II. Summary of Activities and Accomplishments

PD/A CRSP research conducted during this reporting period and described in the Interim Work Plan allowed the successful transition from the third grant, with its focus on production research, to the fourth grant, which emphasizes aquaculture research that addresses environmental effects and social and economic aspects in addition to production optimization. During this reporting period researchers investigated the effects of pond management practices on water quality and on the larger environment. Researchers were also interested in the effects of the environment on efficacy and efficiency of aquacultural practices.

In the field of data analysis and modeling, models from the decision support system POND© proved valuable in an FAO effort to develop a geographical information system for Latin America. A fourth research theme during the past year was fish reproduction research. In addition to the traditional dissemination avenues, CRSP research results and raw data (via the Central Database) are now electronically available on the WWW.

The complete set of abstracts for the research reports summarized here is located in Chapter 4 of this volume. The Fourteenth Annual Technical Report, a companion volume, contains the full text of the research reports and is available by request to the Program Management Office.

Global Studies and Activities

At the Asian Institute of Technology (AIT) in Thailand researchers investigated the effect of reduced fertilization on water quality by comparing ponds fertilized throughout an experimental period (A) to ponds fertilized only until day 80 (B); both types of treatment ponds were given commercial feed starting on day 80 until the end of the experimental period. Fish growth performance was significantly better in treatment A than in treatment B; however, water quality parameters measured for each treatment were not significantly affected. Contrary to earlier studies indicating that pond muds serve as nutrient sinks, the results of this study showed that large amounts of nitrogen and phosphorus were released from bottom soil to the water column during the culture cycle.

To assess the fate of nutrients added to brackish water systems, scientists from Auburn University and the Laboratorio de Calidad de Agua, Honduras, developed budgets for nitrogen and phosphorus of semi-intensively managed shrimp ponds receiving 20% and 30% protein feeds. Gross shrimp yield and final weights did not differ significantly between treatments, and no significant differences were detected between treatment water quality means. However, during the dry season, high protein feed resulted in significantly greater nitrogen, and phosphorus additions to ponds.

Researchers from the University of Hawaii and from Central Luzon State University, Philippines, compared the growth performance of two strains of Nile tilapia: mixed-sex GIFT fish (genetic improvement of farmed tilapia) and GMT fish (genetically produced male tilapia).

In the first treatment inorganic fertilizers were applied weekly with an N:P ratio of 5:1 by weight. The second treatment utilized the same fertilization rate but only for the first 2.5 months of the experimental period. Fish of both strains of tilapia had significantly better yields and growth rates under the management regime that included feeding; however, yields were greater for the GMT fish. In addition, GMT fish exhibited significantly better survival than GIFT fish under the management regime that did not include feeding.

Members of the Data Analysis and Synthesis Team (DAST) at Oregon State University (OSU) used the POND© decision support software in a project with FAOs Inland Water Resources and Aquaculture Service to estimate fish yield in Latin America, which is part of a larger FAO effort to assess aquaculture potential through the use of a geographical information system (GIS). The POND© heat balance model was used to generate water temperature profiles for continental Latin America. Water temperature profiles were then used in the POND© fish growth model together with pre-set satiation feeding levels and harvest sizes to assess the number of crops per year possible under commercial scale aquaculture for Nile tilapia (*Oreochromis niloticus*), tambaquí (*Colossoma macropomum*), pacu (*Piaractus mesopotamicus*), and common carp (*Cyprinus carpio*). The potential for small-scale and subsistence aquaculture was also evaluated.

Through the practical application of POND©, researchers at OSU continued to generate information for pond aquaculture planning and management. A water budget model that considers various sources and sinks was used to predict water requirements for CRSP sites in Thailand and Honduras. Feed requirements for aquaculture ponds were assessed via the POND© bioenergetics (BE) model. Simulations of plankton biomass changes in Nile tilapia ponds were also undertaken using more complex POND© models. POND© heat balance and fish growth models were used to conduct sensitivity analyses.

Efforts such as the creation of a decision support system depend on a large amount of data for model generation and validation. The PD/A CRSP Central Database is the world's largest database containing standardized data on tropical aquaculture. During this reporting period the accessibility and user friendliness of the database have been further improved. The database—now housed at OSU—is managed using Microsoft Access and consists of only one computer file containing multiple data tables. A user and investigator interface to the Central Database is now available at the web site address: http://biosys.bre.orst.edu/crspDB/. In addition, users will also be able to access a mirror site now under construction at the Consortium of International Earth Science Information Network (CIESIN).

A socioeconomic study undertaken by CRSP researchers from Auburn University looked at production and marketing experiences of medium and small-scale family farms. Interviews with tilapia farmers from Rwanda, Honduras, Thailand, and the Philippines yielded information on production cycle characteristics, relative prices of fish, market constraints, and the problems associated with marketing tilapia.

Central America

PD/A CRSP researchers from Auburn University and the Laboratorio de Calidad de Agua in Choluteca, and farm operators from the Grupos Granjas Marinas, Honduras, tested the effects of dietary protein (20% and 40%) and feeding rate on food conversion (FCR) and nitrogen discharge in the semi-intensive production of shrimp (*Penaeus vannamei*). Researchers found that neither a high feeding rate nor a high protein level in the diet of *Penaeus vannamei* affected production.

In a companion study conducted during the dry season, researchers tested the effects of dietary protein and feeding rate on feed conversion and nitrogen discharge in the semi-intensive production of *Penaeus vannamei*. Dietary protein level did not affect shrimp yields, confirming results from previous studies. Increased feeding rate with the 20% protein feed did result in significantly greater shrimp yield; however, neither final individual shrimp weight nor survival differed significantly. Research results concurred with prior studies indicating that minimal shrimp growth occurs after 11 to 12 weeks of culture during the dry season in Honduras.

In an ongoing effort, the Honduras team continued to monitor estuarine water quality. The data collected supplemented baseline information on selected chemical, biological, and physical characteristics of water at points along major shrimp producing estuaries in southern Honduras. The objective of this study was to detect trends over time in the impacts of shrimp farming on water quality. Preliminary results of monitoring since the inception of the project in 1993 indicate that total nitrogen concentrations have not increased with time; however, farm management to minimize effluents during the dry season is critical for preventing an undesirable build-up of nutrients in estuaries and conditions not able to sustain shrimp culture.

Fish reproduction is another focal point of CRSP research. In general, the oral administration of 17α-methyltestosterone (MT) is used for the sex reversal of newly hatched tilapia. Research to determine the optimal dose of MT to date has yielded inconsistent results. This may be due to environmental influences during the treatment. Therefore, PD/A CRSP researchers at Auburn University conducted studies to determine the efficacy of different dosages of MT for sex reversal when tilapia were held either indoors or outdoors. Tests showed that the effectiveness of 17α-methyltestosterone (MT) was not affected by either indoor or outdoor treatments. Differences were not found in the efficacy of treatment dosages. Scientists also evaluated the potential of freeze-dried bull testes as a dietary source of testosterone for tilapia sex reversal and found that freeze dried bull testes were not effective in producing male tilapia populations of 95% or greater.

East Africa

Currently, sex reversal of tilapia requires the daily application of a medicated feed to hapas or aquaria. An alternative approach was tested by OSU researchers who experimented with a short-term immersion procedure for the masculinization of Nile tilapia (*Oreochromis niloticus*) using two synthetic androgens—MT and 17α-methyldihydrotestosterone. This short-term immersion technique, when compared with current techniques for steroid-induced sex inversion of tilapia, shortens the hormone treatment period and reduces the risk of worker exposure to anabolic steroids.

Previous research has shown that sub-optimal storage of hormones and hormone treated feed can greatly affect feed efficiency. PD/A CRSP researchers at Auburn University explored how storage conditions affect methyltestosterone-treated feed in terms of fish growth and sex reversal. Feed stored for extended periods of time at ambient tropical temperatures was compared with feed stored under refrigeration. Studies showed that storage conditions did not affect growth, survival, feed conversion efficiency, or sex reversal success of *Oreochromis niloticus* fry fed a hormone prepared diet of 60 mg MT/kg for 28 days.

Fish farmers have reported red tilapia, a synthetic breed derived from *O. niloticus, O. aureus*, and *O. mossambicus*, is more marketable than Nile tilapia. Hence, researchers at Auburn University conducted an experiment comparing the reproductive efficiency, fry growth, survival, feed conversion, and success of sex reversal of Nile tilapia and red tilapia. Red tilapia fecundity was similar to the fecundity of Nile tilapia, and broodstock survival, fry per kg female, and overall numbers of fry produced were also comparable.

Experiments to evaluate alternative lime requirement determination methods in laboratory microcosms were extended to include the use of artificial enclosures or "isolation columns." If enclosures that are consistently reliable can be developed, they may be useful for testing a number of different kinds of treatments within single ponds. The use of in-pond enclosures could lead to decreased variability among experimental units and reductions in the amounts of pond space, time, and other costs required to conduct pond-based research.

Pond bottom soils play an important role in determining pond productivity. As part of the CRSP effort to select a new prime site in Africa, soil samples were collected from five potential PD/A CRSP research sites in East Africa during site evaluation visits in 1994 and 1995. Researchers at OSU characterized nine soil samples for physical and chemical compositions. Results supplemented information used to evaluate and select the new site for PD/A CRSP research in Africa.

Scientists at the University of Arkansas at Pine Bluff developed a mathematical programming model which used survey data from Rwanda, a former CRSP site, to determine farm plans that maximize returns to a representative Rwandan farm family's resources. Study results indicated that the land holding of both individually- and cooperatively-managed farms were too low to meet the minimum nutritional needs of a family. Nevertheless, model

results indicated that fish production was a profitable enterprise for subsistence farmers in Rwanda and that it competed favorably for scarce land resources, when compared to other crops.

Southeast Asia

PD/A CRSP researchers from AIT and the University of Michigan designed an experiment to test the upper limits of tilapia production utilizing supplemental feeds. Stocking densities of 3, 6, and 9 fish per m^2 were tested. While the fastest growth and highest survival occurred at a stocking density of 3 fish per m^2, the optimal feeding system appeared to be at a stocking density of 6 fish per m^2, particularly if the fish had been allowed to reach 500 g in size.

In terrestrial agriculture, analyses of extracts from soil samples are commonly used to estimate nutrient availability; the amounts of nutrients in these extracts are correlated with concentrations of nutrients in soil solution that are available to plants. It may be possible to perform similar analyses regarding the availability of nutrients in aquaculture ponds from bottom soil properties. Auburn University researchers conducted a study using laboratory soil-water microcosms under controlled conditions to determine if aqueous concentrations of substances could be predicted from soil characteristics. Data suggested that soil analyses can indicate the concentrations of water quality variables that will occur in ponds built on particular soils.

AIT-based researchers designed an experiment to develop an integrated rotation culture system for tilapia. The purpose of the experiment was to determine the effects of stocking densities of small tilapia in open ponds on the growth performance of both caged and open-pond tilapia. One of the major advantages of an integrated culture system is the option of controlling unwanted recruitment. The integrated culture system may be appropriate for small-scale farmers in countries such as Thailand, where large tilapia (> 500 g) receive a much higher market price than tilapia typically harvested in fertilized ponds (250-300 g).

PD/A CRSP researchers from AIT and the University of Michigan also assessed the effects of carp-tilapia polyculture on water quality and fish yield in deep, rain-fed ponds. Experimental results did not reveal any differences between net fish yields from the Nile tilapia monoculture and the polyculture of Nile tilapia with common carp at different densities.

Carp/tilapia polyculture may be more difficult in ponds constructed on acid sulfate soils because carp tend to stir sediment as part of their feeding activities. Researchers from the University of Hawaii and AIT therefore conducted an experiment to determine the effect of carp/tilapia polyculture on fish production, nutrient dynamics, turbidity, and prime productivity. Tilapia growth was slow and uniform across treatments. Carp growth was extremely sensitive and inversely related to stocking density.

Research in the Philippines focused on the extension of CRSP efforts to local fish farmers through on-farm trials. Farms were located in the lowland province (Nueva Ecija) and the mountain province of Central Luzon. Farmers followed CRSP fertilization guidelines. Extrapolated fish yields were extremely variable and ranged from 538 to 3,920 kg/ha/yr. Survival appeared to be the most critical factor in determining fish yield. The reasons for this variability have not yet been identified. Stocking stress as well as poaching may account for some of the mortality.

During the reporting period researchers from the University of Hawaii also analyzed data from the CRSP Central Database to determine the relationship between primary productivity and fish production.

Data Analysis and Synthesis

DAST researchers at the University of California, Davis (UCD) continued work on refining pond models. An aquaculture pond model useful for the analysis of integrated aquaculture-agriculture systems was modified, and changes were made to a model designed to simulate water temperature, dissolved oxygen, and fish growth in stratified fish culture ponds. To refine organic matter dynamics in fish ponds, DAST researchers began modification of two submodels, a bioenergetic, and a multi-G model, which are part of an integrated aquaculture-agriculture model.

The bioenergetic model, which simulates fish growth, was modified to include the effect of feed quality and different digestibility coefficients for various feed types; preliminary results pertaining to fish growth, nitrogen, and organic matter accumulation are now available.

The multi-G model was used to simulate water column and sediment organic matter. Sediment and water column organic matter concentration values were similar to values reported for agriculture waste-fed ponds. Water column nitrate also followed a trend similar to data collected from the PD/A CRSP site in Butare, Rwanda; other nitrogen parameters require further refinement.

To better predict the variability of water quality and fish growth associated with weather conditions at a given location, further modifications were made to a model of water temperature, dissolved oxygen, and fish growth for stratified fish culture ponds by adjusting the procedure for generating daily and hourly solar radiation estimates.