to compare the production costs of sex-reversed and hand-sexed fingerlings.

Materials and Methods

Fry growth rates were determined in the first experiment Four cages, each 50x20x50 cm deep were stocked with 300 fry averaging 8.75 mm in length. Fry were graded to this size using a wire mesh cage which allowed fish less than 10 mm to escape. The four cages were suspended in a productive pond (K-11) and fed to satiation four times daily with a 50/50 mix of commercial chicken feed and fish flour, sieved to a particle size of less than 0.5 mm Minimum and maximum water temperatures were recorded daily. At each sampling and at the beginning of the trial, ten fish were removed permanently from each cage and measured and weighed After 35 days all fish were counted, weighed, and measured.

In the second experiment broodstock were stocked into a spawning tank. Fry were easily dipped out of this tank and stocked into cages in pond K-11 at the same density as in the first experiment. Fish averaged 9-10 mm in length. Feed was prepared as in Experiment 1, with the addition of 60 mg of hormone/kg feed The hormone was dissolved in alcohol before it was added to the feed, which was then dried at 60°C Two hormone treatments were prepared for comparison with a control, one with methyltestosterone (MT) and the other with testosterone proprionate (TP). Fry were fed at 20% body weight per day, and this daily ration was divided into four feedings Each treatment (MT and TP) was administered to three cages for periods of 21, 26, and 35 days. Three cages of 300 fry each received untreated feed and served as a control Fish were grown to 500 mm total length (TL) or more before examination using the carmine red squash technique to determine sex.

Results

Growth

For Trial 1 fry growth corresponded well with average accumulated temperature in degree-days (°C), expressed as $y = 8.06 + 0.032x$ (where y = length in mm and x = degree-days [°C]). The best correlation ($r^2 = 0.97997$) resulted when 17°C was subtracted from the daily average, although $r^2 = 0.97849$ without subtraction for zero growth temperature. The length-weight relationship of Experiment 1 fry was determined to calculate the feeding rate for Experiment 2. For Experiment 2 all fish in treatment TP35 and fish from two of the three controls were lost through holes in cages. For remaining treatments, growth in length did not differ between treatments.

Percentages of males following treatment

The percentages of males resulting from the treatments are shown in Table 1. Control and methyltestosterone treatments were significantly different. In summary:

MT35>MT28=TP28>MT21>TP21=control.

Mortality was high in the cages, and averaged 35.6%. Low DO levels due to clogging of the cages may have been responsible, although cannibalism and predation by frogs is also suspected.

The cost of production of monosex fish was about 6FRw/fingerling. Costs may be reduced by increasing the scale of the operation. Mixed sex fingerlings (0.5 g) can be produced at about 3FRw each.

Anticipated Benefits

These experiments demonstrate that the administration of methyltestosterone-treated feeds to tilapia for 35 days can produce a high percentage of males (94%). Further analysis of the costs of hormone-induced sex reversal and hand-sexing is necessary to determine which approach will optimize returns to the farmer.

Table 1. The percentage of males produced in each of the experimental treatments.

Treatment Days	Control	MT	TP
21	-	62	51
28	-	80	74
35	48	94	-

Economic Analysis of Aquaculture Production Technologies in Rwanda

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Introduction

Fish culture represents a relatively new production alternative for Rwandan farmers. Economic analyses can indicate the benefits and costs involved in fish production and in other forms of agriculture. An analysis of optimal resource use can assist farmers with limited resources in planning production systems that maximize benefits from alternative technologies.

Objectives

The objectives of this study were:
(1) To compare costs of and returns from fish farming at altitudes above and below 1500 m in terms of both cash and in-kind resources; and
(2) To compare labor efficiency in fish farming at altitudes above and below 1500 m.

Materials and Methods

A sample of 60 fish farmers was drawn, 30 with ponds located at altitudes above 1500 m (from the communes of Mubuga and Kanama) and 30 with ponds below 1500 m (from the communes of

Kibayi and Muyira). Individual respondents were selected randomly from lists prepared by the National Fish Culture Extension Service. Data on stocking, harvesting, and years in production were collected from individual pond records.

A questionnaire was developed to obtain data on input costs, product price, marketing channels, and labor inputs for specified fish f. .rming activities. A pilot test of the questionnaire was conducted in Runyinya and appropriate were modifications made. Personal interviews were conducted in Kinyarwanda from 29 July to 12 August 1989.

Survey data will be cross-tabulated. Enterprise budgets and resource flows will be developed. Labor utilization will be analyzed by specific task, and comparisons will be made between high- and low-altitude systems.

Results

Data are being analyzed at the time of this report.

Yields of Tilapia with Nitrogen-Supplemented Organic Fertilizers in Fish Ponds in Thailand

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Introduction

Manures, particularly chicken manure, are phosphorus-rich and nitrogen-poor relative to the 1:7 ratio of P:N required by algae for adequate growth (Redfield et al. 1963; Round 1973; Wetzel 1983). During earlier experiments (McNabb et al. 1989), nitrogen deficiency occurred in Nile tilapia (*Oreochromis niloticus* Trewavas) ponds where chicken manure was used at a rate of 500 kg/ha/wk. Ponds in that treatment had the same microflora/fauna production and fish yield as ponds treated at only 1/10 that amount of chicken manure supplemented with urea to provide a 1:7 ratio of P:N in the fertilizers. Fish yields obtained from 25-g fingerlings stocked at two fish/m^2 were close to 4000 kg/ha/yr in both treatments (McNabb et al. 1989). Data from that work suggest that Nile tilapia yields close to those reported in the literature (Balarin 1984) for well-managed farm ponds using fertilizers and feeds (5000 kg/ha/yr) could be obtained by adding chicken manure in a range of 44 to 200 kg/ha/wk and supplementing it with urea to make the fertilizer P:N ratio 1:5.

Materials and Methods

Twelve 220 m^2 earthen ponds at the Bang Sai Fisheries Station of the Royal Thai Department of Fisheries near Ayutthaya in Thailand (14.2°N, 100.5°E) were stocked on 7 October 1988 with sex-reversed male *Oreochromis niloticus* at a density of 1 fish/m^2. The average weight of stocked fish was 11.8 g. They were harvested 151 days later on 7 March 1989. One week prior to stocking and every week thereafter, ponds were fertilized with chicken manure and urea. There were three fertilization regimes: 44, 100, and 200 kg dry weight chicken manure/ha/wk and a corresponding level of urea to provide a P:N (TP:TN) ratio of 1:5. Fresh chicken manure was collected from hens at Kasetsart University, Bangkok and analyzed for P and N. The results of those analyses were used to calculate urea inputs. Four ponds were randomly assigned to each fertilizer regime. Ponds never overflowed during the experiment and were maintained at an average depth of 0.96 m.

Every two weeks an extensive diel sampling was undertaken beginning with the first week of the study. These diel samplings included measurements for dissolved oxygen, temperature, pH, and alkalinity at three different depths (top, middle, and bottom) for each pond and cumulative wind and solar radiation between each sampling time. There were seven sampling times: pre-dawn, 1000, 1400, 1600, 1800, 2300 hours, and pre-dawn the next day. The following parameters were also measured in all ponds during the diel sampling period: total phosphorus, dissolved reactive phosphorus, Kjeldahl nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, total suspended solids, total volatile solids, Secchi disk visibility, chlorophyll *a*, and dark bottle respiration. In addition, one pond was randomly selected from each treatment and sampled for phytoplankton, primary productivity by the light/dark bottle method, and ammonia during the two-week sampling periods. For the light/dark bottle studies, three bottles (two light and one dark) were suspended at three depths in the ponds (top, middle, and bottom). Ammonia concentrations were determined in the one randomly selected pond in each treatment. Samples were collected from three depths (top, middle, and bottom) at the same time as other diel measurements. All analyses followed *Standard Methods* (APHA 1985).

Results

Data on fertilization rates and fish yield are summarized in this report. Composition of chicken manure as percent dry matter for N and P ranged from 1.0 to 5.4% and 1 9 to 3.4%, respectively, during the 23-week experiment. Average rates of urea supplement, with chicken manure applied at 44, 100, and 200 kg/ha/wk resulted in additions of 10.8, 24.3, and 48.6 kg/ha/wk, respectively.

Fish data are presented in Table 1. Mortality ranged from 13 to 17% and increased with increasing fertilizer inputs. Similarly, fry production, adult fish yield, and total fish yield increased with increasing fertilization Adult fish yield averaged 25.8, 32.2, and 53.3 kg/pond while fry production averaged 0.7, 1.2, and 1.9 kg/pond for treatments A through C, respectively. Total fish yield ranged from 2912 to 6071 kg/ha/yr.

Discussion

This summary reports on work that is part of a continuing series of CRSP experiments. The objective of this series is to establish confirming data for a protocol for fertilizer use that will result in high and relatively predictable fish yields. In earlier experiments, we demonstrated that widely used manures, chicken manure in our case, are deficient in nitrogen relative to needs of microflora at the base of pond food webs. We showed that pond productivity and fish yield obtained with 500 kg chicken manure/ha/wk were the same as those obtained with 44 kg chicken manure/ha/wk supplemented with urea. A rate of urea supplementation was selected that would minimize ammonia-N accumulation and its adverse effects on fish growth in ponds. The experiment in this report repeated the 44 kg chicken manure/ha/wk treatment used earlier with a slight reduction in the urea supplement Two higher loading rates of fertilizers were added as treatments to push pond productivity and fish yield higher than those formerly obtained.

Figure 1 presents average total fish yields versus chicken manure additions. There was a strong linear relationship ($r^2 = 0.98$) between fish yields and fertilizer additions. At the highest fertilization rate (200 kg dry wt/ha/wk chicken manure and 49 kg/ha/wk urea) fish yields averaged 6071 kg/ha/yr, 21% greater than the 5000 kg/ha/yr expected for ponds receiving high rates of fertilization supplemented with feeds (Balarin 1984).

Anticipated Benefits

The highest yields of Nile tilapia realized using fertilizers thus far in the CRSP were obtained in this experiment The data showed that dissolved oxygen levels during treatments were high enough not to hinder growth. Results suggested that higher yields, perhaps as much as 10,000 kg fish/ha/yr, could be obtained by adding either phosphorus or nitrogen on demand to the basic chicken-manure-plus-urea treatment, as long as adequate inorganic carbon was present in ponds. The next experiment is designed to obtain these higher yields. This series of experiments has demonstrated the validity of the scientific basis for their design. Concepts that have emerged are being used to develop a fertilization scheme for a manual that the CRSP team in Thailand is preparing for Thai fish farmers.

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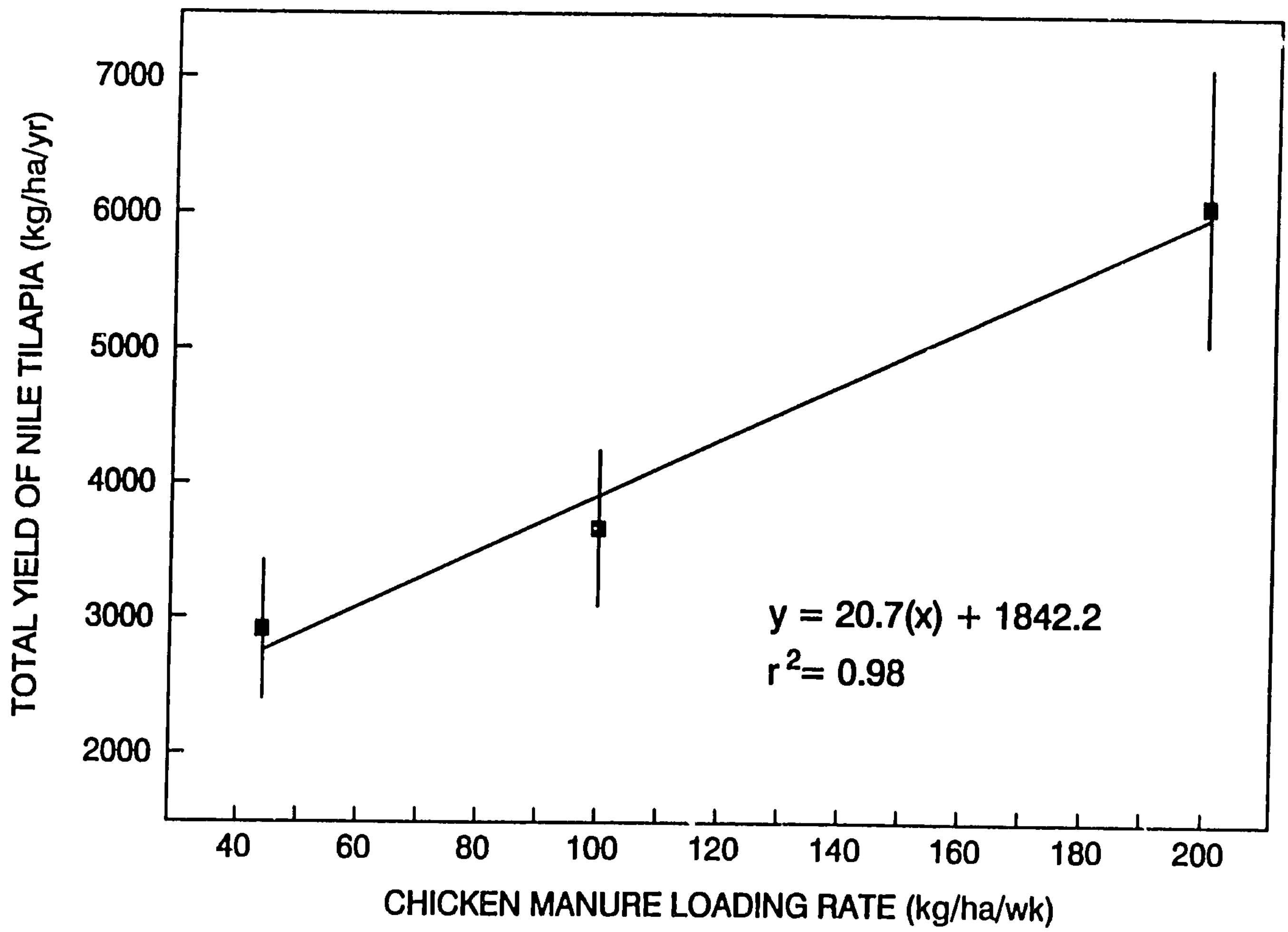

Figure 1. Total fish yields of Nile Tilapia (*Oreochromis niloticus*) versus chicken manure loading in ponds at the Bang Sai Fisheries Station, Thailand. Data points represent means of four ponds; bars are one standard error.

Table 1. Fish data for a 151 day growout experiment at the Bang Sai Fisheries Station. Ponds had a surface area of 220 m² and were planted at a density of one fish/m² with 11.8 g sex reversed male Nile tilapia (*Oreochromis niloticus*) on October 7, 1988 In addition to receiving weekly inputs of dry chicken manure, treatments A-C received supplemental amounts of urea to create a P N ratio of 1:5.

Treatment	Chicken Manure (kg/ha/wk)	Pond	Fish at Harvest			Total Fish Yield (kg)	Total Fish Yield (kg/ha/yr)
			Adults		Fry		
			Wt. (kg)	Number	Wt. (kg)		
A	44	3	29.0	192	2.5	31.5	3,461
A	44	7	16.1	181	0.4	16.5	1,813
A	44	11	34.4	201	0.0	34.4	3,780
A	44	12	23.6	195	0.0	23.6	2,593
		Mean	25.8	192	0.7	26.5	2,912
		Standard Error	3.9	4	0.6	4.0	444
B	100	1	21.1	178	0.2	21.3	2,340
B	100	4	38.5	196	1.0	39.5	4,340
B	100	5	38.4	188	3.5	41.9	4,604
B	100	10	30.6	188	0.1	30.7	3,373
		Mean	32.2	188	1.2	33.4	3,664
		Standard Error	4.1	4	0.8	4.7	515
C	200	6	40.4	178	2.7	43.1	4,736
C	200	8	71.0	204	1.4	72.4	7,955
C	200	9	65.8	187	3.1	68.9	7,570
C	200	14	36.1	164	0.5	36.6	4,021
		Mean	53.3	183	1.9	55.3	6,071
		Standard Error	8.8	8	0.6	9.0	991

The Effect of Stocking Density of *Oreochromis niloticus* on The Dynamics of Aquaculture Ponds

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Introduction

Fish have complex interactions with their ecosystems. This is particularly true in aquaculture ponds, where the water volume is low and fish biomass is high. The factors which fish may influence could potentially include: physical factors, such as mixing and stratification; chemical factors, such as nitrogen or phosphorus availability; biological factors, such as species composition of zooplankton; and yield, by competition for food and space. Control of aquatic systems may occur by nutrient availability, by fish predation pressure, or by a combination of these effects. The purpose of this study was to document the effects of fish stocking density and biomass on the physical, chemical, and biological dynamics of aquaculture ponds.

Materials and Methods

Earthen ponds, 300 m^2 in surface area, were stocked with *Oreochromis niloticus* at 1, 2, and 3 fish per m^2. Fry were sex-reversed using methyltestosterone. Three replicate ponds were run at each density. The ponds were fertilized with chicken manure at 500 kg/ha/week. Physical, chemical, and biological sampling was conducted according to the standard CRSP protocol (Pond Dynamics/ Aquaculture CRSP, November, 1987). Stocking was done on 3 March 1988, and harvesting finished on 20 September 1988.

Results

Fish density in ponds had little effect on the physical or chemical environment (Table 1). There was a significant negative correlation between total inorganic nitrogen and density ($r = -0.59$), but no correlation between Secchi disk depth, chlorophyll *a* concentration, or phosphorus concentration and density stocked

There was a large difference between treatments in the growth of fish (Figure 1), with growth rate inversely proportional to stocking density. This produced a significant correlation between density and growth ($r = -0.84$) There was virtually no reproduction in the ponds due to sex-reversal of the fish. Adult yield was similar among treatments, indicating that carrying capacity was reached in the ponds (Figure 2). There was also a strong correlation between survival and yield ($r = -0.62$), but none between survival and density, indicating variable survivals within treatments. Other significant correlations included the relationship between chlorophyll *a* and total phosphorus

(0.62), and between nitrogen and phosphorus (-0.65). In addition, chlorophyll *a* was correlated with Secchi disk depth (r= -0.66).

These results were in general agreement with earlier experiments on monosex culture of tilapia (Pond Dynamics/Aquaculture CRSP, May, 1989; Diana et al. in review), except that, as expected, the sex-reversed fish did not breed much in these ponds While this lack of breeding clarified carrying capacity in each treatment, the poor survival in one pond of low density (28%), as well as errors in stocking a high-density pond (115% survival was recorded), biased the results somewhat.

Anticipated Benefits

Knowledge of pond carrying capacity is central to aquaculture production. In this experiment, increased stocking density did not increase yield, due to density dependent growth. Carrying capacity of adults was remarkably consistent among treatments.

The overall survival of sex-reversed fish in this experiment was more variable and lower among ponds than that for natural fish (77.2% compared to 90.9%). This is due in part to differences in size at stocking (4 4 g for sex-reversed compared to 32.8 g for normal males), but may also represent lower fitness of genetically manipulated fish. This latter possibility should be examined by direct experiments.

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Table 1 Data from each pond for yield (kg/pond), final weight (g/individual), survival (%), yield of offspring (repro-kg/pond), total phosphorus (P-mg/L), total inorganic nitrogen (N-mg/L), secchi disk depth (SDD-cm), and chlorophyll *a* content (mg/m^3) during the experiment

Density	Yield	Weight	Survival	Repro	P	N	SDD	Cl a
300	75 2	285	88	0	0 13	3 62	20 0	168 63
300	17 9	211	28	0	0 16	3 17	20 0	130 50
300	55 9	205	91	0	0 18	3 80	17 4	93 63
600	49 1	104	79	0	0 19	3 05	17 0	167 38
600	65 6	180	61	1	0.26	3 01	14 9	192 00
600	64 9	94	115	1 9	0.12	3 65	26 6	87 25
900	74 2	90	91	0	0 21	2 92	16 1	188 63
900	78 8	119	74	0	0 20	3 11	18 3	161 63
900	20 8	67	68	0 14	0 14	3 25	23 3	141 88

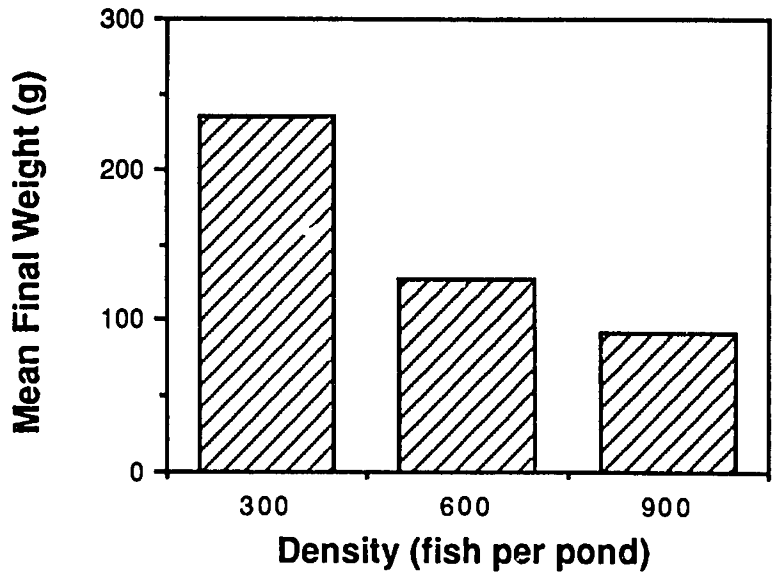

Figure 1. Mean final weight of tilapia under each density treatment.

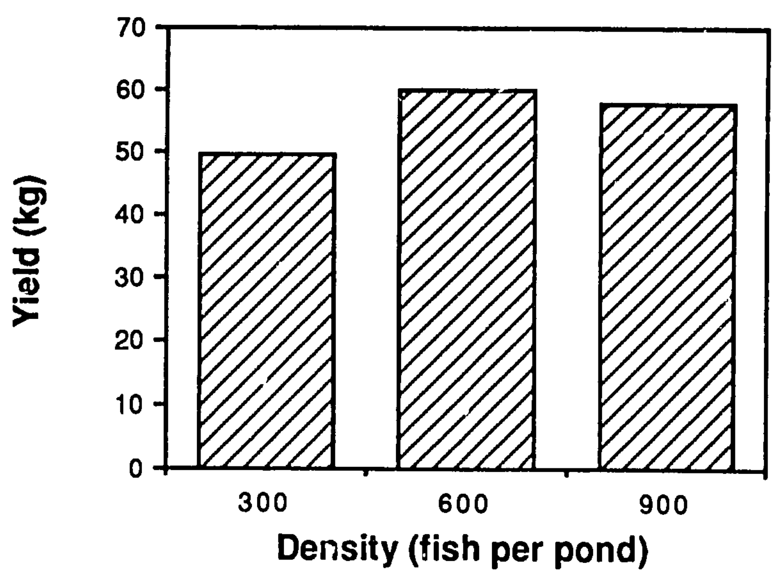

Figure 2. Yield of tilapia produced for each density treatment

Application of Limnology for Efficient Nutrient Utilization in Tropical Pond Aquaculture

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Phosphorus, nitrogen, and carbon have been key limiting nutrients on the forefront of eutrophication literature for more than four decades. Concepts developed by the limnological community regarding these nutrients and their cycles in aquatic environments are now becoming the basis for management of aquaculture systems, particularly those in which fertilizers are used to promote fish production. Animal wastes, with a long tradition of use in tropical aquaculture, represent an inexpensive source of organic carbon for detrital production, and nitrogen and phosphorus for algal production. Manures generally have N:P rations well below the limnologically derived 7:1 ratio required by algae, and thus promote nitrogen-limiting conditions in pond waters. Nitrogen limitation is desirable in aquaculture ponds because efficient ammonia utilization reduces the risk of high unionized ammonia concentrations, which can be lethal to fish.

The results of experiments conducted in Indonesia and Thailand combined with published data suggest that in ponds receiving animal manure with or without additional nitrogen fertilization (e.g., urea or ammonium sulphate) there is a strong relationship between nitrogen input and production of Nile tilapia (*Oreochromis niloticus*). Maximum daily fish growth of about 3.2 g fresh wt/m^2 corresponded to a nitrogen input of approximately 0.7 g N/m^2/d. At greater nitrogen loading rates, algal production became light-limited due to auto-shading, and dissolved inorganic nitrogen concentrations increased to several mg/L. Elevated concentrations of unionized ammonia probably contributed to increased fish mortality and variable total yields.

(This paper was presented at the XXIVth Congress of the International Association of Theoretical and Applied Limnology, 1989.)

UNITED STATES RESEARCH COMPONENT OF THE GLOBAL EXPERIMENT

Introduction

Implicit throughout Title XII of the International Development and Food Assistance Act of 1975 is the understanding that activities should be mutually beneficial to developing countries and the United States. In planning this CRSP, consensus among CRSP participants was that improving the efficiency of pond culture systems through collaborative research involving both U.S and developing country institutions would be mutually beneficial. However, subsequent to awarding the CRSP grant, USAID interpreted "mutually beneficial" to mean that the CRSP should fund research activities both in the U S and in developing countries and instructed the CRSP to direct some of its funds to support research activities at the U.S. institutions.

The U.S. Research Component was organized during the third year of the CRSP. A number of Special Topics Research Studies have been funded and were successfully completed since that time These projects studied timely research problems that could not be addressed in the overseas component Consequently, the projects help to strengthen the overall effectiveness of the CRSP.

In organizing the U.S. Research Component, the CRSP endeavors to ensure that the projects included in this activity are of high technical merit. Formal project proposals are subjected to critical review by peers not affiliated with institutions participating in the CRSP. The proposals and reviews are then submitted to the CRSP Board of Directors for approval. The Board considers the relevance of the proposed work to CRSP goals as well as its technical merit.

The Special Topics Research Studies described above are only one part of the U S. Research Component The overall success of the CRSP depends heavily on the management, analysis, and modeling of data collected from the overseas CRSP sites. Comprehensive analysis of the global data is accomplished at several U.S. universities as part of the Data Analysis and Synthesis Team's activities. Although the CRSP Central Data Base is not part of the U.S. Research Component, it is described in this section because its output provides the foundation for activities conducted by the Data Analysis and Synthesis Team.

The Data Analysis and Synthesis Team and The Central Data Base

Background

The CRSP recognized at the outset that aquaculture ponds are extremely complex ecosystems. The choice of sites, the experimental protocols, the monitoring of variables, and the frequency of measurements were all determined with an understanding of the complexity of the system. Results obtained to date have confirmed this initial perception and have made the establishment and maintenance of a complete data base and the computerized analysis of the data a necessity.

The CRSP Central Data Base is maintained by the Program Management Office. Field personnel send data to their principal investigators at the U.S. universities who check the data sets and forward them to the Program Management Office. The data sets then are electronically translated into a standardized format and sent back to the principal investigators for verification. (Data entry already is standardized through the use of templates that were developed by the Data Base manager and approved by the Technical Committee.) Verified files are entered in the Central Data Base for use by the Data Analysis and Synthesis Team. Specific data sets may be retrieved in virtually any format desired All project teams also independently analyze their data and most have had their results published in journals or proceedings of scientific meetings (see Appendix A).

The CRSP, through its data base, provides a great service for the world aquaculture community by collecting daily measurements of photosynthetically active radiation, rainfall, evaporation, air temperature, and wind speed concurrently with experimental data from ponds Detailed records such as these are rare in the aquaculture literature. This is particularly true for photosynthetically active radiation and on-site rainfall, which are important features of water and nutrient budgets for ponds in the wet tropics. Other records collected by the CRSP also are useful in interpreting pond measurements in relation to physical processes occurring at the surface.

A major accomplishment of the previous reporting period was the completion of the Central Data Base Complete and verified data sets from all sites for the first three experimental cycles thus became available to members of the Data Analysis and Synthesis Team and to other participants. Additional data, generated under the activities of Work Plan IV, were added to the Central Data Base during this reporting period

The Data Analysis and Synthesis Team (DAST) was established in September 1985 to provide comprehensive, global interpretations of the CRSP Central Data Base. The Data Analysis and Synthesis Team's activities are decentralized, members of the Team operate from offices at the University of California at Davis, the University of Michigan, and Oregon State University. Through their involvement on the Technical Committee, members of the Data Analysis and Synthesis Team interact with scientists from the field-based research component of the Global Experiment. The Data Analysis and Synthesis Team works in concert with the Data Base Manager to translate and verify the large amount of data that have been compiled into the CRSP Central Data Base.

The primary objectives of the Data Analysis and Synthesis Team include:

- development of data management techniques;
- definition of site-specific as well as global relationships; and
- development of computer models that make optimum use of the CRSP Central Data Base and are suitable for diverse applications such as teaching, management, planning, and research.

In previous years the Data Analysis and Synthesis Team performed basic statistical analyses on the data A few significant relationships were revealed. Whereas these relationships were determined from the partial data base and did not necessarily provide a general relationship for all research sites, they did show the existence of possible statistical relationships in the data. Additional interpretations of the data presently are being conducted with other statistical methods such as principal component analysis and multiple regression.

The CRSP aims to increase the usefulness of aquaculture models by addressing the limitations inherent in previous computer models, such as difficulty of use, non-compatibility between computers, and oversimplifications of system dynamics. Developers of previous models did not have the benefit of a large standardized data base such as the one created by the CRSP. The Data Analysis and Synthesis Team is using this data base to develop several improved computer models.

These include models to analyze fish growth and factors limiting growth and production, as well as mechanistic models for simulating and predicting pond water quality conditions such as dissolved oxygen concentrations and cycles. In some cases the work involves modifying previously available *fisheries* models for use in *aquaculture*, while in others new models have been constructed for calibration and verification using CRSP data. Much of the work is based on a generalized descriptive model of pond ecosystems developed by CRSP participants during earlier phases of the project (Figure 1)

One of the ultimate objectives of the CRSP is to compile a manual of pond management guidelines for the end-users in aquaculture—the fish farmers and pond managers. Toward this end a computer expert system is being developed to provide pond management guidance based on knowledge gained through CRSP research and modeling as well as on information from independent sources The expert system can be used directly by those with access to personal computers; perhaps more importantly, it will provide the basis for printed management guidelines.

Benefits of analyzing results and developing computer models that simulate pond conditions at the experimental sites will occur on several levels. management and production, design, and planning. The quantification of relationships between variables and the effect of treatments will allow farmers to adopt management practices to achieve production goals within local constraints of climate, water, feed, and fertilizer availability Design of production systems will be improved by matching production facilities and costs with production goals. As the Data Analysis and Synthesis Team moves closer to meeting its objectives, the CRSP will begin to realize its goal of confronting food and nutritional problems through improved aquaculture technologies. The efforts of the DAST members during the past year are detailed in the reports that follow

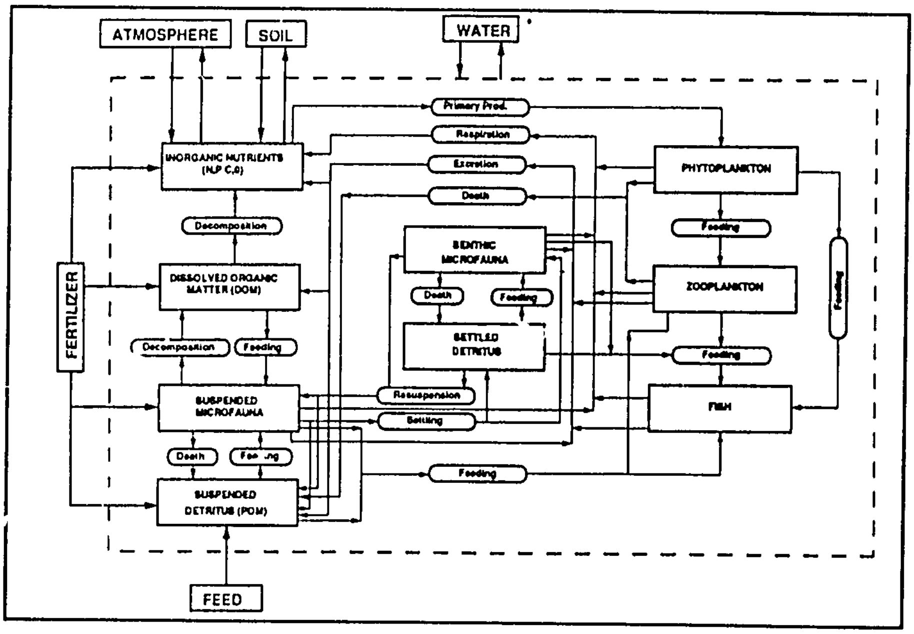

Figure 1 A CRSP conceptual model of an aquaculture pond The arrows connecting the model's components represent the paths for movement of mass in the system The system includes both biological and non-biological components The strictly biological components are phytoplankton, zooplankton, and fish, whereas the non-biological components are the inorganic nutrients that are considered likely to limit productivity Examples of limiting nutrients for photosynthesis are nitrogen, carbon, and phosphorus, and oxygen and nitrogen (ammonia), which affect fish growth, health, and survival. Sediments include decomposing organic matter that settles from the water, the parent soil material, and benthic organisms Particulate organic matter is a composite of dead particulate organics and bacteria that either coat the particles or are in free suspension Most research on fertilized aquaculture ponds has been based on the premise that yields and production rates are determined by primary productivity Nutrients added to a pond must undergo transformations that include fixation by phytoplankton before they are available to fish The importance of the heterotrophic food chain has not been recognized until recently

Summary of Activities: Data Analysis and Synthesis Team

Work by the members of the Data Analysis and Synthesis Team (DAST) is continuing according to the Work Plan. The main areas of activity identified in the Work Plan, and the DAST member given primary responsibility for each area are:

(1) Statistical analysis of the data, concentrating on fish growth (Chang).
(2) Mechanistic modeling of short-term dissolved oxygen cycles (Piedrahita).
(3) Pond classification and information dissemination (Lannan).

Work in each of the three areas has progressed largely independently of the others. As the preparation of the pond management guidelines continues, interaction between the DAST members will increase. Of particular interest is the use of the models developed in the design and evaluation of management guidelines. A meeting was held in October 1989 to improve coordination of efforts, especially those directed towards the completion of the pond management manual. The reports below describe the activities of each of the three DAST members: Dr. William B. Chang, Dr. Raul H. Piedrahita, and Dr. James E. Lannan.

Fish Growth in Warmwater Ponds

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Introduction

One of the major goals of the Pond Dynamics/Aquaculture CRSP is to increase the availability of animal protein in developing countries through pond aquaculture. To meet this goal, the University of Michigan data synthesis team has focused on issues related to increasing fish growth in warmwater ponds and to understanding the factors that contribute to optimal fish production. Conditions limiting warmwater aquaculture have been studied, several methods for modeling rates of growth have been evaluated, and the rates of fish growth at different experimental sites are being estimated. The specific objectives towards which the University of Michigan team is working are listed below.

Objectives

(1) To understand elements limiting growth and yield in warmwater pond aquaculture.
(2) To determine growth coefficients suitable for use in modeling fish production. Von Bertalanffy's growth model has been modified to study growth patterns and dynamics in pond environments, as well as to characterize the rates of fish growth under different culture conditions.
(3) To quantify relations between fish growth and other density dependent factors such as stocking density, weight gain, and reproduction in order to determine the major factors causing the substantial reduction in rates of fish growth as fish gain weight.

Materials and Methods

Statistical analyses and numerical methods were used to test important ecological and growth relationships, determine rate processes, and integrate numerical data.

Data Base Management

Significant efforts were made to standardize the CRSP global data sets collected from Cycles I, II, and III. Potential gaps in the data sets were identified. Continuous efforts were devoted toward improving the data base so that the necessary analyses could be performed. Several data management schemes were implemented in the data base to reduce the limitations on crossreferencing and retrieving data from several data files.

Statistical Analysis

Statistical analyses of the CRSP Central Data Base were conducted to identify ecological relationships important for understanding pond limnology, fish growth, and production. The main computer available at the University of Michigan Computer Center was used for statistical analyses of the large CRSP data set. Statistical programs such as SAS and MIDAS and software available for the IBM microcomputer were used for these analyses.

Development of Fish Production Models

Production models were developed to integrate the variables that are important to fish growth and yield, and to evaluate the the effects of variables such as weight gain, reproduction, and stocking density on fish growth. The production models used the basic framework of Von Bertalanffy's growth model, but revised it to include conditions specific to pond environments. In order to more accurately predict tilapia growth patterns, several numerical methods for modeling fish populations were compared for their ability to estimate pond populations under different natural conditions.

Results

Several tasks were undertaken to accomplish the objectives set for this study. The tasks can be grouped under the following headings: growth modeling, growth reduction factors, and elements of global fish production.

Growth Modeling

Accurate prediction of fish growth and production requires models that can be used to closely describe fish growth under different environmental conditions. To attain this goal, several numerical models for predicting fish growth were studied and compared. Von Bertalanffy's growth model was found to be the most versatile when applied to aquaculture conditions. (For discussion, please see Springborn et al., in review *a*.) Von Bertalanffy's growth model, however, assumes a theoretical age initially starting at zero size, which differs from the conditions existing in aquacultural environments. In aquaculture the initial stocking size is never zero. Therefore, in order to use this model to meet the conditions in aquacultural environments, it was modified to begin at a realistic stocking size and tested for aquaculture conditions. This newly developed model is termed the initial value solution, and has proved to be a more accurate predictor of pond fish growth patterns than the original equation. This model can be used to estimate growth patterns and to predict asymptotic growth. This information is useful in determining the optimal time for culturing tilapia in ponds. Using the new equation, the fish growth coefficients for each site and cycle were estimated, studied, and compared.

Patterns of fish growth differ at different sites, under different physical conditions, and in different pond environments. At some locations, tilapia have high growth rates in early life, while at other locations, accelerated growth occurs midway through the culture period. In order to effectively compare the different patterns of growth, a multivariate method using Von Bertalanffy's growth model was developed for examining the significant change among sites, ponds, and treatments in order to understand the reasons underlying growth pattern differences (Springborn et al., in review *b*). Using these newly developed methods, the elements contributing to growth pattern differences can be traced and incorporated into expansions of the model framework.

Growth Reduction Factors

Earlier analyses found a significant reduction in fish growth rates, with daily growth rates decreasing from 3 g at the beginning of the culture cycle to 1 g at the end. The rate of reduction was found to be highest in those ponds with the highest fertilization, and lower in those ponds which received lower levels of fertilization. Factors contributing to this reduction in growth rates were those which resulted from density dependent factors such as stocking density, increases in fish size, and reproduction as well as other factors related to the pond ecosystem. The first step in this study was to develop a fish population growth model based on Von Bertalanffy's growth model. We then expanded the model to include parameters such as stocking density, reproduction, and fish weight and size. Since stocking density data were not collected in CRSP Cycles I, II, and III, this analysis was based on the numerical simulation of other data, which were available from the literature. The study following this analysis will concentrate on the pond ecosystems to gather evidence on factors other than density dependent factors that may significantly affect fish growth rates.

Elements of Global Fish Production

Major differences were found in rates of growth and levels of production among the sites selected for this CRSP study. The question of why some sites are inherently unproductive while other sites are productive is an important and interesting one for improving fish production in areas where aquaculture has not been productive Earlier analyses showed that of the CRSP sites included in the data base during Cycles I, II, and III, the Thailand site was found to be the most productive, while the Rwanda site was the least productive. The analysis of growth, production, and environmental data showed solar radiation and air temperature to be strongly correlated with the levels of growth and production among the experimental sites. The next step in the study will be to focus on the relationship between these factors and pond conditions, to define the characteristics of highly productive ponds and those of less productive ponds, and to understand additional important geographical and physical elements of fish production

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Springborn, R.R., A.L. Jensen, and W.Y.B. Chang. In review *b*. A multivariate approach for examining *Oreochromis niloticus* growth in aquaculture experiments using Von Bertalanffy's growth solution. Aquaculture.

Analysis and Modeling of Water Quality in Ponds

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Introduction

The focus of the University of California at Davis (UCD) component of the DAST during the 1988-89 year has been the modeling of dissolved oxygen concentrations in ponds, the analysis of internal pond conditions based on oxygen production with respect to environmental conditions, and the analysis of histories of fish growth. The dissolved oxygen models have evolved considerably and their validity has been established by running simulations for the CRSP freshwater sites (Gualaca, Panama, Ayutthaya, Thailand, Bogor, Indonesia, Comayagua, Honduras, and Butare, Rwanda). The validated dissolved oxygen models are now being used as analytical tools to identify and quantify the effects of some important management actions and practices on dissolved oxygen concentrations Analyses of the responses of phytoplankton to environmental conditions have resulted in techniques that may be used to determine the effect of nutrient and light conditions on photosynthesis. The analysis of fish growth histories is expected to result in predictive relationships that can be incorporated into pond management guidelines. Progress towards the achievement of objectives specified in the Fourth CRSP Work Plan is described in this report, which covers activities between September 1988 and August 1989.

Previous Work

Previous work at UCD resulted in the development of three mechanistic models of pond processes. The models developed included:

- a mechanistic ecosystem model to simulate 14 state variables (The Aquaculture Pond Model, TAP, formerly called PondEco),
- a mechanistic model to simulate dissolved oxygen concentrations (PondDO), and
- a mechanistic model to analyze diurnal measurements of dissolved oxygen, pH, temperature, and alkalinity (WholePond).

The models have been described in previous progress reports and in other publications. The TAP model had previously been run with data from CRSP freshwater sites, resulting in simulations of varying quality. The model WholePond had been run with data for a pond in Ayutthaya.

Exploratory analysis of data from the first three experimental cycles had been carried out, focusing on variables related to dissolved oxygen cycles.

Objectives

Activities at UCD during the 1988-89 year relate to the following specific objectives of the DAST, as described in the Fourth Work Plan:

(2) To develop descriptive models based on CRSP data;
(4) To develop mechanistic models of pond processes;
(5) To calibrate the mechanistic models; and
(6) To validate the mechanistic models.

Results

Work on Objective 2 is a new area of activity at UCD, and was directed towards the analysis of fish growth histories. Work on Objectives 4, 5, and 6 involved further development and testing of the models previously described and listed above under the heading "Previous Work." Progress towards the achievement of the objectives listed is described below.

Objective 2

Analysis of histories of fish growth was undertaken to determine growth rates and the possible relationships between growth rates and environmental variables. Total fish biomass values in each pond were obtained from the F templates. The values for replicate ponds (i.e. ponds receiving the same treatment) were averaged The history for each treatment was then analyzed using a non-linear regression procedure to fit the following models:

a. A "Monod" type model:

$$FWeight = A \bullet Time/(B + Time) \quad (1)$$

where,
FWeight = average weight of a fish (g)
Time = Time from the time of initial stocking (d)
A, B = Fitted parameters for the Monod equation

b. An exponential growth model tending towards an asymptote:

$$FWeight = FWeight_0 \bullet Exp(-Time \bullet B) + A \bullet (1 - Exp(-Time \bullet B) \quad (2)$$

where,
$FWeight_0$ = Average fish weight at time of stocking (g)
A, B = Fitted parameters for the exponential growth model.

After initial testing, the second model was found to produce a substantially better fit of the data, as measured with a Pseudo-R^2 value, than did the first model. All further analyses were performed using the exponential growth model only. Results have been highly encouraging, as the Pseudo-R^2 values obtained are very high (Table 1). An example of the exponential model is shown in Figure 1.

In Equation 2, parameter A is the value of the asymptote, while parameter B is an indicator of the rate at which the asymptote is approached. In the context of the fish growth analyses being performed, the asymptote (A), may serve as an indicator of the carrying capacity of the pond, as this is the final weight that the fish are expected to reach. Parameter B, on the other hand, is an indicator of the growth rate.

The next step in this line of work is to complete analyses of growth data for Cycle II, when data become available. Statistical analyses (Analysis of Variance) of the values of parameters A and B will also be performed to identify the factors affecting "carrying capacity" and "growth rate," in an effort to develop predictive equations that can be used in the manual of pond management guidelines.

Objectives 4, 5, and 6

The processes of model development, calibration, and validation are described here for the three types of models under development at UCD.

Ecosystem Model

Refinements on the ecosystem model, TAP, included recompiling using a new FORTRAN compiler that facilitates debugging and formulation changes. The model is also being transcribed to a dynamic modeling language (EXTEND™) based on a C compiler. The EXTEND™ implementation will greatly facilitate the analysis of changes in rate coefficients, the isolation of processes, and the analysis of intermediate parameters not normally included in the model output.

Continuing on work started during the previous year, TAP was executed using data from all the CRSP freshwater sites in operation during the first three experimental cycles. After exhaustive searches of the data base, only one data set suitable for the simulations was found for each of the following sites Gualaca, Ayutthaya, and Comayagua. Two data sets were found for Butare. No complete sets were found for Bogor, because the dates of diel sampling and water quality sampling did not coincide. The data set used for Bogor was constructed using diel measurements for Julian date 345 and averages of water quality measurements obtained on Julian dates 341 and 348.

All the simulations were carried out with the model as calibrated for one pond at Ayutthaya. The only values changed for the different sites were the input data (initial conditions for the state variables, and climate and location indicators). The conditions found to have the greatest effect on the quality of the simulations were the relationships between chlorophyll measurements and phytoplankton and between light penetration, phytoplankton, and particulate organic matter. The response of phytoplankton to environmental conditions is also a major factor determining the quality of the model fit

After validating the model for data from the freshwater sites, it was calibrated for a pond in Bogor and hypothetical situations were created to test hypotheses on the effectiveness of possible management actions for preventing dissolved oxygen depletions during cloudy weather. Results of these simulations will be incorporated into the pond management guidelines.

PondDO Model

A PondDO model has been completed and refined and was the subject of a Masters Thesis awarded in March 1989 This model, based primarily on existing aquaculture models, was tested against data from three CRSP sites. The model was designed to test the ability of conventional dissolved oxygen models to predict dissolved oxygen concentrations in aquaculture ponds given the data available from the CRSP Central Data Base Although the model performed well in general terms, factors not included in the CRSP Data Base or the PondDO model had significant influence on dissolved oxygen concentrations. These factors included diel changes in nutrient concentrations and photosynthetic light sensitivity The subsequent development of the WholePond model was based on the performance of the PondDO model The WholePond model addresses the limitations of conventional dissolved oxygen models and analyzes the effects of changes in nutrient availability and phytoplankton light sensitivity.

Despite efforts to standardize experiments and data, some discrepancies remain between data sets from different sites that preclude a consistent analysis for all sites The sites that were analyzed were those for which daily weather measurements (Template A), weekly and twice-weekly measurements (Template D), and diurnal measurements (Template E) were all available for the same date during Cycle II. Since the model was based on the assumption of uniform conditions throughout a pond, another requirement was that the diel DO data be approximately uniform throughout the depth profile. Sites which have been analyzed at the time of this report include:

Site C, Ayutthaya, Thailand
Site E, Bogor, Indonesia
Site F, Comayagua, Honduras

WholePond Model

This model, developed to analyze diel dissolved oxygen data, was refined and used to formulate and test hypotheses about the responses of phytoplankton to variations in light and nutrient concentrations Data for testing some of these hypotheses has been collected and is being analyzed. The work has resulted in the development of a theoretical model of diel phytoplankton production dynamics in aquaculture ponds This model, based on initial data from the CRSP Central Data Base, suggests that the "condition" of a phytoplankton population can be quantitatively assessed by analyzing the rate of change of dissolved oxygen in the pond with respect to environmental conditions The model evaluates phytoplankton oxygen production rates as a function of temperature, light, nutrient availability, and light sensitivity Of these four variables, light radiation and temperature are external variables that are easily and commonly measured. When temperature and light conditions are measured, the phytoplankton production model can be used to solve directly for terms quantifying the effect of nutrients and light on photosynthesis.

Using data from the CRSP Central Data Base, the WholePond model has been tested on a preliminary basis. The nutrient and light limitation values obtained with the model are consistent with the ranges expected from published literature. These encouraging preliminary results prompted a joint project with the University of Hawaii's Mariculture Research and Training Center and the Hawaii Institute of Marine Biology to evaluate data collected from Hawaiian research ponds using the CRSP models The joint project has provided important data that will be used for validating and testing the CRSP models, and should result in the development of powerful new tools for analyzing conditions in aquaculture ponds

The validated model will be useful for the analysis of new data sets generated by the CRSP, especially since the new CRSP data sets will contain several intense diel sampling runs that include detailed information about pond nutrient conditions, light intensity, and wind speed. The model also has direct application in the formulation of pond management guidelines, because it can simulate phytoplankton condition and responses to environmental and water quality factors.

Development of a Manual of Pond Management Guidelines

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Introduction

One of the purposes of the CRSP Data Analysis and Synthesis Team (DAST) is to translate the results of pond dynamics research into operational procedures or guidelines for pond management. Pond management guidelines are of potential interest to aquacultural producers, development planners, and aquaculture scientists. Translating the results of pond dynamics research requires the development of methods for organizing research results into a form that identifies the correspondences between pond ecology and appropriate management practices. Another requirement is that the organized information must be compiled in a manner that facilitates dissemination to interested audiences.

Previous work

Earlier phases of this project focused on how best to organize research results for conversion into practical management guidelines The approach taken for organizing the information was to develop a functional classification of pond ecosystems in which ponds are organized according to the fertilization practices that have the highest probability for optimizing fish yield. An important aspect of this approach was the development of quantitative functional relationships that describe the appropriate levels and frequencies of fertilization for each class of ponds. The development of a hierarchical classification of tropical farm ponds is complete. Ponds are classified according to source water chemistry, soil properties, and climatic factors. There is a unique set of corresponding practices for each class An "expert system" was developed to compile the information for dissemination to interested audiences. Our expert system is a computer program that identifies the classes to which ponds belong, specifies the appropriate practices for each class, and calculates the levels and frequencies at which the practices should be applied.

A computer program named PONDCLASS has been written and tested. PONDCLASS is a "shell" of the expert system to be used with the pond classification model, and is designed to be run on personal computers. Two versions of PONDCLASS are being developed; one for the IBM-PC and compatibles and one for the Apple Macintosh computer. The IBM-PC version of PONDCLASS was completed last year.

Objectives

The activities described in this report address two of the objectives of the present CRSP grant:

(7) to develop pond operating strategies consistent with each model (described in preceding objectives); and
(8) to compile a manual of pond operating strategies for optimizing yields, which will increase the reliability and improve the efficiency of pond culture systems.

Specific tasks addressed by the DAST in support of these objectives during the period of this report are:

(1) To complete the Macintosh version of the PONDCLASS program; and
(2) To continue the development of functional relationships and the compilation of fertilization guidelines based on research information.

Results

Objective 1

Development of the shell for the Macintosh computer version of PONDCLASS is complete. Both the Macintosh and IBM-PC versions of the program are now operational and ready for the installation of computational algorithms.

Both versions of the PONDCLASS program have been demonstrated to selected aquacultural scientists. The comments received from this informal peer review have been incorporated into the program, resulting in several improvements to the program. The most significant improvement results in simplifying data input. In earlier versions of PONDCLASS, users selected "numerical input" or "descriptive input," depending on the kind of information available for a pond of interest. The program branched to process each kind of information separately. These input branches have now been combined into a single input routine. In the present version of PONDCLASS, the program uses numerical values in computations if a user enters numerical values for pond variables. If no numerical values are entered, PONDCLASS inserts expected values based on descriptive pond information provided by the user. Thus users are no longer limited to the use of only descriptive or numerical input, but may now combine both types of information.

Objective 2

The first version of the CRSP pond management guidelines will have greater predictive capacity than was originally anticipated. At the outset of the present CRSP grant, it was anticipated that the guidelines would be capable of identifying which fertilization practices would be appropriate for a given pond, but that the recommendations for levels and frequencies of fertilizer addition would be limited Based on the synthesis of research information completed to date, it now appears that the guidelines will be capable of specifying recommended levels and frequencies for the addition of several fertilizers and combinations thereof, estimating expected fish yields for selected species, in both monocultural and polycultural combinations, and comparing the relative economic efficiencies of different operating strategies.

Completion of the CRSP guidelines requires the development of two algorithms: (1) an algorithm for estimating the nutrient additions required to achieve reliable, satisfactory fish yields, and (2) an algorithm for comparing the relative efficiencies of alternative pond management strategies. Substantial effort has been directed toward developing these algorithms. The algorithms are based on functional relationships among pond management actions and ecological variables that influence fish yields Functional relationships are quantitative expressions of the relationships between two or more pond variables. They are mathematical functions; if the value of one variable is given, the corresponding values of the other variables are determined.

Several of the functional relationships required for the CRSP guidelines have been developed during the past year. Some were developed from the empirical and mechanistic models being developed by other members of the DAST. Others have been developed from *a priori* relationships. Among the functions derived or developed are:

1 A nutrient requirement function. This function estimates the amounts of lime, nitrogen, and phosphorus required by a given pond per unit time. The function is based on research results from the CRSP Indonesia and Thailand projects (McNabb et al., 1989; Md. Yusoff and McNabb, in press) and CRSP dynamic models (Piedrahita, personal communication), and is calibrated with other CRSP data.

2. A water budget function. This function corrects the nutrient requirement function for concentration or dilution of nutrients associated with the pond water budget.

Other functions being developed for the guidelines include:

1 A nutrient addition function. This function expresses the amount of a given fertilizer or combination of fertilizers that is required to satisfy the nutrient requirements of a given pond (as estimated by the nutrient requirement function described above). The paucity of information about the variation in chemical composition of different organic fertilizers (manures and composts) is a constraint to completing the nutrient addition function. Therefore, we have initiated a modest research activity to compile a base of information about variations in fertilizer composition.

2. A relative efficiency function. This function compares the ratios of inputs to expected yields of alternative pond management actions. Development work on this function up to the present time has been limited to screening existing production functions that can be adapted for use in the CRSP guidelines.

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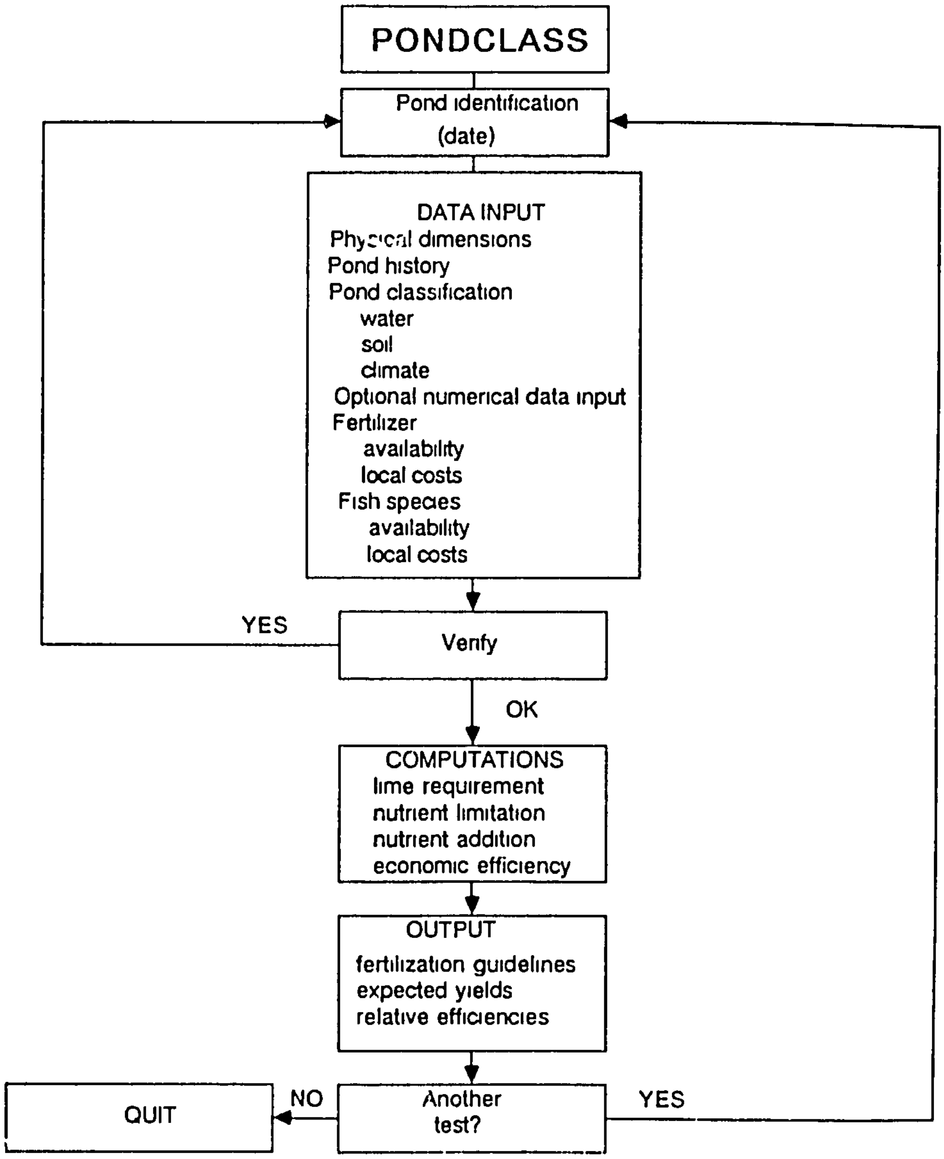
Md. Yusoff, F. and C.D. McNabb. In press. Effects of nutrient availability on primary productivity and fish production in fertilized tropical ponds. Aquaculture.

Figure 1 Schematic diagram of the current version of the PONDCLASS program



U.S. Special Topics Research Reports

The Effect of Ammonia on *Oreochromis niloticus* (Nile tilapia) and Its Dynamics in Fertilized Tropical Fish Ponds

Abdalla, Abdelmoez A.F. 1989. Ph.D. Dissertation
Michigan State University, East Lansing, Michigan

This study was designed to investigate: (1) acute effects of unionized ammonia on 10.7 g fingerlings of *Oreochromis niloticus* at two temperatures (23°C and 33°C,), and at 28°C with two sizes of fish (3.4 g and 45.2 g); (2) chronic effects of unionized ammonia on growth of *O. niloticus* at two temperatures typical of tropical ponds (28°C and 33°C); and (3) losses to the atmosphere and algal uptake as mechanisms that reduce ammonia concentrations and toxic effects in fertilized ponds stocked with *O. niloticus*.

In acute toxicity tests at 23°C and 33°C, 96-hour LC50's were 2.2 and 2.3 mg/L unionized ammonia, respectively. The 96-hour LC50 at 28°C was 1.4 mg/L unionized ammonia for small fish (3.4 g) and 2.8 mg/L for large fish (45.2 g) The effect of temperature on acute toxicity of unionized ammonia was not significant for 10.7 g fish, while there was a significant effect due to fish size at 28°C

In chronic tests, there was a linear decrease in fish weight gain with increasing unionized ammonia concentrations at both 28°C and 33°C The level of no growth effect was 0.06 mg/L unionized ammonia at both temperatures. Effective concentrations for 50% growth reduction were 0.77 and 0.87 mg/L at 28°C and 33°C, respectively. No-growth concentrations were 1.48 and 1.67 mg/L unionized ammonia at these temperatures. The relative growth rate of fish in controls was significantly higher at 28°C than at 33°C.

Three fertilizer treatments were used in ponds in a field experiment. Substantial quantities of ammonia were lost from ponds in each treatment during daylight hours. Increased total ammonia at dawn resulted in increased net primary productivity. Losses to the atmosphere were relatively small, varying from 1 to 9% of total diurnal ammonia losses. Uptake of ammonia by algae was a more important mechanism for the removal of ammonia from ponds. Algal uptake accounted for 37% to greater than 100% of the ammonia lost during daylight hours. Fish mortalities occurred in ponds with the highest fertilizer treatment (3150 g $N/m^2/wk$). The average diel unionized ammonia measure in these ponds was 0.7 mg/L. Interactions between unionized ammonia, low dissolved oxygen, and high pond temperatures appeared to be responsible for the mortalities.

HOST COUNTRY SPECIAL TOPICS RESEARCH

Introduction

This component of the Pond Dynamics/Aquaculture CRSP was created to provide opportunities for host country and U.S. researchers to collaborate on original research directed towards the needs and priorities of the host country. The intent was to strengthen linkages within the host country institution and to contribute to the development of research capabilities within the institution by providing opportunities for scholarly involvement of faculty and advanced students. This component also provides host country institutions and agencies with access to the human resources of the CRSP in seeking solutions to shorter term local problems. Projects focus on specific aspects of the Global Experiment that would benefit from site-specific, detailed investigations. They complement the U S-based Special Topics Research Projects.

Proposals for these Special Topics Research Projects are developed collaboratively by the host country and U.S. scientists. The proposals are endorsed by the host country institution and are reviewed by the CRSP Board of Directors for technical merit and relevance to the CRSP Global Experiment The Board also requires that investigators discuss the proposed project with USAID Missions to ensure that the projects are consistent with USAID and host country development strategies and priorities.

Although the special topics projects are an important part of the CRSP, they are not a major component in terms of funding support or time expenditures. Twenty to twenty-five percent of each research associate's time typically is devoted to this activity. The CRSP places highest priority on the long-term research defined as the Global Experiment Host country agencies and institutions and USAID Missions, however, often consider basic research activities to be of low priority. Consequently, administrators sometimes have difficulty justifying participation in the CRSP. The CRSP support for the Special Topics Research activities helps to justify this participation.

Host Country Special Topics Research Reports

Gonadal Development in Walking Catfish, *Clarias batrachus* (L.), During Environmentally Induced Breeding

Tiruvalloor V. Gayathri Rao. 1989. M.S. Thesis, Asian Institute of Technology, Bangkok, Thailand.

The gonadal development of a group of walking catfish, *Clarias batrachus* (L.), that had previously spawned was studied for a period of 95 days. The fish were induced to spawn by varying the length of time of increased water levels and feeding rates. 2 weeks, 5% body weight (bw)/day; 2 weeks, 10% bw/day, 4 weeks, 5% bw/day; and 4 weeks, 10% bw/day respectively. Nests containing synthetic packing material were provided to aid egg collection. Handling and counting the eggs was facilitated by treating them with 1 0% sodium sulphite to dissolve the gelatinous matrix. Mean final GSI values were 7 69 ± 0 49%, 6 1 ±0.04%, 5 2 ± 1.0%, and 7 2 ± 0 60%, respectively, for females, and 0.03 ± 0.05%, 0 03 ± 0.04%, 0 24 ± 0 01%, and 0 25 ± 0 03%, respectively, for males. No significant differences in ovarian development were observed among treatments Fat tissue losses increased concomitantly with GSI. Total and relative fecundity values were significantly higher at the 5% feeding level. Egg diameter was significantly larger in treatments on 10% feed. No significant differences in water quality were observed among treatments

Nutrient Release Characteristics of Duck Manure for Nile Tilapia Production

Md. Amir Ullah. 1989. M.S. Thesis, Asian Institute of Technology, Bangkok, Thailand.

A series of experiments was conducted to examine characteristics of nutrient release from duck manure and to determine how these nutrients affect Nile tilapia (*Oreochromis niloticus*) yields. The first experiment used fresh manure from ducks fed low- and high-grade diets with and without rice husks as bedding material; the second used four-week-old manure from ducks on the same low-grade diet as used in the first experiment with manure being stored under two different conditions; the third experiment used four-week-old manure stored in the same way as in the second experiment from ducks on a high-grade diet. In the first experiment accumulative ammonia-N released from manure varied from a minimum of 6.5 mg NH_3-N/g dry matter (DM) to a maximum of 9.2 mg NH_3-N/g DM and soluble reactive phosphorus (SRP) release varied from 1.7 to 2.0 mg PO_4-P/g DM. In the second experiment, accumulative ammonia-N release from manure varied from 7.0 to 8 8 mg NH_3-N/g DM and SRP release varied from 2.2 to 2.6 mg PO_4-P/g DM. In the third experiment the release of ammonia-N ranged from 7.1 to 9 1 mg NH_3-N/g DM and the SRP release varied from 3.5 to 4.1 mg PO_4-P/g DM. Nearly all soluble nitrogen and phosphorus were released by the fourth day of manure application Proper storage of manure from ducks fed a high-grade diet increased the rate of nutrient release and fish yields. Use of bedding material caused a reduction of the amount of nutrient release on a per-unit weight basis and did not significantly affect fish yields.

Impact of Attached Microorganism Biomass on Tilapia (*Oreochromis niloticus*) Production

Madhav K Shrestha. 1989. M.S. Thesis,
Asian Institute of Technology, Bangkok, Thailand.

Two 8-week, 2 x 2 factorial experiments were conducted in outdoor concrete tanks. Plastic baffles and bamboo poles were used as substrates to increase surface area for potential attachment of microorganisms Feeding on attached microorganisms by Nile tilapia, *Oreochromis niloticus*, was assessed. Growth of fish raised in "baffle" and "no-baffle" systems was not significantly different. Assessment of attached microorganism biomass showed significantly higher ($p < 0.05$) ash free dry weight (AFDW) in "no-fish" systems as compared to "fish" systems Fish tanks with bamboo poles showed higher growth and production than in fish tanks with plastic baffles. Nile tilapia polyculture with freshwater snails (*Viviparus* spp.) had a 22.9% competition index. Although fish growth obtained was not significantly different in systems with added substrates, it is believed that Nile tilapia feed on attached microorganisms.

A Study of the Plankton Communities of Different Habitats in the Rwasave Fish Ponds

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Introduction and Objectives

The plankton communities of fish ponds are essential components of the process of producing fish for harvest. Understanding the organization and composition of these communities in relation to the habitat structure of ponds better enables biologists to recommend suitable pond management practices. The objective of this study is to describe the plankton composition of communities within defined pond habitats

Materials and Methods

Five habitats in each of four ponds were sampled every two weeks. The habitats were: A, at the surface; B, in compost or at the corners where the compost accumulated in the case of broadcasted compost; C, in the 25- to 50-cm depth (photic zone); D, at the 100-cm depth (aphotic zone); and E, near the bottom. A 90-cm, water-column sample was also taken at three different places in each pond.

Ponds selected for the intensive habitat sampling were part of CRSP Experiment 4b, which was conducted to evaluate different composting methods and mixtures. The ponds were C4 (treatment IP50), C6 (AN80), C8 (IP100), and C9 (AE80). Each pond was stocked with 700 *Oreochromis niloticus* juveniles and sampled monthly Chlorophyll *a* measurements were taken every two weeks. An intensive series of water analyses were conducted at three times during the experiment as noted in the CRSP procedures. Plankton were preserved in Lugol's solution immediately following sampling, then identified to genus and counted using a Sedgwick-Rafter cell. Habitat volumes and Hill's diversity index (N2) were also calculated.

Results

Forty-one genera of Chlorophyta were identified; of these *Pediastrum* and *Scenedesmus* were most abundant. Diatoms numbered 24 genera (*Navicula*, *Pinnularia*, and *Fragilaria* were most abundant). Eighteen genera of Cyanophyta were identified; *Merismopedia*, *Coelosphaerium*, and *Gomphosphaeria* were the most common, although *Anabaena* and *Oscillatoria* appeared explosively in some ponds. The most-frequently observed phytoplankton were *Trachelomonas* species (Euglenoidina). Cyanophytes and Euglenophytes each dominated ponds at particular periods but exhibited some mutual exclusion.

Protozoans were very numerous but were difficult to identify after preservation. Most were large to medium ciliates; a few zooflagellates were also observed. However, based on observations of live specimens, it was concluded that *Stentor*, *Condylostoma*, and *Paradileptus* were the dominant ciliates. Rotifers were most numerous among the zooplankton, *Brachionus* being the most abundant.

The first part of the study, which compared plankton populations, showed that there was less difference between habitats within ponds than between ponds. The only significantly different habitat was habitat E (near the bottom), in which diatoms were more abundant than they were in other habitats.

Phytoplankton-zooplankton interactions are currently being analyzed, as are similarities between 90-cm, water-column samples and estimated total-pond plankton numbers based on habitat volume calculations. Measurements were made for the calculation of biovolumes, but have not yet been applied.

Anticipated Benefits

This study contributes to the basic understanding of pond habitats and their plankton communities. This understanding should enable biologists to improve their pond management recommendations.

Profitability of Integrated Pig and Tilapia Culture Compared to Intensive Tilapia Culture

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Introduction

The integration of animal husbandry with fish culture has long been recognized as a means to assure high fish production and the efficient use of wastes. Although integrated agriculture-aquaculture is widely practiced in Asia, few examples of successful animal-fish programs exist in Africa. Farmers in Rwanda, as well as the rest of Africa, have no tradition of integrated animal husbandry, and have only recently been strongly encouraged to consider the possibility.

Hishamunda (in press) studied the profitability of integrating layer hen, pig, and duck production with the culture of *Oreochromis niloticus* Of the three, he noted that pig production was the least profitable but that a profit of about 500,000 FRw/ha/year (pond surface area) was possible (80 FRw = 1$US). He speculated that the initial investment and technical competence required to manage an integrated animal-fish operation are beyond the means of most farmers.

Objectives

The objectives of this project were to compare the production, and costs and returns of integrated pig-tilapia culture with that of tilapia culture alone, as usually practiced at the Rwasave station.

Materials and Methods

Six 1500-m² ponds were each stocked with 1223 mixed-sex *O. niloticus* fingerlings averaging 24 g. Two additional ponds each received 1500 male juvenile *O. niloticus* averaging 62 g. A total of 63 pigs were raised, giving a ratio of 105 pigs to 1 ha of pond surface. Pigs were fed a mixture of 50% local ration (sweet potatoes, sorghum beer waste, and sweet potato vines and 50% commercially available pig feed). Three of the mixed-sex ponds and one of the monosex ponds received weekly applications of the wastes from 63 pigs in grow-out. Pig wastes consisted of liquid and solid wastes, uneaten feed, and rice hulls or straw used to collect the urine. The wastes were distributed equally over the four ponds

The remaining ponds (3 mixed-sex and 1 monosex) received weekly applications of fresh grass and chicken litter at a rate of 760 kg/ha/week (dry weight) This mixture was composed of 84 kg grass/week (300 kg wet weight) and 30 kg chicken litter (53 kg wet weight) for each pond. Fish in these ponds were fed rice bran at 10% of body weight per day when their average size was less than 50 g and 5 g per fish per day thereafter. Ponds were sampled monthly to measure fish growth. Morning DO, pH, and, temperature at top, middle, and bottom were measured weekly and alkalinity, hardness, and chlorophyll *a* were measured every two weeks. Pond soil characteristics were measured three times during the trial.

Results and Discussion

Pig production was not economically profitable by itself. This was not surprising given that the transport and purchase of feed ingredients normally available to farmers at no cost is usually very costly for government agencies. Additionally, the commercial ration is prohibitively expensive. Losses for the pig-fish combination were about 0.5 FRw for every 1 FRw invested. Losses from pig grow-out would have been much higher had the fish not been raised in association. In summary, the cost of every kilogram of pig manure was 8.5 FRw (including revenues from pig sales) and each kilogram of pig waste resulted in net fish production valuing only 8 FRw. By comparison, the compost and rice bran treatment cost about 1 FRw/kg applied and resulted in 5 FRw in net fish production for every kg applied.

The mean net fish production in the pig manure fertilized ponds was 2548 kg/ha/yr for the mixed sex ponds, as compared with 4239 kg/ha/yr for the single monosex pond. The ponds fertilized with compost and fed with rice bran produced an average of 2083 kg/ha/yr for the three mixed sex ponds and 4642 kg/ha/yr for the monosex pond. The differences between treatments for the mixed sex ponds were not statistically significant. The slight increase in productivity did not offset losses in revenue from pig production. However, the stocking densities used in this trial were probably too low for efficient use of the fertilizers and feeds involved.

Benefits

Detailed tables of prices and costs made for this study will be of use for evaluating other fish farming enterprises As a result of the study, the Rwasave station has changed its pig ration to one of much lower cost and has decreased the pig:pond area ratio to about 50 pigs per hectare. In an attempt to more fully integrate the system, tadpoles, frogs, and lily pads harvested from ponds are now fed to the pigs.

Feeding Habits and Parasitism of *Clarias gariepinus* in Lake Ihema and Impact of *Clarias* on *Haplochromis* stocks

J. Nepomuscene Murwanashyaka
National University of Rwanda, Butare, Rwanda

Introduction and Objectives

Lake Ihema supports an active commercial fishery on tilapias, *Clarias* species, and other fishes. Managers of this fishery have proposed including *Haplochromis* as a target species. These fish populations exhibit complex interactions, including competition, predation, and -- for tilapias -- hybridization, that affect the fishery. The objectives of this study are to assess the level of predation on *Haplochromis* species by *Clarias gariepinus* and to describe the feeding habits and parasites of *Clarias* in Lake Ihema.

Materials and Methods

The stomach contents of 265 *Clarias* specimens were identified and weighed. The fish were supplied by commercial fisherman who utilize gill nets. Parasites were also removed and identified.

Results

Clarias gariepinus was found to consume a wide variety of insects, zooplankton, phytoplankton, detritus, and fish. The dominant portion of the diet, by weight, was fish, with a preference for tilapias followed by *Haplochromis*. Seasonal differences in diet were minor. The level of predation on *Haplochromis* was estimated to be of little impact to the proposed fishery. Reduction in *Haplochromis* stocks by the fishery could slow *Clarias* growth, however.

Clarias had heavy infestations of cestodes and nematodes (*Strongylus* species) due to their predation on species serving as intermediate hosts. A large population of piscivorous birds served as final hosts. The presence of parasites on fish reduces their market value but poses no known health hazard.

Anticipated Benefits

This study provides information that will allow fishery officials to improve the management of an important animal protein source in Rwanda.

PROJECT DEVELOPMENT AND PUBLIC SERVICE

Public Service

As Pond Dynamics/Aquaculture CRSP projects in developing countries become integrated into USAID's "country strategy," opportunities for providing support to scientific research institutions, for training, and for extending CRSP research results to the people of these countries have arisen. In each country project of the CRSP, researchers have recognized these opportunities and have assisted their counterparts in initiating appropriate activities. 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 of these contributions, research capabilities have been substantially strengthened and private, local fish farming operations have been assisted in every developing country in which the CRSP has been active Some of these important contributions are described below.

Institution Building

In Rwanda, construction began on a new indoor hatchery. The CRSP experimental facility at Rwasave continued to be of interest as a destination for student field trips. Primary, secondary, and university students, as well as trainees from the teachers' training center, visited the station, to learn about biology of fish, fish culture techniques appropriate for Rwanda, and recycling of farm by-products. The station also continued to be a resource to fish culture extension agents, who meet with CRSP researchers for discussion and planning. The Rwasave Fish Culture Research Station celebrated the 25th anniversary of the UNR at an exhibition, presenting posters, photos, and live exhibits in aquaria. Ms. Karen Veverica, the U.S. field scientist in Rwanda, taught short courses at the National University of Rwanda (UNR) in introductory ecology, fisheries, introductory fish culture, and biological productivity. She also gave a one-day short course on aquaculture to farmers from area communes.

Researchers in Honduras also taught short courses. Dr. David Teichert-Coddington gave a course on water quality and fish ponds to students from a forestry school in Siguatapeue, and Dr. Bart Green spent two weeks in Guatemala giving an intensive course in water quality to university students and some local shrimp producers.

In Thailand, Dr. Chris Knud-Hansen introduced research methods into the curriculum at the Asian Institute of Technology by teaching a course entitled *Experimental Design and Analysis in Aquaculture.* CRSP scientists working in each country have been involved as advisors in the research programs of students at host-country universities.

Training

Although training is not formally a component of this CRSP, 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 at the CRSP research sites or at other overseas locations (both in host countries and regionally) by CRSP researchers. The number of individuals who have benefited from informal training activities since the beginning of the program is over 70; of this total, at least 20 individuals were trained during this reporting period. Many additional individuals are known to have benefited through similar contacts with CRSP activities and scientists, even though their numbers were not recorded.

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 in at least seven overseas institutions and at all of the collaborating universities in the U.S. (Table 1). Prior to this reporting period at least 43 degrees (B S., M S., and Ph.D.) were awarded, and during this period another 42 were either completed or underway (Table 2).

The number of individuals involved in all forms of training, from non-degree activities through work on advanced degrees, has climbed to well over 150 since the beginning of the program. Most of the trainees have come from PD/A CRSP host countries (Panama, Philippines, Indonesia, Honduras, Thailand, and Rwanda), however, the benefits of CRSP-related training have extended well beyond the borders of the six collaborating countries, as evidenced by the fact that participants have been drawn from at least 25 countries over the course of the program Although many participants may not remain directly involved in aquacultural work in the future, the experience they have gained with the CRSP program allows them to contribute to awareness and interest in the wider community, as they take up positions in schools, banks, agriculture research institutes, national parks services, development projects, and agricultural extension services in their respective countries.

Linkages

The CRSP continues to establish and maintain important linkages with other organizations involved in aquacultural and agricultural research and development. During this reporting period Michigan State University (MSU) received a grant from the U.S. Department of Agriculture Cooperative State Research Service to continue to serve as the North Central Regional Aquaculture Center (NCRAC). MSU was identified as the lead university for the NCRAC largely because of its long-standing involvement in the PD/A CRSP. Dr. C.D. McNabb, from MSU, visited officials of the Oceanic Institute at Makapuu Point, Oahu, Hawaii, for discussions about linking PD/A CRSP work to aquacultural undertakings at the USDA Center for Tropical and Subtropical Aquaculture.

Members of the Data Synthesis and Analysis Team (DAST) at 'he University of California, Davis (UCD), undertook a joint project with the University of Hawaii's Mariculture Research and Training Center and the Hawaii Institute of Marine Biology to evaluate data collected from Hawaiian research ponds using CRSP models. Such collaborative work not only provides additional data for validating CRSP models, but also extends the usefulness and applicability of CRSP models and research efforts.

Close ties are maintained with the International Center for Aquaculture (ICA), in Auburn, Alabama through Auburn University's involvement in the CRSP. We are also working with the International Center for Living Aquatic Resources Management (ICLARM) on the development of a handbook of aquaculture research techniques. This handbook is an outgrowth of the CRSP work plans, and addresses a need identified by CRSP scientists in the early stages of the program—to establish standardized techniques for use in aquacultural research worldwide.

In addition to the organizations specifically mentioned above, the CRSP maintains ties with numerous other organizations. These include:

Zamorano, Honduras
The Peace Corps, Honduras and Thailand
The University of the Philippines in the Visayas (UPV)
Department of Aquaculture (DINAAC), Panama
Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Institut Pertanian Bogor (IPB), Indonesia
Western Regional Aquaculture Consortium (WRAC), Seattle, Washington
International Rice Research Institute (IRRI), Philippines

Project Development

New Areas of Emphasis for the CRSP

Sensitivity toward the environment and appreciation of the need for sustainable agriculture have always been characteristic of the PD/A CRSP. This year, the CRSP helped in natural resource policy development and implementation at several sites. A corollary to successful sustainable agriculture is a strong Women in Development component; increasing women's economic status eases population pressure The PD/A CRSP has taken a more active role in encouraging women in aquaculture Transfer of successful and appropriate technology continues to take place, as the private sector capitalizes on the CRSP research. These payoffs occur not only in the Host Countries, but also in the United States Finally, the CRSP is beginning socioeconomic studies designed to analyze optimal resource use.

Natural Resource Policy

In Rwanda, the CRSP Research Associate advised the AID Mission on the design of the Natural Resource Management Project. Through her efforts, fish culture concerns were included in the project. She also advised the FAO on the development of new fisheries and aquaculture laws for Rwanda, with emphasis on land tenure in the wetlands. The Rwasave station is used as an example of a research center that address environmental issues. CRSP experiments in Honduras addressed water quality issues, which are of concern not only in ponds, during the production cycle, but also as effluents leave ponds and are returned to the larger ecosystem. A concern for the wider environment and the effects of aquacultural production on it is shared by CRSP scientists at all sites. Environmental concerns must continue to be given highest priority in all countries, whether temperate or tropical, lesser-developed or highly developed, as researchers attempt to find improved techniques for meeting the nutritional needs of a rapidly growing world population.

As environmental concerns move us toward more sustainable agricultural systems worldwide, aquacultural production will continue to fill an important niche. Pond production of animals and plants is an important 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 need not be dumped directly into natural waterways, but can be used for irrigation, and 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. Other examples of the integration of pond aquaculture with other forms of agricultural production include such combinations as pig-fish, chicken-fish, and duck-fish operations, and the use of farm by-products such as manures, grasses, inedible plant parts, and composts as nutrient sources in ponds. CRSP research at all sites continues to emphasize the development of efficient ways of utilizing these agricultural by-products to enhance production in ponds, and to contribute to sustainability by recycling farm materials.

CRSP scientists are also involved in research geared toward increasing food production using indigenous fish species. For example, recent work in Thailand has been concerned with environmentally induced ovarian development and hatchery techniques for fry production of the walking catfish, *Clarius batrachus*. Species such as *C. batrachus* are suitable for aquaculture and can contribute greatly to overall food production because they are already well-known, desired food fish and because they are hardy. This hardiness makes it possible for farmers to stock and grow them at relatively high densities or in oxygen-poor water; it also means that the fish can be marketed live, an important factor to consumers in many regions. The use of indigenous species wherever possible reduces potential risks to ecosystems which may result from the indiscriminate use of exotic species.

Women in Development

Women's involvement in aquaculture can have profound effects on the environment and the economy of a country. With population pressure the main threat to the environment, it is imperative that women feel secure in having fewer children whose chances for survival are good. Improved nutrition from fish can provide that security. A first step in involving women in aquaculture is to provide training. At least 39 women from eleven countries have been involved in CRSP-related training or other educational activities since the inception of the program. Women account for more than 25% of all training that has occurred because of the CRSP's existence. Twenty-eight women received training at overseas locations, and eleven studied at U.S. institutions. Training included 17 non-degree activities (short courses, etc.), and 26 degree-related efforts (19 B S's, 4 M.S.'s, and 3 Ph D.'s) During this reporting period, 11 women either completed degrees or other training activities or continued work on degree programs. This constitutes approximately one-third of all those receiving some form of training during the period.

In Rwanda, one quarter of fish farmers today are women. They are benefiting from CRSP research on integrated fish farming, which uses low-cost agricultural waste to enhance pond productivity. Rwandan women are also responsible for helping to break down cultural resistance to eating fish.

Private Sector Involvement

The Rwasave Fish Culture Research Station in Rwanda has become almost self-supporting, using funds generated from the sale of fish, pork, produce, and water quality laboratory services. CRSP researchers also advise private and communal farms on integrated fish farming, and have begun collaborating with private farmers in conducting on-farm trials of techniques developed at the CRSP research site. In Honduras, the CRSP collaborates directly with a large private shrimp farm (Granjas Marinas San Bernardo). All inputs are provided by the farm, but the CRSP provides the technical assistance in formulating and managing the experiment. CRSP studies on feeding behavior of juvenile marine shrimp translated to annual savings of $975,000 for this facility alone.

CRSP research findings do not benefit only Host Country producers; research proving the efficacy of sustainable inputs such as green grass and compost will have immediate application in California and Idaho, where fish farmers are investing heavily in tilapia ventures, and in other Less Developed Countries (LDC's) as results are published in scientific journals and shared with other scientists at international meetings and conferences. Tilapia, the key species used in CRSP experiments, also has marketing potential in the U.S. As U.S. demand for fish soars, aquaculture expansion will probably become pronounced in the South and Southeast, where farmers searching for new cash crops are expected to convert more agricultural land to aquacultural production.

Socioeconomic Studies

In Rwanda a study was undertaken to analyze the economics of aquaculture production. Sixty farmers (30 each in low- and high-altitude regions of the country) were interviewed to obtain data on stocking, harvesting, years in production, input costs, product prices, marketing channels, and labor inputs. These data will be analyzed to compare labor efficiency and costs and returns for aquaculture in low- and high-altitude regions. In Thailand, considerable effort has been devoted to compiling cost and return information to supplement the technical data collected during the CRSP experiments. This information will be used to conduct economic studies of existing aquaculture operations, but will also be useful to those considering future investments in aquaculture in Thailand.

Participation in International Scientific Meetings and Conferences

CRSP scientists continue to maintain contact with the wider aquaculture community and share the results of their research through participation in scientific meetings and conferences.

- At least six CRSP participants attended the annual meeting of the World Aquaculture Society held in Los Angeles, California, in February 1989. Three papers based on CRSP research were presented. Among those attending were Dr. James Diana, Mr. Dan Dettweiler, Dr. Raul Piedrahita, Dr. James Szyper, Dr. Cal McNabb, and Dr. Ted Batterson

- Drs C. Kwei Lin, Peter Edwards, and Cal McNabb represented the CRSP project in Thailand at the Second Asian Fisheries Forum in Tokyo, Japan in April 1989, and presented two papers.

- Four papers were presented by CRSP participants at the Programa Cooperativo Centroamericana para el Mejoramiento de Cultivos Alimenticios (PCCMCA), which was held at San Pedro Sula, Honduras, in April 1989. Those attending included Mr. Hermes Alvarenga, Mr. Luis Lopez, Mr. M. Ivan Rodriguez, Dr. David Teichert-Coddington, and Dr. Bart Green.

- Dr. Raul Piedrahita, of the Data Analysis and Synthesis Team (DAST), presented a paper a the meeting of the American Society of Agricultural Engineers held in Quebec, Canada, in June 1989.

- Mr. Eugene Rurangwa presented a paper at the Annual Symposium of the Hydrobiological Society of East Africa (HYSEA) held in Nairobi, Kenya, in December 1988.

- Dr. Chris Knud-Hansen presented a paper at the XXIVth International Congress of the Association of Theoretical and Applied Limnology in Munich, Germany in August 1989.

Table 1. List of Participating Institutions

National University of Rwanda
University of Panama
Catholic University of Chile
National Autonomous University of Honduras
Institut Pertanian Bogor (Indonesia)
University of the Philippines in the Visayas
Asian Institute of Technology (Thailand)
Kasetsart University (Thailand)
Oregon State University
The University of California at Davis
Auburn University
Michigan State University
The University of Michigan
The University of Hawaii

Table 2. Degrees Awarded For CRSP-Related Studies

	B.S.	M.S.	Ph.D.	Total
Before 1988	34	7	2	43
1988-1989	19	15	8	42
Total	**53**	**22**	**10**	**85**

PROGRAM MANAGEMENT AND TECHNICAL GUIDANCE

Program Organization and Structure

The basic organizational structure of the Pond Dynamics/Aquaculture CRSP remained the same as in previous years although there were some notable changes in membership of the various governing bodies New membership reflects the consolidation of the CRSP into three countries. New appointments were made to the Management Entity, the Board of Directors, and the Technical Committee

Management Entity

Oregon State University continued to function as the Management Entity for the Pond Dynamics/ Aquaculture CRSP. The Management Entity moved to the Office of International Research and Development (OIRD) in the summer of 1986 from its original home in Newport, where it had been based since 1982 The new location, which is next to the Oregon State University Administration Building, facilitates the streamlining of many administrative details essential in properly servicing the CRSP Grant The CRSP also is part of OSU International Fisheries at OIRD, which is comprised of the Consortium for International Fisheries and Aquaculture Development (CIFAD), the Foreign Fisheries Observer Program, and the International Institute of Fisheries Economics and Trade The new arrangement with OIRD affords the Management Entity increased support in accounting, purchasing, and other services The Management Entity is now fully integrated into the larger framework of international agricultural programs at Oregon State University and derives benefits from interacting with these programs The CRSP, formerly part of the Department of Fisheries and Wildlife in the College of Agriculture, now reports directly to the Vice President for Research, Graduate Studies, and International Programs through the Director of OIRD. Ties to the Department of Fisheries and Wildlife, however, are maintained through faculty appointments and academic interests

The Program Management Office provides executive linkage between the Management Entity and operations under the CRSP During this reporting period, members of the Program Management Office included:

- Dr. Howard H. Horton, Director (0.55 FTE)
- Ms. Hillary S. Egna, Associate Director (1.0 FTE)
- Ms. Hilary Berkman, Data Base Manager (0.4 FTE)
- Mrs. Lydia Perry, Secretary (0.5 FTE)

The Management Entity 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 compliance with terms of the Grant;
- Providing a focal point for the interaction of the Technical Committee, Board of Directors, External Evaluation Panel, USAID Staff, and BIFAD/JCARD;

- Executing the decisions of the governing and advisory bodies;
- Implementing the program; and
- Maintaining liaisons with overseas and domestic participants.

The ME also is responsible for communications, publications, and management of the CRSP Central Data Base.

Specific accomplishments include:

- Preparation of a five-year continuation plan, which was reviewed in May and September by BIFAD, JCARD, and accepted by AID as the new CRSP grant document for 1990-1995;
- Preparation of CRSP budgets and subcontractual modifications for extending funding and performance periods;
- Continued assistance in processing travel clearances for CRSP personnel and approvals for purchases of restricted goods for country projects;
- Continuation of a technical information service for overseas research staff — abstracts and tables of contents of current journals are sent to each U.S. Research Associate as requested;
- Publication of research results in two new technical report series and in USAID program newsletters;
- Organization of the sixth annual CRSP meeting in Davis, California on May 2-4, 1989 and participation in attendant Board Meetings and Technical Committee meetings;
- Coordination of the development of the Fourth and Fifth Work Plans;
- Compilation of the standardized data sets from the three work plans (experimental cycles completed at seven overseas locations;
- Coordination of activities for the CRSP Data Analysis and Synthesis Team, the principal U.S -based research component of the CRSP;
- Development of questionnaires to evaluate the Annual and Technical Committee meetings, and to coordinate meeting logistics to better enable host country participants to attend;
- Creation of a new directory which lists CRSP participants' electronic mail codes (e.g., FAX. BITNET, TELEX, MCI);
- Initiation of dialogue with Mr Floyd O'Quinn (USAID/Washington) regarding CRSP and University of Arkansas at Pine Bluff (UAPB) participation in the grants program for historical black colleges and universities and support of UAPB's proposal;
- Coordination of activities (meetings and travel) for the External Evaluation Panel and USAID staff as part of the Triennial Review;
- Participation in Board Meetings and Technical Committee meetings;
- Assistance to S&T/AGR through participation on several CRSP Council Conference calls; and
- Coordination of new administrative and contractual details for collaborative research projects in Thailand, Rwanda, and Honduras.

Technical Committee

Technical guidance is provided by a Technical Committee composed of the Principal Investigators of CPSP Research Projects and at-large members appointed by the Board of Directors. The Technical Committee has four standing subcommittees; Work Plans, Materials and Methods, Budgets, and Technical Progress. The membership of the Technical Committee and subcommittees is presented in the following table.

TECHNICAL COMMITTEE MEMBERS

Name	Institution	Subcommittees
Principal Investigators (Voting Members)		
Dr Ted Batterson	Michigan State University	B*
Sr Marco Rodriquez	Directorate of Renewable Natural Resources, Honduras	B
To be named	National University of Rwanda	W
Dr James Diana	University of Michigan	T
Dr Peter Edwards	Asian Institute of Technology, Thailand	W
Dr. Carole Engle	University of Arkansas at Pine Bluff	W
Dr Kevin Hopkins	University of Hawaii at Hilo	W*
Dr Kitjar Jaiyen	National Inland Fisheries Institute, Thailand	M
Dr James Lannan, Chair	Oregon State University, Chair of Tech. Committee	T*
Dr Raul Piedrahita	University of California at Davis	M*
Dr Thomas Popma	Auburn University	W
Mr Wayne Seim	Oregon State University	B
Non-Voting Members		
Mr H. Alvarenga	Directorate of Renewable Natural Resources, Honduras	
Ms Hilary Berkman	Oregon State University, Management Entity	
Mr Dan Dettweiler	University of Michigan	
Dr Bryan Duncan	Auburn University	
Mr. Bart Green	Auburn University in Honduras	
Mr Sompong Hiranyawat	National Inland Fisheries Institute, Thailand	
Dr Howard Horton	Oregon State University, Management Entity	
Dr Chris Knud-Hansen	Michigan State University, in Thailand	
Dr, Kwei Lin	University of Michigan and AIT, Thailand	
Dr Cal McNabb	Michigan State University	
Mr Eugene Rurangwa	National University of Rwanda	
Dr. James Szyper	University of Hawaii at Manoa	
Dr David Teichert-Coddington	Auburn University in Honduras	
Mr Sompote Ukkatawewat	National Inland Fisheries Institute, Thailand	
Ms Karen Veverica	Oregon State University and Auburn University in Rwanda	
At-large-Members		
Dr Donald Garling	Michigan State University	
Dr R O Smitherman	Auburn University	
Dr George Tchobanoglous	University of California at Davis	
Ex-officio Members		
Ms Hillary Egna	Oregon State University, Management Entity	
USAID Project Officer	S&T/AGR, U.S. Agency for International Development	

W=Work Plans, B=Budgets T=Technical Progress, M=Materials and Methods

*Subcommittee Chairpersons

Board of Directors

As the primary policy-making body for the CRSP, the Board of Directors has taken an active role in program guidance. The Board is composed of three members, one of whom is elected chairman. Each of the participatory institutions is represented on the Board. The Program Manager from USAID 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. Donovan Moss, Auburn University, Chairman (to Oct 1988);
- Dr. R. Oneal Smitherman, Auburn University, Member (from May 1989);
- Dr. Robert Fridley, University of California at Davis, Member;
- Dr. Philip Helfrich, University of Hawaii (CIFAD institution), Member and Chairman (from May 1989),
- Dr. Richard Neal, USAID S&T/AGR, Ex-Officio Member (to June 1989);
- Mr Chris Jones, NMFS, IPA to S&T/AGR , Ex-Officio Member (from August 1989);
- Dr. Howard Horton, Oregon State University, CRSP Director, Ex-Officio Member.

The Board of Directors convened five times during this reporting period.

October 21, 1988	Corvallis, Oregon
May 3-4, 1989	Davis, California
August 3, 1989	Telephone Conference Call
November 8, 1989	Telephone Conference Call

The Board of Directors is responsible for:

- Reviewing program budgets and the allocation of funds to research projects and the management office;
- Making recommendations to the Management Entity on budget allocations;
- Evaluating the administrative and technical accomplishments of overseas research projects and U.S.-based research activities;
- Advising the Management Entity on policy guidelines; and
- Reviewing the performance of the Program Director and Management Entity.

Specific accomplishments and recommendations made during this reporting period include:

- Review of progress of Data Management activities and the Data Analysis and Synthesis Team;
- Approval of management and research budgets;
- Appointment of a new Chairman of the Board;
- Annual meeting agenda input and approval;
- Advice on international travel procedures;
- Guidance on efforts to strengthen the program in the face of funding constraints; and
- Participation in the seventh annual program meeting in May 1989.

External Evaluation Panel

The External Evaluation Panel is composed of impartial senior aquaculture scientists. The three members of the Panel represent the major disciplines of the CRSP. All have considerable international experience in aquatic sciences. During this reporting period, the members of the External Evaluation Panel were:

- Dr. Homer Buck, Illinois Natural History Survey, Illinois
- Dr. Kenneth Chew, University of Washington, Seattle, Washington
- Dr. Herminio Rabanal, Aquaculture Consultant, Manila, Philippines

The External Evaluation Panel reviewed the technical plan for continuation of the Global Experiment from 1990 to 1995. At the Sixth Annual Meeting in January 1988, the External Evaluation Panel initiated its second major review of the program by interviewing CRSP researchers and staff from the Program Management Office. They followed up these interviews with visits to the three current CRSP sites and to two former CRSP sites (the two sites in Panama were not visited). Their review, with the USAID Administrative Management Review, provided guidance for the Triennial Review, which is conducted by the JCARD CRSP panel and USAID's Agriculture Sector Council Subcommittee The results and recommendations of the Triennial Review were discussed during the Seventh Annual Meeting in Davis, California, and were included in the Continuation Plan that was submitted to JCARD, BIFAD and AID in May and September, 1989.

CRSP Publications

The CRSP has facilitated technology dissemination through the establishment of various publications. These publications reach a broad domestic and international audience. During this reporting period, the number of publications resulting from CRSP research continued to grow. Over 300 reports and theses have resulted from CRSP research worldwide.

The two publication series that were launched in 1987 have attracted many new readers. Nearly 300 people now receive our publications. These two publications highlight CRSP research on a variety of subjects related to aquaculture. *CRSP Research Reports* contains scientific papers written by CRSP researchers. 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. For this purpose, *Collaborative Research Data Reports* was created.

Collaborative Research Data Reports contains the results and data from the Global Experiment, which is the major research activity of the CRSP. *Collaborative Research Data Reports* presents the CRSP Central Data Base along with interpretations of site-specific results. The first volume of *Collaborative Research Data Reports* is a reference for the series; it contains descriptions of sites and experimental protocols for the Global Experiment. Subsequent volumes focus on each research site separately by experimental cycle. The rate of output of both *Collaborative Research Data Reports* and *CRSP Research Reports* has accelerated as a result of recent improvements in the Central Data Base.

These two publications add to the informational base that the CRSP has established over six years. *Aquanews*, the program's newsletter, contains informative articles on field projects, summaries of training courses and meetings about aquaculture, and brief notes on the program and its participants. *Aquanews* provides a forum for host country and U.S. participants to share ideas and preliminary research findings.

The Program Management Office also contributes articles to international newsletters, such as AID's *Star* and *Frontlines* and newsletters from other CRSP's and international programs. Other reports published by the CRSP Program Management Office include Annual Administrative Reports, Program Grant Proposals, Work Plans, CRSP Directories, and Instructions for Data Entry.

A number of documents were prepared and disseminated during this reporting period. These are briefly described below. Reports of CRSP research that were *not* processed by the Program Management Office are listed in Appendix B.

Administrative Reports

Annual Administrative Report

Pond Dynamics/Aquaculture CRSP, Program Management Office. May 1989. Sixth Annual Administrative Report. Office of International Research and Development, Oregon State University, Corvallis, Oregon 139 pp.

CRSP Work Plan

Pond Dynamics/Aquaculture CRSP, Program Management Office. January 1989. Revised Work Plan: Fourth Experimental Cycle, September 1, 1987-August 31, 1989. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 44 pp.

Pond Dynamics/Aquaculture CRSP, Program Management Office. July 1989. Draft Work Plan: Fifth Experimental Cycle, September 1, 1989 - August 31, 1991. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 54 pp.

Pond Dynamics/Aquaculture CRSP, Program Management Office. December 1989. CRSP Central Data Base: Instructions for Data Entry, edition 2.1. Office of International Research and Development, Oregon State University, Corvallis, Oregon. 14 pp.

Directory

Pond Dynamics/Aquaculture CRSP, Program Management Office. 1988 CRSP Directory. Office of International Research and Development, Oregon State University, Corvallis Oregon.

The CRSP Directory was updated twice during this reporting period, in October 1988 and June 1989, to account for changes in program personnel. The directory contains an organizational flowchart and addresses of current CRSP members from USAID, BIFAD, USAID Missions, the External Evaluation Committee, Technical Committee, Management Entity, Board of Directors, and the Collaborative Research Projects. The directory also was expanded to include electronic mail access codes.

Newsletter

With the emergence of the new CRSP technical publications, the relative need for a program newsletter has declined *Aquanews* will continue as an occasional publication. It will serve to inform CRSP participants and others of program activities that are not of a technical nature. *Aquanews* will contain information on meetings, travel of CRSP participants, and site visits. Additionally, the CRSP will continue to take advantage of other vehicles for communication such as the USAID *Star* newsletter (of the Office of Agriculture's Bureau of Science and Technology) and *Frontlines*. Improved communication among Collaborative Research Support Programs during the past year has resulted in exchanges between newsletters

Egna, H.S. Spring 1989. Fish Pond Management Guidelines: A CRSP Goal. STAR (Science and Technology Agricultural Reporter), US Agency for International Development.

Technical Reports

CRSP Research Reports

Chang, W.Y.B. 1989. Estimates of hypolimnetic oxygen deficits in ponds. CRSP Research Reports 89-17, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Chang, W.Y.B. and H. Ouyang. 1989. Dynamics of dissolved oxygen and vertical circulation in fish ponds CRSP Research Reports 89-14, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Diana, J.S., P.J. Schneeberger, and C. K. Lin. 1989. Relationships between primary production and yield of tilapia in ponds. CRSP Research Reports 89-19, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Diana, J.S. and A.W. Fast. 1989. The effects of water exchange rate and density on yield of the walking catfish, *Clarias fuscus*. CRSP Research Reports 89-18, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Fast, A.W., K.E. Carpenter, V.J. Estilo, and H.J. Gonzales. 1989. Effects of water depth and artificial mixing on dynamics of Philippines brackishwater shrimp ponds. CRSP Research Reports 89-13, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Green, B.W., R.P. Phelps, and H.R. Alvarenga. 1989. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds. CRSP Research Reports 89-15, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Lin, C.K. and M. Boonyaratpalin. 1989. An analysis of biological characteristics of *Macrobrachium rosenbergii* (de Man) in relation to pond production and marketing in Thailand. CRSP Research Reports 89-16, Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 1 p.

Collaborative Research Data Reports

Batterson, T.R., C.D. McNabb, C.F. Knud-Hansen, H.M. Eidman, and K. Sumatadinata. 1989. Indonesia: Cycle III of The Global Experiment. Collaborative Research Data Reports, Volume Three, Number Three. Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 141 pp.

Hanson, B., V. Ndoreyaho, R. Tubb, F. Rwangano, W. Seim. 1989. Rwanda: Cycle I of The Global Experiment. Collaborative Research Data Reports, Volume Five, Number One. Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 77 pp.

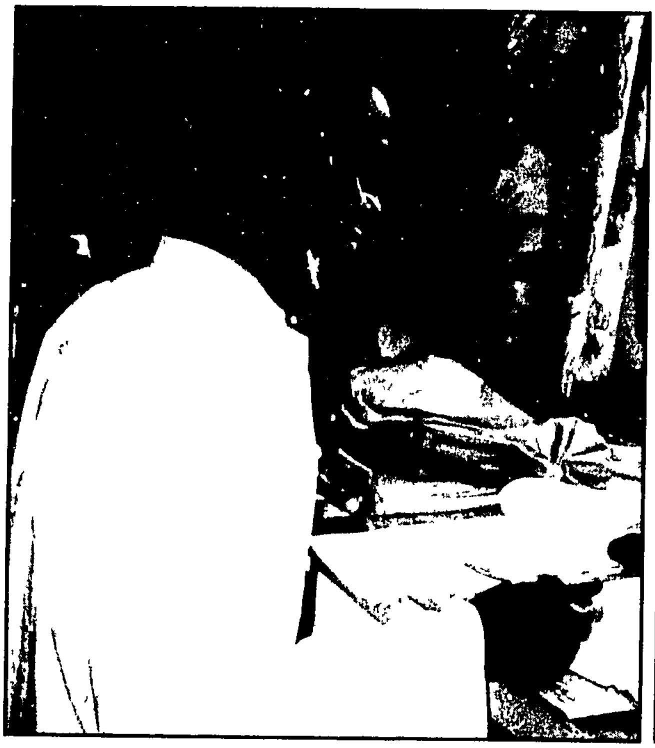
B.W. Green, H.R. Alvarenga, R.P. Phelps, and J. Espinoza. 1989. Honduras: Cycle III of The Global Experiment. Collaborative Research Data Reports, Volume Six, Number Three. Program Management Office, Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon. 146 pp.

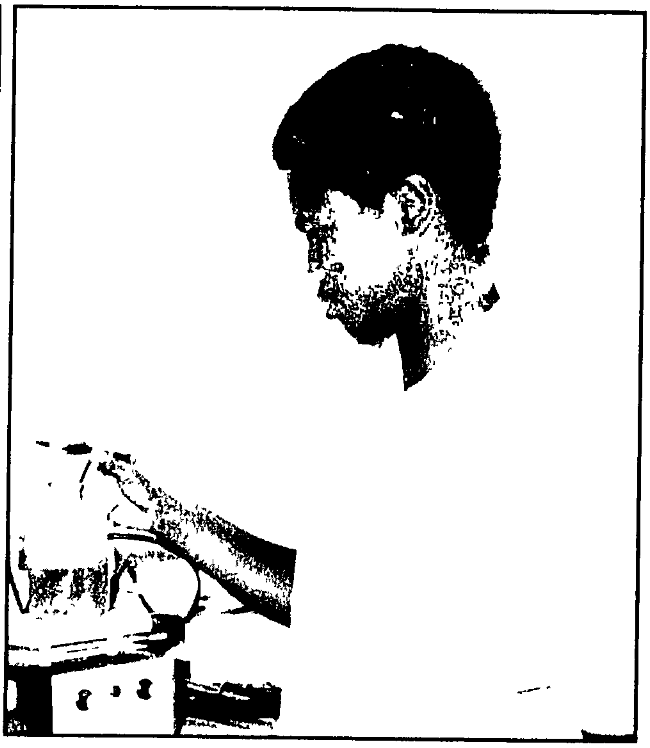
STAFF SUMMARY

The Pond Dynamics/Aquaculture CRSP represents the joint efforts of more than 25 professionals and a number of support personnel from U. S. universities. It also represents the collaborative efforts of over 30 scientists, technicians, and graduate students from three project sites in three developing countries. The expertise of host country and U.S. personnel is broad-based and encompasses the major fields of specialization included in this CRSP: Limnology and Water Quality; Fisheries and Aquaculture; Data Management, Analysis, and Modeling; Research Administration; and Agricultural Economics.

In addition to staff with formal CRSP assignments, many individuals have participated in the development of host country projects. The CRSP team in Rwanda reported that local scientists now use the Rwasave lab for water, soil, and food analysis.

The major United States-based research activity, Data Analysis and Synthesis, involves 11 researchers from the University of California at Davis, Oregon State University, and the University of Michigan. Scientists from Michigan State University, Auburn University, the University of Arkansas at Pine Bluff, and the University of Hawaii also participate in U.S.-based research activities.





STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin.	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
BOARD OF DIRECTORS						
Dr. Philip Helfrich	Chairman (from 5/89)	X		X		Kaneohe, Hawai
Dr. Donovan Moss	Chairman (to 5/89)	X		X		Auburn, Alabama
Dr Robert Fridley	Member	X	X	X		Davis, California
Dr. R. Oneal Smitherman	Member	X		X		Auburn, Alabama
AT-LARGE TECHNICAL COMMITTEE						
Dr. Donald Garling	Member			X		East Lansing, Michigan
Dr R. Oneal Smitherman	Member			X		Auburn, Alabama
MANAGEMENT ENTITY						
Dr. Howard Horton	Director	X		X		Corvallis, Oregon
Ms. Hillary Egna	Associate Director	X	X	X		Corvallis, Oregon
Ms. Hilary Berkman	Data Base Manager		X	X	X	Corvallis, Oregon
Mrs. Lydia Perry	Secretary	X				Corvallis, Oregon
Mr. Bruce Sorte	Fiscal Officer	X				Corvallis, Oregon

STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin.	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
DATA ANALYSIS AND SYNTHESIS						
DATA ANALYSIS AND SYNTHESIS - OREGON STATE UNIVERSITY						
Dr James Lannan	Data Synthesis Team Member	X		X	X	Newport, Oregon
Mr. Jim Bowman	Graduate Student		X	X		Corvallis, Oregon
Mr. Shree Nath	Graduate Student		X	X		Corvallis, Oregon
Mr Andy Snow	Graduate Student		X	X		Corvallis, Oregon
M S Miller	Secretary	X				Newport, Oregon
Mr. Bruce Sorte	Fiscal Officer	X				Corvallis, Oregon
DATA ANALYSIS AND SYNTHESIS - UNIVERSITY OF MICHIGAN						
Dr William Chang	Data Synthesis Team Member	X	X	X	X	Ann Arbor, Michigan
Mr. Steve Riggs	Data Synthesis Assistant		X	X	X	Ann Arbor, Michigan
Mr Bob Springborn	Data Synthesis Assistant			X	X	Ann Arbor, Michigan
Mr Kwang-Ming Liu	Data Synthesis Assistant			X		Ann Arbor, Michigan
Ms Barbara Murphy	Fiscal Officer	X				Ann Arbor, Michigan
DATA ANALYSIS AND SYNTHESIS - UNIVERSITY OF CALIFORNIA AT DAVIS						
Dr Raul Piedrahita	Data Synthesis Team Leader		X	X	X	Davis, California
Mr Philip Giovannini	Data Synthesis Assistant		X	X	X	Davis, California
Mr. Zhimin Lu	Post-Graduate Researcher				X	Davis, California
Mr George Max	Fiscal Officer	X				Davis, California

(1) Denotes primary work location and excludes host country site visits and travel for attendance of meetings.

STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin.	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
HONDURAS						
HONDURAS -AUBURN UNIVERSITY						
Dr Claude Boyd	U.S. Co-Principal Investigator (from 9/88)	X	X	X		Auburn, Alabama
Dr. Bryan Duncan	U.S. Co-Principal Investigator (from 9/88)	X		X		Auburn, Alabama
Dr. David Teichert-Coddington	U S Research Associate		X	X		Auburn, Alabama
Dr Bart Green	U S Research Associate		X	X		Auburn, Alabama
Mr Donald Large	Fiscal Officer	X				Auburn, Alabama
HONDURAS-UNIVERSITY OF HAWAII						
Dr. Kevin Hopkins (2)	U S. Co-Principal Investigator (from 1/89)	X	X	X	X	University of Hawaii
Dr. James Szyper (2)	U.S. Co-Principal Investigator (from 1/89)	X	X	X		University of Hawaii
Ms Cora Chai	Fiscal Officer	X				University of Hawaii
HONDURAS-HOST COUNTRY PERSONNEL						
Ing Marco Ivan Rodriguez	H.C Principal Investigator			X		Comayagua, Honduras
Mr Nelson Claros	H C. Chemist		X			Comayagua, Honduras
Ms. Sagrario Calix	H.C. Secretary	X				Comayagua, Honduras
Mr. Miguel Zelaya	H.C. Lab Technician			X		Comayagua, Honduras
Mr. Luis Lopez	H.C. Field Technician			X		Comayagua, Honduras
Ms. Myra Lara	H.C. Biologist/ Chemist			X		Comayagua, Honduras

(1) Denotes primary work location and excludes host country site visits and travel for attendance of meetings.
(2) Researchers involved in two projects

STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
		RWANDA				
RWANDA-OREGON STATE UNIVERSITY						
Mr Wayne Seim	U S. Co-Principal Investigator	X	X			Corvallis, Oregon
Dr Richard Tubb	U.S. Co-Principal Investigator	X		X		Corvallis, Oregon
Mr. Bruce Sorte	Fiscal Officer	X				Corvallis, Oregon
Mr. Felicien Rwangano	Oregon State University Graduate Student			X		Corvallis, Oregon
RWANDA-AUBURN UNIVERSITY						
Dr. Tom Popma	U.S Principal Investigator (from 9/88)	X		X		Auburn, Alabama
Ms. Karen Vevenca (2)	U S. Research Associate		X	X		Auburn, Alabama
Mr Donald Large	Fiscal Officer	X				Auburn, Alabama
RWANDA-UNIVERSITY OF ARKANSAS AT PINE BLUFF						
Dr Carole Engle	U S Principal Investigator	X		X		Pine Bluff, Arkansas
RWANDA-HOST COUNTRY PERSONNEL						
Dr Innocent Butare	H C Principal Investigator	X				Rwanda
Mr Eugene Rurangwa	H.C. Research Associate			X		Rwanda
Dr. Maurice Ntahobari	UNR Rector	X				
Dr. Runyinya Barabwiliza	H C Participant	X				Rwanda
Mr Ngoy Kasongo	H.C. Technician		X			Rwanda
Mr. Alfonsine Murekeyisoni	H.C. Technician		X			Rwanda
Mr Joseph Murangwa	H.C. Computer Technician				X	Rwanda

(1) Denotes primary work location and excludes host country site visits and travel for attendance of meetings.
(2) Researchers involved in two projects

STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin.	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
THAILAND						
THAILAND - UNIVERSITY OF MICHIGAN						
Dr. James Diana	U.S. Principal Investigator (from 2/87)		X	X	X	Ann Arbor, Michigan
Dr C Kwei Lin	U.S. Co-Principal Investigator		X	X		AIT, Thailand
Mr. Daniel Dettweiler	U S. Research Assistant		X	X		Ann Arbor, Michigan
Ms Barbara Murphy	Fiscal Officer	X				Ann Arbor, Michigan
THAILAND - MICHIGAN STATE UNIVERSITY						
Dr. Clarence McNabb	U S. Co-Principal Investigator		X	X		East Lansing, Michigan
Dr. Ted Batterson	U.S. Co-Principal Investigator	X	X		X	East Lansing, Michigan
Dr Chris Knud-Hansen	U.S. Research Associate		X	X		AIT, Thailand
Dr Jeffrey Hanson	U.S. Scientific Collaborator			X		East Lansing, Michigan
Mr. Abdelmoez A.F. Abdalla	U S. Research Assistant		X	X		East Lansing, Michigan
Mr. Gerald Jacobs	Fiscal Officer	X				East Lansing, Michigan
THAILAND - UNIVERSITY OF HAWAII						
Dr. Kevin Hopkins	U.S. Co-Principal Investigator (from 1/89)	X	X	X	X	Honolulu, Hawaii
Dr James Szyper	U.S Co-Principal Investigator (from 1/89)	X	X	X		Honolulu, Hawaii
Ms Cora Chai	Associate Fiscal Officer	X				Honolulu, Hawaii
THAILAND - HOST COUNTRY PERSONNEL						
Dr. Kitjar Jaiyen	H.C. Principal Investigator (from 2/87)		X	X		NIFI, Thailand
Dr Sompote Ukatawewat	H.C. Research Associate	X		X		Ayutthaya, Thailand
Mr Kiengkai	H.C. Research Associate		X			NIFI, Thailand
Mr. Sanga	H.C. Research Associate		X			NIFI, Thailand
Mr. Agaluck Saloaw	H.C. Research Associate			X		AIT, Thailand

STAFF SUMMARY: COLLABORATIVE RESEARCH PROJECTS

Individual	CRSP Function	Field(s) of Specialization: Research Admin	Limnology/ Water	Fisheries/ Aquaculture	Data Management	Location of Work (1)
THAILAND - HOST COUNTRY PERSONNEL						
Mr. Tongsuk Saelee	H.C. Research Associate			X		AIT, Thailand
Mr. Wirawan Chinaksorn	H C. Research Associate			X		Ayutthaya, Thailand
Ms Tanaporn	H.C Research Assistant		X			Bangkok, Thailand
Mr. Wongbathom Konmonrat	H.C Research Assistant			X		Bangkok, Thailand
Mr Supranee Chinabut	H C. Scientific Collaborator			X		NIFI, Thailand
Mr Chalor Limsuwan	H.C Scientific Collaborator			X		Kasetsart Univ., Thailand
Ms Ratana Chuenpagdee	H C Scientific Collaborator			X		Kasetsart Univ , Thailand

FINANCIAL SUMMARY

This section summarizes the expenditure of USAID, non-federal, and host country funds for CRSP research activities and program management. This unaudited summary is intended to provide an overview of CRSP progress relative to program budgets and matching support.

The expenditure of USAID funds by Collaborative Research Projects, Special Topics Research, and Program Management is presented in Table 1 for the PD/A CRSP contract year of September 1, 1988 to August 31, 1989 The data for the Collaborative Research Projects includes all expenditures made to support research efforts at three project sites from September 1, 1988 to August 31, 1989, in accordance with our Continuation Plan . No expenditures were reported by the University of Arkansas at Pine Bluff for activities in Rwanda, although a socioeconomic study was initiated just before the end of this reporting period The financial figures for the U S Research Component includes expenditures to support the Data Analysis and Synthesis Team's activities at the University of California at Davis, Oregon State University, and The University of Michigan.

The information on Program Management expenditures includes expenses to support the Program Management Office, the Board of Directors, the External Evaluation Panel, Research Publications and Administrative Reports, and the Data Base Management function. Because this period overlapped with a Triennial Review year, expenses for the External Evaluation Panel were substantial.

Cost sharing contributions from the U.S. institutions are presented in Table 1. The amounts reported give a cost sharing of 31 percent, considerably in excess of the 25 percent requirement These data reflect a strong and continuing commitment by program entities to participation in the CRSP. However, confirmation of these data requires further accounting because the amounts to be excluded in calculating cost sharing requirements in accordance with BIFAD guidelines must be determined after the fact.

Host country contributions (in U.S. dollars) are also presented in Table 1. These data were provided by the Principal Investigators of the projects. Although Host Country cost sharing is not required, these data indicate a continuing commitment to participation in the CRSP by our collaborators.

Table 1. Financial Summary of The Pond Dynamics/Aquaculture CRSP Funds, Cost Sharing, and Host Country Contributions from the period September 1, 1988 to August 31, 1989.

		USAID Funds		Cost Sharing		Total		Host Country Contribution	
		1989	Cumulative	1989	Cumulative	1989	Cumulative	1989	Cumulative
Research Program									
Honduras:	Auburn U.	185,019	301,801	60,655	93,351	245,674	395,152	42,500	79,583
	U. Hawaii	14,028	14,028	3,024	3,024	17,052	17,052		
Rwanda:	Auburn U.	94,091	135,911	39,949	60,053	134,040	195,964		
	Oregon St. U.	78,962	767,640	19,444	104,554	98,406	872,194	48,000	221,399
	UAPB	0	0	0	0	0	0		
Thailand:	Michigan St. U	73,281	103,684	14,862	54,973	88,143	158,657		
	U Michigan	168,887	280,088	34,378	47,632	203,265	327,720	43,000	86,000
	U. Hawaii	52,540	57,848	33,390	33,390	85,930	91,238		
Subtotal		666,808	1,661,000	205,702	396,977	872,510	2,057,977	133,500	386,982
US Research Component									
U. California at Davis		44,243	79,113	11,500	22,150	55,743	101,263		
Oregon St. U.		41,689	113,359	10,422	27,835	52,111	141,194		
U. Michigan		16,859	41,427	6,778	24,485	23,637	65,912		
Subtotal		102,791	233,899	28,700	74,470	131,491	308,369		
Management Entity		148,427	323,014			148,427	323,014		
TOTAL		918,026	2,217,913	234,402	471,447	1,152,428	2,689,360	133,500	386,982

APPENDICES

Appendix A. Excerpts from the CRSP Fourth Work Plan.

This work plan differs from earlier work plans in which the same experiment was conducted at each location. Hypotheses about pond dynamics will be tested in different field experiments at each research location. It is anticipated that this procedure will allow the CRSP to proceed rapidly through the testing process. Otherwise, many years of work would be required to thoroughly evaluate each hypothesis at all sites.

In addition to the division of experiments between the sites, the CRSP global experiment will continue intensive sampling of pond variables during the course of each field experiment. A standard sampling protocol will be used at all locations, and the standardized data will be added to the CRSP Data Base to make the existing information even more comprehensive. Sampling protocol, descriptions of field experiments, and data synthesis activities are presented below

The CRSP Global Experiment

CRSP researchers should read this section carefully because there have been significant changes from previous work plans In particular, section headings have been changed to reflect alterations in the sampling protocol, some parameters are no longer required, and the frequency of sampling for the "diurnal" studies (now more appropriately named "diel" studies) has been changed from every six hours to the following: pre-dawn, 1000, 1400, 1600, 1800, 2300, and pre-dawn of the next day. Unless otherwise indicated, the fish cultural and analytical methods are as presented in appropriate appendixes to the third CRSP work plan Please refer to Standard Methods for the Examination of Water and Wastewater for methods not included in the third work plan. Some methods for new procedures are included in the appendix for easy reference. All research locations will follow the same protocol for daily measurements, intensive sampling measurements, fish measurements, optional measurements, and occasional measurements.

Daily Measurements

The following meteorological and physical pond parameters will be recorded daily:

- Solar Radiation
- Wind Speed (*Note*: Anemometers are to be set at a height of 2 m above the level of the pond banks)
- Air Temperature (maximum and minimum)
- Rainfall
- Evaporation
- Pond Depth
- Pond Inflow

Intensive Sampling Measurements

There will be three intensive sampling periods for each experiment: (1) during the second week; (2) midway through the experiment; and (3) during the final week. A number of parameters will be determined on a whole water column sample for each pond in addition to the studies. Primary productivity will be determined by calculation from data collected during the diel studies (i.e., whole pond determinations). The variables to be observed are:

- Total Kjeldahl Nitrogen
- Ammonia Nitrogen
- Total Phosphorus
- Secchi Disk
- Chlorophyll *a*
- Dark Bottle Respiration
- Total Suspended Solids
- Total Volatile Solids
- Diel Studies (Sampling times: pre-dawn, 1000, 1400 1600, 1800, 2300, and pre-dawn the next day. Sample at three depths (top, middle, bottom) for each pond): Dissolved Oxygen
  Temperature
  pH
  Alkalinity
  Wind (cumulative between sampling times)
  Solar Radiation (cumulative between sampling times)

Fish Measurements

Sex-reversed *Oreochromis niloticus* of an average weight of 25 grams will be stocked at a rate of two fish/m^2 (20,000 fish/hectare). In addition to the specific measurements listed below, a record will be kept of any reproduction that may occur during the experiment.

- Initial Stocking
  - Total Number
  - Group Weight
  - Mean Weight per Individual
  - Mean Length per Individual
- Monthly Sampling
  - Sample Number
  - Group Weight
  - Mean Weight per Individual
  - Mean Length per Individual
- Harvest
  - Total Number
  - Group Weight
  - Mean Weight per Individual
  - Mean Length per Individual
  - Survival (% of initial stocked)

Optional Monthly Measurements

- Phytoplankton Composition
- Zooplankton Composition
- Benthos Composition

Occasional Measurements

- Pond Soil Characteristics at the beginning and end of each experiment
- Liming Requirements
- Pond Morphometric Characteristics
- Seepage (to complete hydrological characteristics, most of which are included under "Daily Measurements" above)
- Chemical Oxygen Demand (COD) of Inputs
- Nutrient Analysis of Inputs

Appendix B. List of Publications.

Pond Dynamics/Aquaculture
Collaborative Research Support Program
As of 12/89

AUBURN/HONDURAS

Theses

Berrios, J. In preparation. Growth and survival of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) fingerlings during the nursery phase. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Cerna, C. In preparation. Zooplankton dynamics in *Tilapia nilotica* production ponds fertilized with triple superphospate. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Echeverria, M.A. In preparation. Primary production in *Tilapia nilotica* production ponds fertilized with triple superphosphate. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Garces, C. 1986. Quantitative analysis of zooplankton in fish ponds fertilized with triple superphosphate during the rainy season. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Gomez, R. 1988. Effect of fertilizer type on the production of male *Tilapia nilotica*. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Lopez, L. In preparation. Production of *Tilapia nilotica* in ponds fertilized with layer chicken litter. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Mejia, C. In preparation. Rainy season phytoplankton dynamics in ponds stocked with *Tilapia nilotica* B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Paz, S.A. In preparation. The relationship between primary productivity and chlorophyll and their relation to tilapia production. B.S. thesis, Dept. of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Sherman, C. In preparation. All female culture of *Tilapia nilotica* in ponds fertilized with chicken litter. B.S. thesis, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (In Spanish.)

Reports

Alvarenga, H.R. and B.W. Green. 1985. Production of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) fingerlings. C.R.S.P. Technical Report, unpublished. 12 pp. (In Spanish.)

Alvarenga, H.R. and B.W. Green. 1986. Growth and production of all male *Tilapia nilotica* and all male hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) in ponds. Rev. Latinoamericana de Acuicultura 29:6-10. (In Spanish.)

Alvarenga, H.R., B.W. Green and M.I. Rodriguez. In preparation. Pelleted fish feed vs. corn gluten as feed for tilapia and Chinese carp polyculture in ponds. C.R.S.P. Technical Report, unpublished. (In Spanish.)

Alvarenga, H.R., B.W. Green and M.I. Rodriguez. In preparation. Production of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) fingerlings using two different brood stock densities. C.R.S.P. Technical Report, unpublished. Auburn University, Alabama.

Alvarenga, H.R., B.W. Green and M.I. Rodriguez. 1987. Production of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) in ponds using corn gluten as a supplemental feed. C.R.S.P. Technical Report, unpublished. 13 pp. (In Spanish.)

Alvarenga, H.R., B.W. Green and M.I. Rodriguez. 1984. A system for producing hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) fingerlings at the El Carao Aquaculture Experiment Station, Comayagua, Honduras. C.R.S.P. Technical Report, unpublished. 9 pp. (In Spanish.)

Green, B.W. 1985. Report on the induced spawning of the silver and grass carps. C.R.S.P. Technical Report, unpublished. 8 pp. (In Spanish.)

Green, B.W. and H.R. Alvarenga. 1985. Tilapia and carp polyculture in ponds receiving organic fertilization and supplemental feed. C.R.S.P. Technical Report, unpublished. 10 pp. (In Spanish.)

Green, B.W., H.R. Alvarenga, R.P. Phelps and J. Espinoza. 1988. Technical Report: Honduras Aquaculture C.R.S.P. Cycle III Rainy and Dry Season Phases. C.R.S.P. Technical Report, unpublished. Auburn University, Alabama.

Green, B.W., H.R. Alvarenga, R.P. Phelps and J. Espinoza. 1987. Technical Report: Honduras Aquaculture C.R.S.P. Cycle 2 Rainy Season Phase. C.R.S.P. Technical Report, unpublished. Auburn University, Alabama.

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Appendix C. List of Acronyms.

AID	Agency for International Development
AIT	Asian Institute of Technology, Thailand
AU	Auburn University
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
BIFAD	Board for International Food and Agricultural Development, U.S.
Bilateral Programs	assistance programs involving arrangements between a single developing country and a single donor country
BOA	Basic Ordering Agreement
Board of Directors for a CRSP)	an advisory body selected to assist, advise, and make policy recommendations to the ME in the execution of a CRSP; members represent the interests of the CRSP
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
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
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

EOP	Equal Opportunity Programs
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
Field Experiments	controlled fish production experiments in which quantitative responses to different levels of treatments are measured
FTE	Full Time Equivalent
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)
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
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; improvements may include physical facilities, equipment, furnishing, transportation, organization, but refers primarily to development and training of professional cadre
IPA	Inter-governmental personnel act
JCARD	Joint Committee on Agricultural Research and Development (formerly Joint Research Committee), BIFAD
JRC	Joint Research Council, USAID

LDC	Lesser Developed Countries
Matching Requirement document	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")
ME	Management Entity
Mission	a formally organized USAID unit in a developing country led by a Mission Director or a country representative
MOU	Memorandum of Understanding
MSU	Michigan State University
NIFI	National Inland Fisheries Institute, Thailand
NMFS	National Marine Fisheries Service
OIRD	Office of International Research and Development
OSU	Oregon State University
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	Principle Investigators - scientists in charge of the research for a defined segment or a scientific discipline of a CRSP
PMO	Program Management Office
Practices	fish cultural activities related to design, management, and operation of pond culture systems
Predictive Models	mathematical models used to simulate the process 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

RENARE	Department of Renewable Natural Resources, Honduras
S&T Bureau S&T/AGR)	Bureau of Science and Technology, a central bureau of AID in Washington, charged with administering worldwide technical and research programs for the benefit of USAID-assisted countries
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
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
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
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
USAID	United State Agency for International Development
USAID Project Officer	an official AID employee designated to oversee a CRSP on behalf of AID