RESEARCH PROJECTS

POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

Staff

Auburn University, Auburn, Alabama

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

Background

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

Work Plan Research

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

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

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

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

Networking

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

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

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

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

Student Involvement

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

Educational Outreach

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

Publications

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

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

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

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

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

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

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

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

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

Presentations

Boyd discussed CRSP findings in the following presentations:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Conferences

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

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

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

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

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

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

Workshops

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

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

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

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

Perth, Australia, 6 May 1999.

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

Award

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

POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL ORGANIC MATTER AND NUTRIENTS

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

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

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

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

ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

Staff

University of Oklahoma, Norman, Oklahoma

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

Background

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

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

Work Plan Research

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

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

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

Networking

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

Presentation

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

Conference

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

METHODS FOR ANDROGENESIS TECHNIQUES APPLICABLE TO TILAPIA

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

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

ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

Staff

Auburn University, Auburn, Alabama

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

Background

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

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

Work Plan Research

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

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

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

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

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

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

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

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

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

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

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

DETECTION OF MT IN POND WATER AFTER TREATMENT WITH MT FOOD

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

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

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

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

ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

MOU No. RD009C

Staff

Oregon State University, Corvallis, Oregon

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

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

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

Background

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

Work Plan Research

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

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

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

Networking

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

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

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

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

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

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

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

Educational Outreach

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

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

Publications

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

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

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

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

Presentation

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

Conference

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

EFFECT OF TREATMENT TIMING AND DOSE ON MASCULINIZATION WITH TRENBOLONE ACETATE

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

Martin S. Fitzpatrick and Wilfrido M. Contreras-Sánchez
Department of Fisheries and Wildlife
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Carl B. Schreck
Oregon Cooperative Fishery Research Unit
Biological Resources Division—U.S. Geological Survey
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

ABSTRACT

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

AQUACULTURE SYSTEMS MODELING RESEARCH

Subcontract No. RD010A-03

Staff

University of California, Davis, California

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

Background

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

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

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

Work Plan Research

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

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

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

Networking

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

Educational Outreach

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

Publications

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

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

Presentation

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

Conference

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

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

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

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

ABSTRACT

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

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

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

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

ABSTRACT

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

EFFLUENTS AND POLLUTION RESEARCH

MOU No. RD009C

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

Principal Investigators

Oregon State University, Corvallis, Oregon

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

Background

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

Work Plan Research

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

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

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

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

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

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

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

ABSTRACT

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

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

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

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

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

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

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

ABSTRACT

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

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

Staff

University of Arkansas at Pine Bluff, Arkansas

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

Asian Institute of Technology, Pathum Thani, Thailand

Harvey Demaine	Host Country Principal Investigator (from January 1999)

Background

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

Work Plan Research

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

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

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

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

Networking

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

Educational Outreach

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

Publications

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

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

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

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

NONPARAMETRIC ESTIMATION OF RETURNS TO INVESTMENT IN HONDURAS SHRIMP RESEARCH

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

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

ABSTRACT

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

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

RISK ANALYSIS OF SHRIMP FARMING IN HONDURAS

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

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

ABSTRACT

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

DEVELOPMENT OF CENTRAL AMERICAN MARKETS FOR TILAPIA PRODUCED IN THE REGION

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

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

ABSTRACT

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

ECONOMIC AND SOCIAL RETURNS TO TECHNOLOGY AND INVESTMENT IN THAILAND

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

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

ABSTRACT

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

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-18

Staff

Auburn University, Alabama

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

Background

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

Work Plan Research

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

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-10

Staff

Auburn University, Alabama

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

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

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

Sagana Fish Farm, Sagana, Kenya

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

Background

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

Work Plan Research

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

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

Networking

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

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

Educational Outreach

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

Publications

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

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

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

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

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

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

ABSTRACT

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

SOURCES OF TECHNICAL ASSISTANCE FOR FISH FARMERS IN THE PERUVIAN AMAZON

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

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

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

ABSTRACT

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

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-14

Staff

Auburn University, Alabama

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

University of Delaware, Newark, Delaware

Norman Schwartz	US Co-Principal Investigator

Cooperators

Panama
Hugo Perez Athanasiadis

Guatemala
Carol and Eduardo Godoy

Background

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

Work Plan Research

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

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

Networking

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

Publications

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

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

Presentation

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

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

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

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ABSTRACT

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

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

DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

Staff

Oregon State University, Corvallis, Oregon

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

Cooperator

University of Georgia, Athens, Georgia
Shree Nath

Background

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

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

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

Work Plan Research

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

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

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

Networking

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

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

Educational Outreach

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

Publications

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

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

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

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

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ABSTRACT

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

HONDURAS PROJECT

Subcontract No. RD010A-06

Staff

Auburn University, Auburn, Alabama

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

Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras

Marco Polo Micheletti Bain	Host Country Principal Investigator

Laboratorio de Calidad de Agua La Lujosa, Choluteca, Honduras

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

Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras

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

Cooperators

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

Site Background

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

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

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

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

Work Plan Research

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

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

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

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

Networking

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

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

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

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

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

Educational Outreach

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

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

Publications

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

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

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

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

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ABSTRACT

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

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

Estuarine Water Quality Monitoring and Estuarine Carrying Capacity

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

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Abstract

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

Water Exchange to Rectify Low Dissolved Oxygen

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

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Abstract

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

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

HONDURAS PROJECT

Subcontract No. RD010A-05

Staff

University of Texas, Austin, Texas

George Ward — US Principal Investigator, Project Leader

Background

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

Work Plan Research

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

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

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

Publication

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

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

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

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ABSTRACT

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

HONDURAS PROJECT

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

Staff

University of Georgia, Athens, Georgia

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

Auburn University, Auburn, Alabama

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

Escuela Agrícola Panamericana El Zamorano, Honduras

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

Cooperators

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Robert Nelson

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

Site Background

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

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

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

Work Plan Research

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

PERU PROJECT

Subcontract No. RD010A-12

Staff

Southern Illinois University at Carbondale, Illinois

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

Ohio State University, Columbus, Ohio

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

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

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

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

Enrique Rios Isern	Host Country Co-Principal Investigator

Site Background

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

Work Plan Research

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

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

Networking

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

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

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

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

Educational Outreach

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

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

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

Publications

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

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

Presentation

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

Conference

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

PERU PROJECT

Subcontract No. RD010A-13

Staff

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann — US Co-Principal Investigator, Project Leader

Background

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

Work Plan Research

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

Networking

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

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

Educational Outreach

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

Publication

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

KENYA PROJECT

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

Staff

Oregon State University, Corvallis, Oregon

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

Auburn University, Auburn, Alabama

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

Fisheries Department, Nairobi, Kenya

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

Sagana Fish Farm, Sagana, Kenya

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

Cooperator

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

Site Background

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

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

Work Plan Research

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

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

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

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

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

Networking Activities

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

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

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

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

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

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

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

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

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

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

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

Educational Outreach

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

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

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

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

Publication

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

Presentations

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

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

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

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

Conferences

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

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

NEW SITE DEVELOPMENT AND CHARACTERIZATION

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

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ABSTRACT

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

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

Strain Variations in Sex Ratio Inheritance

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

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Abstract

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

Relative Contribution of Supplemental Feed and

INORGANIC FERTILIZERS IN SEMI-INTENSIVE TILAPIA PRODUCTION

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

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University of Nairobi
Nairobi, Kenya

Thomas Popma
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ABSTRACT

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

REGIONAL OUTREACH IN AFRICA

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

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ABSTRACT

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

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

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

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

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

Jim Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

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

ABSTRACT

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

AQUACULTURE TRAINING FOR KENYAN FISHERIES OFFICERS AND UNIVERSITY STUDENTS

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

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Bethuel Omolo and Judith Amadiva
Sagana Fish Farm
Sagana, Kenya

James R. Bowman
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Oregon State University
Corvallis, Oregon, USA

ABSTRACT

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

ESTABLISHMENT OF COMPANION SITES IN THE AFRICA REGION

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

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Auburn University, Alabama, USA

Daniel Jamu
ICLARM/Malawi
National Aquaculture Center
Zomba, Malawi

ABSTRACT

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

REGIONAL OUTREACH IN AFRICA

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

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Bethuel Omolo
Kenya Fisheries Department
Sagana Fish Farm
Sagana, Kenya

James R. Bowman
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Oregon State University
Corvallis, Oregon, USA

ABSTRACT

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

KENYA PROJECT

Subcontract No. RD010A-13

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

Principal Investigators

University of Arkansas at Pine Bluff, Arkansas

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

Background

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

Work Plan Research

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

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

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

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

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

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

Rebecca Lochmann and Peter Perschbacher
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

ABSTRACT

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

KENYA PROJECT

Subcontract No. RD010A-07

Staff

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

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

Cooperator

University of Nairobi, Kenya
Nancy Karanja

Background

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

Work Plan Research

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

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

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

Networking

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

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

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

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M. Bernard Meso
Department of Soil Science
University of Nairobi
Nairobi, Kenya

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

Nancy Karanja
Department of Soil Science
University of Nairobi
Nairobi, Kenya

ABSTRACT

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

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

PHILIPPINES PROJECT

Subcontract No. RD010A-15

Staff

University of Hawaii, Manoa, Hawaii

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

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

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

Site Background

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

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

Work Plan Research

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

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

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

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

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

Site Improvements

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

Networking

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

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

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

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

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

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

Educational Outreach

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

Presentation

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

Conference

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

TIMING OF THE ONSET OF SUPPLEMENTAL FEEDING OF TILAPIA IN PONDS

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

Remedios Bolivar
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Central Luzon State University
Muñoz, Philippines

Chris Brown
Hawaii Institute of Marine Biology
University of Hawaii
Manoa, Hawaii, USA

ABSTRACT

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

PHILIPPINES PROJECT

Subcontract No. RD010A-15

Staff

University of Arizona, Tucson, Arizona

Kevin Fitzsimmons — US Principal Investigator, Project Leader

Background

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

Work Plan Research

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

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

Networking

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

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

Publications

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

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

Presentation

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

Conferences

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

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

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

THAILAND PROJECT

Subcontract No. RD010A-04

Staff

University of Michigan, Ann Arbor, Michigan

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

Asian Institute of Technology, Pathum Thani, Thailand

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

Site Background

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

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

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

Work Plan Research

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

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

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

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

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

Site Improvements

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

Networking

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

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

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

Educational Outreach

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

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

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

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

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ABSTRACT

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

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

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

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ABSTRACT

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

CULTURE OF MIXED-SEX NILE TILAPIA WITH PREDATORY SNAKEHEAD

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

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ABSTRACT

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