RESEARCH PROJECTS

POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

Staff

Auburn University, Alabama

Claude E. Boyd	US Principal Investigator, Project Leader
C. Wesley Wood	Research Associate
Julio Queiroz	Postdoctoral Fellow (Brazil) (through February 1998)
Laurence Massaut	Postdoctoral Fellow (Belgium)
Brenda Wood	Technician

Background

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

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Networking Activities

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

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

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

Publication

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

Presentations

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

Boyd, C.E. Shrimp farming and the environment. Presented to the IV Ecuadorian Symposium on Aquaculture, Guayaquil, Ecuador, 22-27 October 1997.

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

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

Boyd, C.E. and C.W. Wood. Conceptual model of aquacultural pond soil development. Presented to the Soil Science Society of America Annual Meeting, Anaheim, California, 25-30 October 1997.

Boyd, C. E., A. Gross, and M. Rowan. Laboratory studies of sedimentation as a technique for treating pond effluents. Presented to Aquaculture '98, WAS Annual Meeting, Las Vegas, Nevada, 15-19 February 1998.

Wood, C.W., C.E. Boyd, and J. Queiroz. Aquaculture pond soil development. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Conferences

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

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

Workshops Given

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

POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL ORGANIC MATTER AND NUTRIENTS

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

Claude E. Boyd and Julio Queiroz
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Auburn University, Alabama, USA

C. Wesley Wood
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ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

Staff

University of Oklahoma, Norman, Oklahoma

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

Background

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

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Networking Activities

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

Conferences

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

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

NILE TILAPIA GAMETE MANAGEMENT FOR CHROMOSOME MANIPULATION

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

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

ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

Staff

Auburn University, Alabama

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

Background

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

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Presentation

Smith, E.S. and R.P. Phelps. Effect of feed storage time and storage temperature on growth rate of tilapia fry and efficacy of sex reversal. Presented at the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997.

Conferences

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

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

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

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

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

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

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

ABSTRACT

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

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

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

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

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

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

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

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

ABSTRACT

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

DETECTION OF MT IN POND WATER AFTER TREATMENT WITH MT FOOD

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

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

ABSTRACT

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

REPRODUCTION CONTROL RESEARCH

MOU No. RD009C

Staff

Oregon State University, Corvallis, Oregon

Martin S. Fitzpatrick	US Co-Principal Investigator, Project Leader
Carl B. Schreck	US Co-Principal Investigator
Wilfrido M. Contreras Sánchez	Graduate Research Assistant (Mexico)
Ruth H. Milston	Undergraduate Student Researcher
Rik Hornick	Undergraduate Student Researcher
Michael Lucero	Undergraduate Student Researcher
Grant W. Feist	Research Assistant

Cooperator:

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

Background

Broodstock and seed supply was identified as a major constraint in the *Continuation Plan 1996-2001*, resulting in reproductive control becoming one of the CRSP research priorities. Much of the CRSP research effort has focused on tilapia, for which management of unwanted reproduction is an essential part of most culture systems. The objectives identified in this work plan include a series of studies which address this issue from various perspectives.

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Networking Activities

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

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

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

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

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

Publications

Contreras Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck, 1998. Masculinization of Nile tilapia (*Oreochromis niloticus*) by single immersion in 17α-methyldihydrotestosterone and trenbolone acetate. In: K. Fitzsimmons (Editor), Tilapia Aquaculture: Proceedings from the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 783-790.

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

Conferences

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

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

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

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

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

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Carl B. Schreck
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Biological Resources Division—U.S. Geological Survey
Department of Fisheries and Wildlife
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Abstract

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

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

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

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Abstract

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

Detection of MT in Aquarium Water after Treatment with MT Food

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

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Abstract

The following study tested the hypothesis that 17α-methyltestosterone (MT) persists in the environment after its use for masculinizing Nile tilapia (*Oreochromis niloticus*). Fry were treated with a masculinizing dose of MT (60 mg kg^{-1}) for four weeks beginning at the initiation of feeding in model ponds which consisted of 3.7-l jars that contained 3 cm of soil. Water and soil samples were taken before the onset of treatment and weekly beginning on the last day of treatment (water samples were also taken weekly during the four-week treatment period). Concentrations of MT were determined by radioimmunoassay, which revealed that the levels of MT in the

water peaked between approximately 1 and 2 $\mu g\ l^{-1}$ at 14 and 21 days after the onset of feeding. Concentration of MT in water decreased to background level by 35 days after the onset of feeding (one week after the end of treatment with MT-impregnated food). In contrast, the levels in the soil were 1.4 to 1.7 $\mu g\ kg^{-1}$ at 28 days after the onset of feeding with MT-impregnated food and remained detectable in the soil at between 0.8 and 1.6 $\mu g\ kg^{-1}$ through 49 days (three weeks after ending treatment with MT-impregnated food). These results suggest that MT persists in sediments for at least weeks after cessation of MT treatment, which raises the possibility that unintended exposure to MT may occur.

AQUACULTURE SYSTEMS MODELING RESEARCH

Subcontract No. RD010A-03

Staff

University of California, Davis, California

Raul H. Piedrahita	US Principal Investigator, Project Leader
Daniel Jamu	Research Assistant (Malawi)
Zhimin Lu	Research Assistant (People's Republic of China)

Background

The current work on aquaculture systems modeling builds on previous experience and achievements under the PD/A CRSP. Models of aquaculture ponds developed to date have been deterministic and have evolved from the original models in which water quality was assumed to be uniform throughout a pond to models of stratified ponds. One of the models currently under development uses stochastic weather inputs to generate probability distributions for pond water quality and fish yields. The second model is used to analyze the flow of nutrients, particularly nitrogen, in an integrated aquaculture/agriculture system. The two distinct efforts will result in models that are useful for: 1) the study of pond management practices and the evaluation of possible production targets; 2) the analysis of environmental impacts from aquaculture; and 3) the study of nutrient and resource cycling in integrated agriculture/aquaculture systems.

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Networking Activities

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

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

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

Publications

Jamu, D.M., Z. Lu, and R.H. Piedrahita, 1998. Secchi disk visibility and chlorophyll *a* relationships in aquaculture ponds. In: M.B. Timmons and T. Losordo (Editors), Advances in Aquacultural Engineering: Proceedings from the Aquacultural Engineering Society (AES) Technical Sessions at the Fourth International Symposium on Tilapia in Aquaculture. NRAES, Ithaca, New York, pp. 159-162.

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

Conferences

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

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

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

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

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

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

ABSTRACT

A model developed to analyze the environmental impacts of aquaculture and the productivity and ecological function of integrated aquaculture/agriculture systems was evaluated using sensitivity analysis and model verification methods. The verified model was used to identify priority areas for future research in integrated aquaculture/agriculture systems and to study the long-term accumulation of nitrogen in pond

sediments. Sensitivity analysis results showed that the most sensitive parameters were maximum specific phytoplankton production rate per unit of carbon, aerobic sediment depth, oxygen threshold for aerobic conditions, water infiltration rate, and organic matter sedimentation rate. Application of a qualitative evaluation of research priorities that combined sensitivity analysis and parameter availability identified stocking practices, sediment processes, and water management as priority areas for future research in integrated aquaculture/agriculture systems. Model verification was established by the successful replication of observed patterns for individual fish weight, dissolved oxygen, total ammonia nitrogen, sediment organic matter, sediment nitrogen, chlorophyll *a* biomass, and corn grain yield. A ten-year simulation showed a marginally greater increase in sediment organic matter concentration in ponds receiving chicken manure and artificial feed inputs when compared to ponds receiving a combination of chicken manure and plant wastes. Steady-state conditions for sediment organic matter concentrations were not achieved within the ten-year simulation period. These results were consistent with observations made in fish ponds but different from published model predictions. Based on the verification and application results, the model appears to be appropriate for analyzing the management of organic matter and nitrogen in integrated aquaculture/agriculture systems. The model is also useful for identifying research areas that may be important in the scientific understanding of these systems.

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

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

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

ABSTRACT

A model has been developed for the prediction of water temperature, dissolved oxygen (DO), and fish growth using stochastically generated input weather variables. The model has been calibrated and validated using data from pond sites in Thailand, Honduras, and Rwanda. The model includes modules for the generation of weather parameter values and for the calculation of water quality and fish growth. The weather parameters generated include hourly solar radiation, air temperature, wind speed, and wind direction. The water quality variables modeled include water temperature, DO, total ammonia nitrogen, and phytoplankton (in terms of chlorophyll *a*). For modeling purposes, the water column is divided into three layers, each of which is considered to be fully mixed. Temperature and DO are calculated separately for each of the three layers resulting in simulations of stratified ponds. Given the stochastic nature of the weather input variables, the model must be run a number of times for a given set of pond management conditions. Typically, the model was run 20 times for each data set in the calibration and validation process. The simulation results obtained and presented in this report include mean, maximum, and minimum values for each time step. The simulated water temperature and DO are in good agreement with data for the Honduras and Rwanda sites; however, simulated and observed values for chlorophyll *a* at the Thailand site differ. Probability distributions for water quality and fish yield can be calculated from the simulation results and are useful to pond managers, planners, researchers, and teachers.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

Staff

University of Arkansas at Pine Bluff, Pine Bluff, Arkansas

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

Background

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Networking Activities

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

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

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

Presentation

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

Conferences

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

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

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

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

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

Printed as submitted

ABSTRACT

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

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-10

Staff

Auburn University, Alabama

Joseph J. Molnar	US Principal Investigator, Project Leader
Malkia Lockhart	Graduate Research Assistant (Bahamas) (from October 1997)

Sagana Fish Farm, Kenya

Judith Amadiva	Social Development Officer

Cooperator:

Sagana Fish Farm, Kenya
Bethuel Omolo

Background

Advances in basic understanding of the pond environment and cultural practices must eventually be translated and diffused to hatcheries, fish farmers, and other agencies and organizations involved in aquaculture development. Documenting the central mechanisms of transaction between fish farmers and the knowledge system in aquaculture is a fundamental objective of this work. This research addresses these issues at new sites and expands the scope of and clarifies socioeconomic dimensions as they affect the conduct and progress of the overall research program through the efforts of individual scientists and their host institutions.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Networking Activities

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

Publication

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

Presentations

Molnar, J. Doing development by growing fish: A cross-national analysis of the impacts of aquacultural research. Presented to the Annual Meeting of the Rural Sociological Society, Toronto, Canada, 1997.

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

Conferences

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

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

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

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

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

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

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

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

ABSTRACT

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

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

ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-14

Staff

Auburn University, Alabama

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

University of Delaware, Newark, Delaware

Norman Schwartz	US Co-Principal Investigator

Cooperators:

Panama
Hugo Perez Athanasiadis

Guatemala
Carol and Eduardo Godoy

Background

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

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Networking Activities

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

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

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

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

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

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

ABSTRACT

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

DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

Staff

Oregon State University, Corvallis, Oregon

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

Cooperators:

Auburn University, Auburn, Alabama
Joseph Molnar

Food and Agriculture Organization, Rome, Italy
James Kapetsky

Background

Aquaculture planners and managers are increasingly confronted with complex decisions regarding routine operations of culture facilities, effects of such operations on the surrounding environment, and the role of aquaculture production facilities within larger farming systems. Such decision-makers require analytical tools that integrate various components of the knowledge base and provide capabilities to rapidly examine the economic and environmental consequences of different decisions. These tools, termed decision support systems, integrate knowledge in the form of mathematical models, rule-based (expert) systems, and/or databases into user-friendly software systems focused on developing, analyzing, and optimizing management strategies.

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

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

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Networking Activities

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

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

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

Publications

Aguilar-Manjarrez, J. and S. Nath, 1998. A Strategic Reassessment of Fish Farming Potential in Africa. CIFA Technical Paper No. 32. FAO, Rome, 170 pp.

Kapetsky, J.M. and S.S. Nath, 1997. A Strategic Assessment of the Potential for Freshwater Fish Farming in Latin America. FAO COPESCAL Technical Paper No. 10, FAO, Rome, 124 pp.
Nath, S.S. and J.P. Bolte, 1998. A water budget model for pond aquaculture. Aquacult. Eng., 18(3):175-188.

Presentations

Bolte, J., D. Lowes, and S. Nath. Geographic Information System technologies for aquaculture decision support. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.
Ernst, D.H., S.S. Nath, and J.P. Bolte. Software for design and management of aquaculture facilities. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.
Nath, S.S., B.P. Verma, G. Rosenberg, and D. Nute. Integrated, multi-perspective approaches to decision support: Case study in Honduras. Presented at the 1998 Institute of Biological Engineering Meeting, 10-12 July 1998, Orlando, Florida.

Conferences

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

POND© Software Development and Refinement

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

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

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

Abstract

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

Macro-Level Agroecological Systems Analysis and Socioeconomics of Pond Aquaculture

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

John P. Bolte
Department of Bioresource Engineering
Oregon State University
Corvallis, Oregon, USA

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

Abstract

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

HONDURAS PROJECT

Subcontract No. RD010A-06

Staff

Auburn University, Auburn, Alabama

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

Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras

Marco Polo Micheletti Bain	Host Country Principal Investigator

Laboratorio de Calidad de Agua La Lujosa, Choluteca, Honduras

Jaime Lopez	Lab Technician
Delia Martinez	Chemist
Eneida Ramírez	Assistant Chemist

Centro Nacional de Investigación Piscícola El Carao, Comayagua, Honduras

Nelson Claros	Chemist
Rene Palcios	Lab Technician
Carolina Cardona	Biologist

Cooperators:

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

Site Background

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

Work at the inland site concentrated on aquacultural production systems and management regimes applicable to subsistence farmers and small to mid-sized commercial tilapia producers. In southern Honduras, work concentrated on determining the impact of shrimp farming on the estuarine environment and investigating techniques for reducing nutrient discharge from ponds.

Research in Honduras in the reporting period is being conducted at both inland and coastal sites.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

Note: Research under this subcontract is revised from that described in the *Eighth Work Plan*. The new (replacement) work plan appears in the forthcoming *Second Addendum to the Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. No report was submitted for HR1; please see Editor's Note to HR1 abstract. The study HR2, "Estuarine water quality monitoring and estuarine carrying capacity," is a collaborative project between the University of Texas (under Subcontract No. RD010A-05) and Auburn University. The HR2 report (HR2-1) submitted by Auburn University addresses the first HR2 work plan objective; the second study objective is addressed in the HR2 report (HR2-2) submitted by the University of Texas.

Site Improvement

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

Networking Activities

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

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

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

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

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

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

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

Publications

Green, B.W., D.R. Teichert-Coddington, M.P. Micheletti, and C.A. Lara, 1997. A collaborative project to monitor water quality of estuaries in the shrimp producing regions of Honduras. Proceedings of the IV Ecuadorian Aquaculture Symposium, 22-27 October 1997, CENAIM, ESPOL, Camera Nacional de Acuacultura, Guayaquil, Ecuador, CD-ROM.

Teichert-Coddington, D.R. and B.W. Green, 1997. Experimental and commercial culture of tilapia in Honduras. In: B.A. Costa-Pierce and J.E. Rakocy (Editors), Tilapia Aquaculture in the Americas, Vol. I. World Aquaculture Society, Baton Rouge, Louisiana, pp. 142-162.

Presentation

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

Conferences

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

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

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

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

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

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

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

ESTUARINE WATER QUALITY MONITORING AND ESTUARINE CARRYING CAPACITY

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

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ABSTRACT

Water quality was monitored in estuaries of the shrimp-producing regions of southern Honduras. This project is a collaborative effort of universities, the private sector, and the public sector, with each group contributing time and resources to the overall effort. The project goal is to provide a scientific basis for estuarine management and sustainable development of shrimp culture in Honduras. Specific objectives are to: 1) detect changes in estuarine water quality; 2) formulate and validate predictive models for estuarine water quality; and 3) estimate assimilative capacity of selected estuaries in the shrimp-producing region of southern Honduras based on water quality, farm chemical budgets, and estuarine fluid dynamics. Samples were collected from June 1997 to June 1998 from 20 sites on 12 estuaries. Data were added to the database on estuarine water quality established in 1993. Nutrient sources for riverine estuaries include nutrient load in river discharge and rainfall or irrigation runoff from the watershed, and shrimp farm discharge. Changes in land-use patterns in the Gulf of Fonseca watershed also will affect estuarine water quality because of changes in runoff patterns and volumes. Examples of this effect already have been observed in the upper reaches of a couple of estuaries where stands of mangroves have died apparently because of sedimentation, which resulted from severe reduction of runoff caused by watershed land-use changes. Water quality in riverine estuaries continues to be influenced directly by seasonal variation in river discharge and watershed runoff, while embayments of the Gulf of Fonseca experience less seasonal variation in water quality. The impact of the El Niño in Honduras this past year was delayed and reduced rains, which resulted in higher observed salinity, total nitrogen, and chlorophyll *a* concentrations at sampling sites along riverine estuaries in comparison to 1996 and 1997. Embayment water quality was less affected by the El Niño. Declines in water quality in riverine estuaries were exacerbated with increasing distance upstream because water exchange with the Gulf of Fonseca decreases rapidly with distance upstream. No trends for total nitrogen or total phosphorus enrichment were evident in riverine estuaries or embayments during the period from 1993 to 1998. Total nitrogen and total phosphorus concentrations in riverine estuaries were reduced by 10 to 30% during the rainy season because of river discharge and watershed runoff.

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

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

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ABSTRACT

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

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

WATER EXCHANGE TO RECTIFY LOW DISSOLVED OXYGEN

Eighth Work Plan, Honduras Research 4 (HR4)
Abstract

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ABSTRACT

In Central America semi-intensive shrimp production technology is used by many producers. Semi-intensive production technology is characterized by final stocking rates of 5 to 11 shrimp m^{-2}, daily water exchange at ≤ 10% of pond volume, and use of 20 to 25%-protein feeds. The role of water exchange in semi-intensive shrimp culture is being evaluated in Honduras. Recently completed research (HR3) indicated that daily or emergency water exchange did not affect significantly shrimp production, but that water quality was better in ponds that received daily water exchange. However, differences in water quality generally did not become pronounced until the latter half of the 12- to 16-week production cycle. Producers may find unacceptable the risk associated with utilizing an emergency-only water exchange policy. However, it appears that the current standard practice of initiating water exchange the fourth week post-stocking is not the most efficient exchange strategy. This experiment builds on the previous experiment. The objectives of this experiment are to evaluate the effect of time of initiation of water exchange on pond dissolved oxygen, water quality, and shrimp production. Nine 0.93-ha ponds located on a commercial shrimp farm in southern Honduras are being used for this completely randomized design study. Water will be exchanged at 10% of pond volume per day, six days per week beginning four, seven, or ten weeks after stocking. The experiment is being conducted during the rainy season and will be repeated during the dry season. Ponds for the rainy season experiment were stocked with hatchery-spawned post-larval *Penaeus vannamei* at 150,000 PL ha^{-1} (15 PL m^{-2}) on 14 August 1998. Shrimp are fed six days per week beginning two weeks after stocking. Feed rate for all ponds is based on the theoretical feeding curve for *Penaeus vannamei*:

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

where

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

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

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

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

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ABSTRACT

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

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

HONDURAS PROJECT

Subcontract No. RD010A-05

Staff

University of Texas, Austin, Texas

George Ward — US Principal Investigator, Project Leader

Background

A baseline of water quality has been established for the major estuaries supporting the shrimp culture industry in southern Honduras. Correlation between industry farm management and estuarine water quality can now be drawn by continued time-series measurements. Models will serve both a diagnostic purpose, in assisting the interpretation of the results of the estuarine sampling program, and a prognostic purpose, in acting as a tool for predicting the estuary responses to shrimp farm operations.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

Note: The research schedule under this subcontract is revised from that described in the *Eighth Work Plan*. Please see Appendix 4, "Completion Dates for Eighth Work Plan Studies," for new schedule information. The Eighth Work Plan study HR2, "Estuarine water quality monitoring and estuarine carrying capacity," is a collaborative project between Auburn University (under Subcontract No. RD010A-06) and the University of Texas. The following report addresses the second HR2 work plan objective; the first study objective is addressed in the HR2 report (HR2-1) submitted by Auburn University.

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

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

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ABSTRACT

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

PERU PROJECT

Subcontract No. RD010A-12

Staff

Southern Illinois University at Carbondale, Carbondale, Illinois

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

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

Gonzalo Llosa Talavera	Host Country Project Leader
Fernando Alcántara	Host Country Co-Principal Investigator
Palmira Padilla Perez	Aquaculturist
German del Aquil	Technician
Armando Conde Sánchez	Technician
Lamberto Arevalo	Technician
Cesar A. Flores	Technician
Arturo Flores Huang	Technician

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

Enrique Rios Isern	Host Country Co-Principal Investigator

Site Background

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

Three important institutions conduct research on aquaculture in the region: the Instituto de Investigaciones de la Amazonia Peruana (IIAP), the Peruvian Government, and the Universidad Nacional de la Amazonia Peruana (UNAP). In the past ten years they have produced thousands of fry and have developed various aquacultural techniques. *Colossoma* and *Piaractus* are considered by local aquaculturists as the best fishes for commercialization in the tropical part of Peru. (Tilapia have been introduced to all eight USAID-presence countries in South America. However, they are illegal in the Peruvian Amazon basin.)

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Site Improvement

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

Networking Activities

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

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

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

Publication

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

Presentation

De Jesus, M.J. and C.C. Kohler. Analysis of the commercial fisheries in the Peruvian Amazon. Presented to the Illinois Renewable Natural Resources Conference, Springfield, Illinois, 4-6 March 1998.

Conference

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

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

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

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

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

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ABSTRACT

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

NEW SITE DEVELOPMENT AND CHARACTERIZATION

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

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ABSTRACT

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

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

KENYA PROJECT

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

Staff

Oregon State University, Corvallis, Oregon

Jim Bowman	US Co-Principal Investigator, Project Leader
Christopher Langdon	US Co-Principal Investigator
Gene Wooden	Student Assistant (from December 1997)

Auburn University, Auburn, Alabama

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

Fisheries Department, Nairobi, Kenya

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

Sagana Fish Farm, Sagana, Kenya

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

Site Background

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

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

Eighth Work Plan Research

These subcontracts were awarded funding to conduct the following studies:

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

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

KR3A, "Nutritional contribution of natural and supplemental foods for Nile tilapia: Stable carbon isotope analysis," (under Subcontract No. RD010A-13, University of Arkansas at Pine Bluff) brings in UAPB as a third US collaborator (please see following project description).

Site Improvement

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

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

Networking Activities

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

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

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

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

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

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

Presentation

Bowman, J. Soil pH and liming: A review of acidity/alkalinity management practices in aquaculture. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Conferences

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

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

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

New Site Development and Characterization

Eighth Work Plan, Kenya Research 1 (KR1)
Abstract

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Jim Bowman
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Abstract

Site development and characterization activities for the new prime site at Sagana, Kenya, began immediately upon arrival of the Africa Project's resident researcher, Karen Veverica, on 31 March 1997. Major undertakings that were required to make the site suitable for CRSP research included modification of the existing ponds, refurbishment of the water quality laboratory, acquisition of suitable laboratory and farm supplies and

equipment, installation of a weather monitoring and recording (datalogger) system, and acquisition of a new computer system and an appropriate four-wheel-drive vehicle. Pond and laboratory renovations proceeded rapidly, and the major portions of these tasks were complete by the end of September 1987. Four existing 4000-m^2 production ponds were modified to create twelve 800-m^2 ponds of uniform size and shape for CRSP research. Extra soil from the pond renovation was used to make seven additional ponds, ranging from 800 m^2 to 1500 m^2, which will be used as holding ponds, for fry production, or for activities requiring the use of hapas. Three of the extra ponds have dimensions appropriate for experimental work. Farm and laboratory supplies and equipment, including a new desktop computer, laboratory instruments, and seines, were shipped from the US on 30 June and arrived at Sagana on 3 September. A Land Rover was purchased from the United Kingdom and shipped to Kenya on 1 July, becoming available for project use in mid-September. Installation of the weather monitoring system was begun at the end of November and weather data were recorded beginning the first week of December. In addition, observations on pond soil and source water chemistry and annual weather patterns were begun to allow complete characterization of the new site. Initial pond soil samples were collected in October 1997, and water samples for source water characterization were collected starting in October 1997. Weather data recording was begun in December 1997. Solar radiation, photosynthetic active radiation (PAR), precipitation, relative humidity, wind speed, and air temperature were recorded hourly. Four temperature probes were suspended in one pond (D6) to record pond temperature at 5, 25, 50, and 75 cm depth as of April 1998. Preliminary analyses of pond soil samples indicate that they are mainly of the "black cotton soils" variety, high in 2:1 type clay minerals (70 to 90% clay), with cation exchange capacities typical for that type of soil (30 to 55 meq 100 g^{-1}), and pH values ranging from 5.4 to 7.5. Lime will be required to ensure that carbon is not limiting in fertilization experiments or during production cycles. Lime requirements of 5 to 10 tons ha^{-1} have been calculated. The phosphorus adsorption capacity of these soils is expected to be quite high. Total alkalinity and total hardness levels of water provided to the Sagana ponds through the 2-km canal system are typically 10 to 20 mg l^{-1} as $CaCO_3$. Conductivity was measured at 0.05 mmho cm^{-1}. Detailed characterization of the pond soils and source waters for the Sagana station, as well as a summary of the first year's weather, will be included in the final report for this activity.

STRAIN VARIATIONS IN SEX RATIO INHERITANCE

Eighth Work Plan, Kenya Research 2 (KR2)
Abstract

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ABSTRACT

Pond D3 at Sagana Fish Farm, Sagana, Kenya, was dedicated to pair spawns and rearing of fry for this activity. In addition to work conducted in 1997, fry from 24 pair spawns were transferred to hapas from January through April 1998. Although more than 100 fry were obtained from most spawns, survival to 3 g was very low in the rearing hapas, and fewer than 25 fingerlings per spawn were obtained. This number was too low to complete the protocol as planned, and the fingerlings were discarded. Survivals of about 80% were obtained during sex reversal in similar hapas in a similar pond. The only difference is that fry being sex-reversed are reared at much greater densities than the single-spawn fry. To date, only six batches of single-spawn fingerlings with adequate survival beyond a size of 3 g have been obtained. These were initially reared in hapas, followed by three weeks in the hatchery. However, these batches still contained no more than 60 fish, which is an insufficient number for this study. Recently a blower has been installed in the hatchery and a complete diet has become available, so we plan to grow out single spawns in the hatchery after the end of the cool season (end of August). Temperatures in the cool season are too low (20°C and less) for growing tilapia fry in the hatchery.

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

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

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

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

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ABSTRACT

A 20-week experiment was conducted at Sagana Fish Farm, Kenya, to achieve the following: 1) characterize the productive capacity of ponds at this new CRSP research site; 2) evaluate the relative contributions of inorganic fertilizers and supplemental feeds to fish production; and 3) determine lowest-cost combinations of rice bran and inorganic fertilizer. Twelve 800-m^2 ponds were stocked with juvenile (32 g each) *Oreochromis niloticus* at 2 m^{-2} and *Clarias gariepinus* fingerlings (average weight 4.6 g) at 0.24 m^{-2}. Ponds contained about half sex-reversed and half mixed-sex tilapia, with an estimated ratio of approximately 75% males to 25% females at stocking. Four treatments were applied in triplicate as follows: 1) Urea and DAP to provide 16 kg N ha^{-1} wk^{-1} and 4 kg P ha^{-1} wk^{-1}; 2) Urea and DAP applied to give 8 kg N and 2 kg P ha^{-1} wk^{-1}, plus rice bran fed at 60 kg ha^{-1} d^{-1}; 3) Rice bran fed at 120 kg ha^{-1} d^{-1}; and 4) Rice bran as in Treatment 3 and fertilizer as in Treatment 2. Net fish yield averaged 1,127, 1,582, 1,607, and 2,098 kg ha^{-1} for Treatments 1 through 4, respectively. Fish in Treatments 2 through 4 were still growing rapidly at harvest time, but the growth rate of fish in Treatment 1 was beginning to decrease near the end of the experiment. Treatment 1 was the most cost-effective, but Treatments 1, 2, and 4 all resulted in fairly similar net profits. Input costs for Treatments 1 and 2 will be of interest to fish farmers, although it is possible that fish raised using only fertilizer at the rates in Treatment 1 may never reach market size at this stocking density, because of their reduced growth towards the end of the culture period and their resulting low final average weights, which were less than 100 g.

TRAINING

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

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Fred Pertet
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Nairobi, Kenya

ABSTRACT

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

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

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

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

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

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

REGIONAL OUTREACH IN AFRICA

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

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Nairobi, Kenya

ABSTRACT

Regional outreach activities were undertaken under the Eighth Work Plan as a means of disseminating information developed through CRSP research; giving CRSP researchers opportunities to learn about fish culture practices, research priorities, and research activities in other parts of Africa; encouraging efforts to create linkages between research and extension activities in the region; and in general continuing the process of making contacts and regionalizing CRSP efforts in Africa. In an effort to disseminate information to extension personnel, CRSP researchers attended meetings of District Fishery Officers of Central Province and a meeting for Provincial Fisheries Officers (Kenya). During these meetings the PD/A CRSP was described, pond management recommendations were outlined, proposed on-farm trials were discussed, pond census forms were distributed, information was provided on sex-reversed tilapia, and the results of our first experiment at Sagana Fish Farm were presented. Students doing research at Sagana in connection with that experiment also presented short summaries of their research findings. Several regional meetings were attended by CRSP personnel during the reporting period. The first was the 5th Session of the Organization of African Unity's Scientific, Technical, and Research Commission (OAU/STRC) Inter-African Committee and Symposium on Oceanography, Sea and Inland Fisheries, Mombasa, Kenya, 4-8 May 1998, hosted by Fred Pertet, member of the OAU/STRC and Host Country Principal Investigator for the Africa Project. Karen Veverica and Bethuel Omolo also attended this meeting, which provided an excellent opportunity to publicize the CRSP and to present Sagana Fish Farm as an ideal aquaculture training site. Veverica and Omolo also attended the 8th annual East African Environmental Network (EAEN) conference, 29-30 May 1998 in Nairobi, where they presented an invited paper entitled "An overview of aquaculture practices in East Africa: Potential environmental impacts and prospects for sustainable livelihoods." CRSP Africa Project team members from Kenya and the US plan to attend a Fisheries Society of Africa (FISA) meeting scheduled to take place in Grahamstown, South Africa, 13-19 September 1998, and have submitted abstracts for five presentations. In addition, CRSP researchers contacted the conference organizers to inquire about and encourage the inclusion in the conference of a special discussion session on the status, constraints, and priorities of aquaculture in Africa. This has been accepted and Jim Bowman will serve as rapporteur for the session, to be entitled *Aquaculture in Africa—Quo Vadis*. These outreach efforts are helping to inform interested regional parties about the CRSP; to develop a better understanding of regional research needs among CRSP participants and others; and to encourage communication and the formation of linkages among regional organizations and individuals interested in aquaculture. It is anticipated that participation in the upcoming FISA conference will greatly increase the level of benefits realized under this activity.

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

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

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ABSTRACT

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

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

KENYA PROJECT

Subcontract No. RD010A-13

Staff

University of Arkansas at Pine Bluff, Arkansas

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

Background

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

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Networking Activities

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

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

Conferences

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

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

Award

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

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

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

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ABSTRACT

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

THAILAND PROJECT

Subcontract No. RD010A-04

Staff

University of Michigan, Ann Arbor, Michigan

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

Asian Institute of Technology, Pathum Thani, Thailand

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

Cooperators:

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

Site Background

The PD/A CRSP has worked collaboratively with the Asian Institute of Technology (AIT), Thailand, since the program's inception in 1982. AIT is an important regional training center, providing not only excellent research facilities but also regional networking opportunities for outreach activities.

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

CRSP research on semi-intensive culture of tilapia has continued work on mud turbidity, pond draining, supplemental feeding, and nutrient regeneration in pond bottoms, all of which are related to farmer practices in the wet and dry seasonal climates of the region. Outreach activities have focused on aquaculture practices in rainfed ponds.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following studies:

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

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

Site Improvement

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

Networking Activities

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

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

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

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

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

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

Publications

Cao, T.B., C.K. Lin, and H. Demaine, 1998. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: I. Selection of supplemental diets. J. Asian Fish. Sci. (in revision).

Cao, T.B., C.K. Lin, and H. Demaine, 1998. Evaluation of low-cost supplemental diets for culture of Nile tilapia in North Vietnam: II. Supplemental feeding rates in fertilized ponds. J. Asian Fish. Sci. (in revision).

Diana, J.S. and C.K. Lin, 1998. The effects of fertilization on growth and production of Nile tilapia in rain-fed ponds. J. World Aquacult. Soc. (in press).

Yi, Y., 1998. A bioenergetics growth model for Nile tilapia (Oreochromis niloticus) based on limiting nutrients and fish standing crop in fertilized ponds. Aquacult. Eng. (in press).

Presentations

Lin, C.K. and C. Limsuwan. Management strategies and approaches for water quality improvement in shrimp farming. Presented at the American Association for the Advancement of Science at Philadelphia, Pennsylvania, 12-17 February 1998.

Lin, C.K., J.B. Hambrey, and J. Szyper. Environmental impact assessment for a shrimp farm project in Tanzania: a case study. Presented at the Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Lin, C.K., W. Ruttanagosrigit, D. Thakur, and P. Wanuchsoontorn. Organic matter and nutrients in sludge of closed ponds for intensive shrimp culture. Presented at Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

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

Conferences

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

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

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

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

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

Eighth Work Plan, Thailand Research (TR1)
Final Report

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ABSTRACT

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

MANAGEMENT OF ORGANIC MATTER AND NUTRIENT REGENERATION IN POND BOTTOMS

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

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ABSTRACT

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

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

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

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ABSTRACT

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

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

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

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ABSTRACT

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

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

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

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ABSTRACT

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

PHILIPPINES PROJECT

Subcontract No. RD010A-11

Staff

University of Arizona, Tucson, Arizona

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

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

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

Cooperator:

Chino Valley High School, Chino, Arizona
David Pereda

Site Background

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

While the search for a lead US university for the Philippines Prime Site was underway, the University of Arizona was contracted to conduct one study at the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU). The experiment attempts to develop low-cost supplemental feeds by using agricultural by-products. The project will determine if agriculture by-products including rice bran or straw can be used in pelleted diets. Yeast and rice bran or composted straw will be tested as possible ingredients.

Eighth Work Plan Research

This subcontract was awarded funding to conduct the following study:

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

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

Site Improvement

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

Networking Activities

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

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

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

Presentations

Brown, J.J., E.P. Glenn, and K.M. Fitzsimmons. Forage crop production on highly saline aquaculture effluent. Presented to Aquaculture '98, WAS Annual Meeting at Las Vegas, Nevada, 15-19 February 1998.

Fitzsimmons, K. and B.C. Posadas. Consumer demand for tilapia products in the U.S. and the effects on local markets in exporting countries. Presented to the Fourth International Symposium on Tilapia in Aquaculture at Orlando, Florida, 9-12 November 1997.

Conferences

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

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

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

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

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

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

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ABSTRACT

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