Advances in Aquaculture: The Role of Aquaculture CRSP-Supported Research, Training, and Information Exchange on the Culture of Cichlids in CRSP Host Country Institutions

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INTRODUCTION

The training of extension agents, fish farmers and students is a fundamental component of Aquaculture Collaborative Research Support Program (ACRSP) activities. The need to deliver timely information and appropriate technological packages to end-users is critical for the development of sustainable aquaculture. To this end, ACRSP sponsored trainings and workshops are a proven and effective means for achieving these goals. Researchers obtain feedback useful for identifying and prioritizing future research hypotheses to be tested from workshop participants. According to The PD/A CRSP Training Plan: Perspective, Experiences, and Directions (Bolivar et al., 2002), the training of technicians, farmers, and extension agents is an effective way to disseminate research results and good management practices in aquaculture.

Unfortunately, much of the knowledge, technologies, and experiences generated by the ACRSP host country institutions has remained largely within the borders of each country and not enough information exchange has occurred. Although limited information exchange takes place at the ACRSP annual meetings, the adoption of new techniques and experiences has largely remained at the national and regional levels.

To overcome the inherent problems related to global distances and difficulties with communications, this project facilitated travel of host country PIs, collaborators, and students to selected host country institutions. This strategy reduced the time needed to produce training manuals, proposals or publish research results and allowed for a better understanding of the techniques developed for cichlid culture at each ACRSP host country institution.

The objectives of this activity were as follows:

A. To learn from Host Country institutions of the ACRSP through direct exposure to research and extension activities at other ACRSP sites;
B. To strengthen the networking capabilities among the ACRSP host country institutions working with cichlid culture;
C. To organize and implement short courses, seminars, and classroom presentations that include information on some aspects of cichlid culture that have been derived from ACRSP supported efforts around the globe;
D. To develop concepts for joint future research and extension proposals between and/or among the ACRSP host country institutions working on cichlid culture; and
E. To learn lessons from successes in other host countries for application by HCPIs in their respective home countries.

Five institutions participated in this activity. The strengths of each institution are presented as follows:

1. Panamerican Agricultural School, Honduras

The Panamerican Agriculture School, also known as Zamorano, is a private, non-profit, US corporation operating in Honduras. The Zamorano student body of 850 is drawn from 18 countries from throughout Latin America. Zamorano has an active outreach program for more than 20 years and the institution has outstanding facilities and human resources for applied research and organizing and providing training to students, farmers, extension agents and other interested individuals or groups.

The Zamorano Aquaculture Station, founded in 1976, has an important role in both formal and informal training of individuals interested in fish and crustacean farming in Latin America. Zamorano's research efforts in aquaculture have focused on studying and developing efficient techniques to manage production systems, reduce feed inputs and the environmental impacts derived from aquaculture operations, and evaluating genetic stocks for use in the region. We have developed a series of manuals and a web site in Spanish to facilitate information exchange and promote the culture of tilapia and other species regionally. Our station has excellent infrastructure for training and research activities in aquaculture with ponds and tanks (total > 100 units), laboratories for water and microbiological analysis of samples, modern classrooms and office space. We have been actively involved in fish culture extension in Central America for more than 15 years. We have received support for our outreach activities from many donors, including the GTZ and DSE of Germany, Public Welfare Foundation and USAID, NOAA-Sea Grant, and others. In collaboration with other agencies and interested groups, we routinely organize field-days, short courses and seminars on multiple topics related to successful fish and shrimp culture.

2. Fisheries Department (FD), Kenya

The Sagana Aquaculture Centre has served as the Kenya FD principal warm-water research, educational and seed supply center since 1948. Currently there are 113 ponds of different sizes that are used for research and fish production. Part of the site has been integrated with ongoing dairy, agro-forestry, and poultry programs. ACRSP activities, such as in-service training in aquaculture for the Fisheries Extension Staff, have involved collaboration between the FD, Moi University, Oregon State University, and Auburn University.

Research topics and related ACRSP activities at Sagana Aquaculture Centre include a) determination of the performance of three strains of tilapia (*Oreochromis niloticus*); b) determination of the most cost-effective fish feed combination for tilapia culture; c) cage culture of tilapia using low-input feeding regimen in static water ponds; d) training of Fisheries Extension Staff in construction and management of fish ponds, and enterprise budgets; and e) on-farm trials of selected pond management techniques.

The Sagana Aquaculture Centre is involved in the recruitment of an indigenous species (*Labeo* spp.) as a potential candidate for farming. Documentation on our experiences in

semi-intensive, low-input systems of tilapia culture is available. A manual for aquaculture trainers has been produced, arising from training of fisheries front-line staff between 1999 and 2003. In addition, we are organizing a Documentation Center to facilitate dissemination of information to interested parties.

3. Universidad Juárez Autónoma de Tabasco (UJAT), Mexico

The Laboratory of Aquaculture (LA) at UJAT has been addressing the problems that small-scale farmers face in the region by: 1) developing masculinizing systems for tilapia and native fish which are safe for fish farmers and the environment, 2) producing a new line of tilapia for brood-stock replacement, 3) diversifying aquaculture practices using native species, 4) implementing polyculture alternatives for shrimp farmers, and 5) conducting regional workshops on safe handling of steroids and sex inversion techniques.

An important aspect of all projects at UJAT has been the incorporation of an extension program. The primary results that can benefit other institutions are: a) development of a filtration system that eliminates MT from intensive masculinization ponds; b) development of a methodology to sex inverse larvae of carnivorous species of fish using *Artemia* nauplii as vehicle; c) effective masculinization of two native cichlids and feminization of the tropical gar; and d) selection of a tilapia line that performs better than the brood-stock traditionally used in Tabasco. The LA has produced videos, pamphlets and written materials that may be helpful to other countries. UJAT will benefit from other institutions that are currently working on reproduction and grow-out systems, genetic line selection and extension methods.

4. Central Luzon State University (CLSU), Philippines

The CLSU houses the Freshwater Aquaculture Center (FAC) which is a multidisciplinary research unit of the university. FAC is responsible for aquaculture and fisheries research and development through close collaboration with the College of Fisheries, with which FAC shares a core research staff and physical facilities. Current research topics at FAC include tilapia genetics, water quality management, fish health management, fish nutrition, fisheries economics, aquaculture systems and aquatic ecology. The ACRSP funded research at FAC focuses on evaluating tilapia feeding strategies in semi-intensive culture systems and surveying management practices on private tilapia farms.

The establishment of the Tilapia Science Center (TSC) at CLSU is in recognition of the outstanding achievements and significant contributions made by the institutional partners to promote the growth and development of the tilapia industry. The TSC is a unique partnership of agencies and institutions representing academe (CLSU), the public sector (Bureau of Fisheries and Aquatic Resources-National Freshwater Fisheries Technology Center), a non-profit NGO (GIFT Foundation, International, Inc.) and a private company (FISHGEN, Inc.). This strategic alliance combines innovative education with research, extension and entrepreneurship to effectively improve the quality of life of tilapia farmers in particular and of other people in general. These institutions are located in the vicinity of the FAC.

Facilities of the FAC include research laboratories for water quality, aquatic biology, fish pathology, and fish nutrition, experimental ponds, tanks, hapas and aquaria. The FAC has a living museum intended to showcase a living collection of indigenous freshwater fishes from the Philippines.

5. Asian Institute of Technology (AIT), Thailand

The AIT hosts the post-graduate academic and research program on Aquaculture and Aquatic Resource Management (AARM), focusing on improving regional institutional capacity through innovative approaches that integrate education, research, and outreach. AIT is a research/education hub for the region.

Three cross-cutting research themes are currently emphasized in aquaculture within AARM: 1) small-scale aquaculture, 2) seed production and genetics, and 3) fish nutrition and feed management. AIT has extensive pond facilities, water chemistry, nutrition and genetics laboratories, a hatchery, and a team of 30 professionals.

Some on-going ACRSP supported research activities at AIT include: a) innovations in *Macrobrachium* culture in recirculating systems; b) fertilization regimes for ponds with Nile tilapia receiving supplemental feeds; c) use of rice-straw as a resource for freshwater pond culture; d) polyculture of lotus and snakehead for recycling wastewater from intensively fed ponds; e) reproductive performance and growth of improved tilapia (*Oreochromis niloticus*); f) use of ultra-sound in immersion protocols for efficient sex-reversal of Nile tilapia; g) reproduction of indigenous species such as *Spinibarbus denticulatus*; and h) impact of tilapia introductions on native indigenous species. AIT provides training, study tours and has an extensive network of farmers, entrepreneurs, and academic/research institutions to partner with for the dissemination of research results and other technical information.

COUNTRY PERSPECTIVES

Honduras

The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) and ACRSP have operated in Honduras during the last 23 years. During this period, small and medium-scale aquaculture farms have flourished in Honduras and surrounding countries. During the period 1984-89, the commercial culture of marine shrimp and tilapia began in the region.

Today, Honduras is an important supplier of fresh tilapia fillets to North American markets (about USD 50 million in 2006) and commodity and processed shrimp to the US, European and other markets (about USD 120 millions in 2006) around the world.

<u>Strengths gained through participation in the ACRSP</u>

Good management practices (GMPs) are employed to present clear and understandable guidelines or strategies to be adapted to each farm's particular environment (Haws et al.,

2001). These strategies have to be proven economically feasible to be used long-term. Generally, GMPs should improve profitability by promoting the use of fewer inputs and better environmental management that should result in better production levels and greater efficiencies.

1. Tilapia fingerling assessment and utilization

Several GMPs were gained on this area such as: 1) Fish culture production should be based on the culture of endemic species, or to species and genetic lines that have been historically stocked in the country/region/area, 2) Extreme care and precaution should be taken to prevent the introduction of any aquatic species into waters where they are not naturally present/found, c) Tilapia fingerlings should be cared humanely for and handled correctly during their production, preparation for transport, during transport, and during the tempering procedure, to reduce losses and minimize harm and stress to the fish, d) High quality tilapia fingerlings to be obtained should be of generally uniform size and color and e) When sex-reversed fish are purchased, each lot should consist of $\geq$ 97% males.

When movement of any fish across an international border or frontier should be done, it should be in accordance with and obeying all local laws and regulations of both countries. Some of the GMPs in this area are: 1) All fish for export should be certified by a recognized veterinarian or competent animal health specialist, that they are in good health, and that they are free of any parasites and infection, 2) The imported fish should be isolated from other stocks and quarantined for a minimum of 15 days before general stocking on the farm, 3) Any abnormal behavior, presence of lesions or infection, observed among the imported fish should be reported immediately to the local health officials/offices for investigation and treatment, and the affected fish maintained in quarantine.

2. Definition of nitrogen and phosphorus levels for pond fertilization and efficient tilapia production in Honduras

During the period 1983-1992, eleven studies were done to define fertilization rates for tilapia production and evaluate several options or combinations of fertilizers and manufactured fish pelleted feed. The results of these studies form one of the major impacts of the ACRSP in Central America. These experiments demonstrated conclusively that tilapia can be cultured profitably under conditions of Central America, particularly in Honduras.

Additionally, these studies proved that tilapia can be successfully reared utilizing low-cost inputs, including chicken litter, urea, triple super phosphate and other fertilizers in Central America. Several studies indicated that net income increased from fish ponds managed with organic fertilizers, versus the use of chemical fertilizers and feeds. Fish production was greatest with manufactured feeds but the net income, as a percent of total costs, was lower than for fish produced with the organic fertilizers.

3. Improved feeding strategies

Most ACRSP sponsored work with feeding has been in experiments combining the use of manufactured feeds with organic and/or chemical fertilizers. These combinations generally resulted in high fish yields and net income in the range of USD 900 to 1800/ha in six-month production cycles.

Most small and medium-scale fish farmers in Honduras utilize chicken litter and other animal manures to fertilize their ponds and begin fattening of their fish. These techniques are used mostly with recently purchased fingerlings and small fish. Generally these farms switch to a manufactured diet when the fish attain an average weight above 50 g.

4. Capacity building

Our efforts have focused on training regional farmers to begin tilapia production and to train extension agents working with NGOs to help disseminate useful information to others. Participants in our ACRSP-sponsored events have received for more than 6000 man-days of training since 1999. These events have been held in nine different countries (Belize, Costa Rica, Panama, Nicaragua, Guatemala, El Salvador, Dominican Republic, Chile and Honduras). There were seven events held in Honduras.

We recommend that training of farmers, extension agents and other interested individuals in the fundamentals of aquaculture and tilapia culture include similar amounts of theoretical and "hands on" practical experience with the fish. Appropriate written materials should be developed for the situation/conditions in each country or region and in accordance with the educational level of the interested or targeted audience.

Few farmers and extension agents in Central America understand English. Therefore, it is a requirement to develop both written and electronic sources of information in the local language for its effective utilization by the local audience.

We have distributed more than 3000 copies of the tilapia production manual titled "Producción de tilapia en fincas integradas" which includes useful illustrations to assist in differentiating between male and female fish. We recently published a manual on the reproduction and rearing of tilapia fry.

Beginning in 2001, we have developed a web site to disseminate useful information in Spanish to interested persons on the fundamentals of fish farming and culture of tilapia. This web site is: www.acuacultura.org and it is now hosted by a server located at Zamorano.

The CRSP has been responsible for training many Central Americans on the fundamentals of tilapia reproduction and sex-reversal of fry during more than 10 years. These training have resulted in an increase in the number of fingerling producers in Honduras and in improving the quality of fingerlings available for distribution to fish farmers.

Through ACRSP, several persons have received formal training in aquaculture and related areas. These were: Oscar Zelaya (M.Sc., Ph.D. and M.B.A. at Auburn University), Suyapa Triminio Meyer (M.Sc. at Auburn University), Elizabeth Trejo (M.Sc. at Auburn University) and Pablo Martinez (M.Sc. and Ph.D. at Auburn University).

5. Tilapia fingerling production

A series of experiments were run to improve our knowledge and develop improved techniques for production of tilapia fingerlings in Honduras and in the region. These experiments included a trial to determine the frequency of fingerling harvests for production of all-male hybrid tilapia. Results indicated that a 7-day interval of harvest yielded a greater number of fingerlings than harvesting at 25-day intervals.

Another experiment evaluated the water temperature and production of tilapia fry destined for sex-reversal with complete harvests at 17 culture days (Israel system). The data was accumulated from more than 33 trials from 1988 to 1990. The results indicated that the highest production of tilapia larvae of adequate size (<12 mm total length) is obtained when they are harvested at 195 to 220 degree-days of culture.

In an additional experiment oral administration of the hormone was tested for 21 and 28 days and the fish were stocked at 2000, 4000 and 6000 larvae/m^2. The percentage of male fish produced did not vary between duration of treatment (21 and 28 days) nor with the stocking density.

We have also worked to define the costs and net income (± 90% profit) derived from different management schemes for producing and commercializing all-male tilapia fingerlings in Honduras.

In an experiment of tilapia fingerling production, we found that fingerling mortality was significantly lower when they were stocked in fiber-glass tanks compared to concrete tanks and hapas at 1000 and 2000 larvae/m^3.

6. Native cichlid species

The ACRSP also sponsored research on a native cichlid (the tiger guapote *Cichlasoma managüense*) and its reproduction in ponds. The results indicate that more fry were produced by stocking one male with each female guapote. Guapote reproduction was observed almost exclusively during the warm months of the year (March to August) in Honduras.

7. Economic analysis in the commercial cage culture of tilapia

We have studied the economics of commercial cage culture of tilapia on Lake Yojoa. This study revealed that the co-op members lack technical training to adequately utilize inputs and they do not maintain complete records of their expenses and sales of fish. Zamorano donated a PC computer to the co-op to assist them in improving their production operation. Up to 2006, we continue to provide assistance and advice to this group of ex-fishermen. They sold their entire fish inventory during Easter week of 2006.

Lessons learned through participation in the ACRSP's "HCPI Tilapia Exchange Project"

We are implementing more intensive management protocols in fry production by utilizing hapas for broodstock fish and artificial incubation of eggs and newly hatched fry on our campus facility. These practices were observed in our visit to Thailand and the Philippines. These techniques to intensify tilapia reproduction and fry production are generally not used in this region.

We have begun looking at native species with potential for aquaculture. We observed snook (*Centropomus*) polycultured with tilapia in Tabasco, Mexico. We did a trial with local snook fingerlings found in an estuary in southern Honduras. We evaluated their ability to survive capture and transport to Zamorano, and to adapt to and survive conditions in fresh water in our campus. We then studied their consumption of a variety of feeds. Overall, the survival was 98% and the fish adapted well to local conditions and fresh water. The best growth was observed among the fish fed tilapia fry, which gained an average of 0.5 g per day during the trial.

Kenya

Since its inception in 1996, the A CRSP-Kenya Project has primarily been conducted at the Sagana Aquaculture Center, Ministry of Livestock and Fisheries Development, in Central Province and at the Department of Fisheries and Aquatic Sciences, Moi University, in Rift Valley Province. Researches have been conducted in the following research themes: pond dynamics, feeds and fertilizers, fry production, new aquaculture systems/new species, effluents and pollution, fish marketing, economic analysis and adoption/diffusion. Experiments conducted evaluated practices and technologies focused on increased pond fish production. Research at the Kenya site continued the line of inquiry previously developed for the former PD/A CRSP site in Rwanda majoring on the effect of supplemental feeds on Nile tilapia (*Oreochromis niloticus*) production and an emphasis on the development of new aquaculture techniques.

Strengths gained through participation in the ACRSP

1. Pond management

Pond management, including water flow control, feeding and fertilizing options, had been one of the biggest problems in aquaculture extension in Africa. At the Sagana Aquaculture Center, experiments were conducted to achieve the following: 1) to characterize the productive capacity of ponds at the Sagana Aquaculture Center; 2) to 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. Soil samples from Sagana Aquaculture Center were collected, characterized, and treated in the laboratory to evaluate the suitability of the site pond soils at the Sagana Aquaculture Center.

Fertilizers were applied in the ponds to increase inorganic nutrient concentrations that favor phytoplankton growth and enhancing production of fish. Nitrogen, phosphorus, and carbon availability are important considerations in the management of ponds for optimum

fish production. Operation of the ACRSP focuses on the optimization of nutrient inputs into pond systems and falls into the research theme of Feeds and Fertilizers. This was the first in a series of experiments to determine optimal rates of nitrogen, phosphorus, and carbon additions to ponds for fish production. Results of these trials provided N, P, and C application rates to obtain fish yields with the greatest profit. Additionally, identification of optimal nutrient application rates would reduce the environmental impact of pond effluents. Input costs for feed and fertilizer applications would also be of benefits to fish farmers.

Experiments were further conducted to characterize the productive capacity of ponds and determine least-cost combinations of rice bran and inorganic fertilizer. Stocking of tilapia has risen from one fish per m2 to 2-4 per m2. Higher net returns have been realized with farms that combine fertilizer and feed applications. Graduate thesis work that focused on developing techniques on survival and growth of catfish has had tremendous success. An increased supply of fingerlings will benefit both farmers wishing to produce catfish for the food fish market and fishermen who use them as bait in the Lake Victoria long-line fishery. This use of farmed fingerlings as bait is expected to assist with conservation of Lake Victoria's fish diversity by protecting vulnerable and fragile species that fishers target as bait for the long line fishery. Besides, it would also preserve a very delicate wild catfish wetland habitat that is essential for recruitment of other important lake species. In addition, farmers who produce catfish fingerlings will realize increased earnings.

2. Capacity building

In Kenya, extension efforts have been concentrated for some years to bring farmers' understanding on better pond management. On-farm testing conducted in Kenya was therefore a logical step in transferring research-based technologies to the farm. On-farm testing of various alternatives allowed farmers to assess their costs and benefits under local conditions as well as to receive instruction and training in basic pond management skills. It also allowed project personnel to work with and train the fisheries extension officers, complementing the experience they gained through formal training activities. These trials have helped farmers and extension workers to gain a better understanding of pond management.

Water levels in stocked ponds are maintained throughout the culture period until fish are ready for harvest. During harvesting, ponds are drained to levels where fish can be recovered via nets. One result of pond draining is effluent discharge into natural waterways. Effluents from fertilized ponds have relatively high nutrient concentrations and can be potential sources of pollution and eutrophication for receiving community waters. In Kenya, little work has been conducted on the use of fishpond effluent as a source of irrigation water for high-value crops although in limited cases, pond effluents have been used to irrigate crops. One study was undertaken to determine the effects of irrigation with polyculture (tilapia and catfish) pond water on French bean yields. Preliminary results showed that drip irrigation appears most promising when water and fertilizer application is split into several events over a cropping season.

Lack of technical training was cited as one of major reason for the low output of fish ponds in Kenya. Training programmes were therefore undertaken by PD/A CRSP

researchers to build capacity and provide a cadre of trainers with extensive practical fish production experience. The overall plan was to train all extension workers in the government, private hatchery managers and later progressive farmers in record keeping and hatchery management techniques. The progressive (contacts) farmers would then provide farmer to farmer training in simple techniques for spawning, hatching, and rearing tilapia and catfish juveniles. Participants were also drawn from Kenya Marine and Fisheries Research Institute and an additional six hatchery managers were supported by the Government of Uganda.

The programme provided full scholarship support for Moi University graduate students (M.Sc.) working on tilapia and catfish production researches. Opportunities were also provided to undergraduate students from the same University. In addition, following requests from farmers, a program of farmer education days was developed, which is being continually improved based on feedback from the farmers. Farmer training sessions have also been conducted at selected farmers' ponds. It is hoped that the Kenya Fisheries Department under the Ministry of Livestock and Fisheries Development through the trained staff will continue to train extension agents in pond management. Field days and annual meetings will also be used to pass on information to other farmers.

Through the training of the extension workers, fish farmers and officials in microfinance institutions have learned about a wide range of topics related to enterprise budgeting and the development of business plans for establishing and managing fish farms up to marketing of the fish. Small-scale farmers were able to get credits for their enterprises from some financial institutions. A group of trained trainers now have the capacity to train and have been regularly training various participants. The training acquired by the trainers was supported by ACRSP capacity building efforts.

In an effort to stimulate an increase in the fingerling production of African catfish (*Clarias gariepinus*), blowers were installed in both Sagana and Moi University hatcheries to increase the aeration system and ultimately the dissolved oxygen level. This is envisioned to improve the growth and survival of African catfish juveniles.

Lessons learned through participation in the ACRSP's "HCPI Tilapia Exchange Project"

The lesson learned in this project particularly from the Thailand visit included the following: 1) practical example of commercialization of small scale fisheries, 2) private sector specialization in commercial hatcheries, a case that is not in Kenya and which Kenya should promote, 3) use of hapas (net enclosures) in ponds, 4) cage farming (series of small cages for commercial enterprise) in rivers, 5) a well-established training institute (Asian Institute of Technology in Bangkok, Thailand) that can develop tailor-made aquaculture courses and from which Kenya took advantage to build capacity for aquaculture development. Kenya sent four officers who are in-charge of departmental fish farms to AIT for training so that they can acquire knowledge on various aquaculture techniques. This training of fisheries officers is expected to accelerate aquaculture growth in Kenya.

Mexico

Aquaculture in Mexico is just beginning. Despite initial governmental initiatives and support for the introduction of species such as tilapias, carps, shrimps and prawns, the industry has not developed its potential. During the last few years, aquaculture has been taking a new impulse generated by a larger investment of both the private and government sectors. In southeastern Mexico, the Laboratory of Aquaculture at the Biological Division of UJAT has played a major role in aquaculture development. During the late 90´s, we focused on analyzing the situation of the sector and identified the problems derived from the abandonment of the initial guidelines. The need for basic and applied research in our region guided our efforts. The inclusion of UJAT in the ACRSP work plans helped us to orient our investigation towards solving major problems faced by aquaculture farmers.

Tilapia aquaculture was proposed as an alternative to help maintain the volumes of fish allocated in markets after overfishing reduced both the quantity and variety of fish. However, production techniques were not appropriate and the amount of qualified people was not enough to help this practice to grow. Fry quality was a very important issue in this region of Mexico and the use of sex-reversed fish was not practiced in most farms. One big concern for us was the inappropriate handling of methyltestosterone (MT) and the fate of this steroid in farm effluents. All things combined did not help tilapia culture development because many farmers and interested people were discouraged due to bad practices and poor productivity. On the other hand, tilapias were introduced in all reservoirs generating a large fishery and displacing the native fish. This situation posed a challenge to our team dividing our efforts between better practices for tilapia culture and the incorporation of native species into aquacultural practices. ACRSP research conducted at UJAT helped in developing practices related to cross cutting themes in tilapia culture as well as to native fish culture.

<u>Strengths gained through participation in the ACRSP</u>

1. Safe handling of steroids and effluent quality in sex-reversal treatment of tilapia fry

The development of methods on the safe handling of steroids and disposal of good effluent quality in the sex reversal treatment of tilapia fry are areas of interest by the UJAT group. It also included the improvement of sex inversion after feeding the fry with hormone-treated fish for 24 day upon yolk-sac absorption. In Mexico, sex reversal treatment is mainly conducted in earthen ponds and we were able to show that MT is very unstable in the water and accumulates in the pond sediment, posing a potential risk to other organisms that are not the target of the treatment. Filters for the elimination of methyltestosterone (MT) in the water were designed and implemented at UJAT. This filter consists of three forms of steroid elimination: chemical (activated charcoal); biological (biological filtration); and solar (exposure of the water to sunlight). This system was first evaluated at UJAT and provided good results; therefore, filters were promoted and implemented in some hatcheries. Currently, the office of aquatic health in Tabasco is promoting the use of steroid removal in order to certify hatcheries with good quality standards. Training on safe handling of steroids is conducted as part of a workshop in aquaculture that is offered annually to farmers in our laboratory. All the

information are available in a manual on tilapia fry production and safe handling of steroids. A specific workshop on these topics was designed and implemented in three cities of Mexico (Villahermosa, Mazatlán and Mexico City), Honduras (San Pedro Sula) and Guatemala (Guatemala City). More than one hundred and fifty people attended these workshops.

2. Genetic improvement of tilapia in Tabasco

A very important concern in Southeastern Mexico was the quality of the fry produced due to a lack of a genetic program and poor broodstock management, resulting in bad performance and very low yields of tilapia. To attend this situation, we implemented a line selection project using a strain of Nile tilapia imported from Egypt by the State government. After five years of selection, we were able to replace 100% of the broodstock used in the largest hatchery of Tabasco. This improved the fry quality and increased the fry quantity in this hatchery. In 2000, tilapia fry production was only 2 million/year but currently the annual production is 8 million fry. To date, most farms are using this line which we have called "Tabasco-CRSP line". This line performs better than the other lines evaluated. It provides better growth and the broodstock provides a larger number of fry per spawning.

3. Native species as candidates for aquaculture

Incorporation of native species of fish into aquacultural practices is another area where UJAT had gained strength. Overfishing has depleted native species populations in several regions of Southeastern Mexico. As an alternative, UJAT has developed technological packages to produce fingerlings in aquaculture facilities. Three species of cichlids (*Petenia splendida*, *Cichlasoma urophthalmus* and *C. synspillum*) and one lepisosteid (*Atractosteus tropicus*) have become candidates as aquaculture species due to the efforts of the UJAT. A CRSP-supported research had helped increase the knowledge for managing these species, but more importantly, it has provided infrastructure to conduct the research needed. Many students were supported in the conduct of their thesis experiments. To date, we have supported the creation of five farms in Tabasco, both with technology transfer and training of the farmers involved. From lessons learned in other countries, we have incorporated sex inversion of the cichlids to improve production. Feminization of gars is currently being evaluated.

4. Capacity building

On capacity building, UJAT has played a very important role in building human capacity in southeastern Mexico. Our strong linkage to aquaculture in the region is due to the amount of workshops and outreach activities that we conduct every year. So far, more than 50 students have been trained in our laboratory and nearly 30 undergraduate and 10 graduate theses have been supported through the A CRSP projects. Formal workshops at the Biological Sciences Division have strengthened technical support to farmers. Several extension agents, technicians and farmers have taken our workshops. On-farm training workshops have also been conducted, helping people to improve their production systems, increase fry production quality and incorporate steroid safe handling methods for an accurate sex reversion process. A very important part of our outreach efforts is

focused on tilapia aquaculture in cages, earthen ponds and circular tanks small farmers from poor communities. In our laboratory, we provide technical assistance on the average to 3 farmers a day.

Recently, we have transferred our technological packages for native species and expertise on sex inversion and safe handling of steroids to farmers in Honduras and Guatemala. Our communication with colleagues at the University of Zamorano in Honduras and the University of San Carlos in Guatemala City has increased significantly and collaborative projects are underway.

Since cost of feeds for tilapia culture is high in Mexico, we have adopted the fertilization methods evaluated in the Philippines. This method is currently being promoted by our extension personnel.

Lessons learned through participation in the ACRSP's "HCPI Tilapia Exchange Project"

All trips conducted to Host countries were truly enlightening and encouraging. Every single place visited had an experience to hear and opportunities to work collaboratively. Practices that were implemented by our HCPIs partners in their countries have been implemented in farms that are willing to experiment with these new practices. Pond fertilization and delayed feeding with commercial feeds is currently used in two cooperative farms. We want to implement alternate-day feeding strategy in two farms using the information for an undergraduate thesis project. A very important contribution to our team was on the intensive fry nursing using artificial egg incubators. This technique was not used in Mexico before; now, we are encouraging fry producers to use this system to increment fry production and quality. One farm that started production in 2007 is currently building a system based on artificial egg incubators. Eggs will be collected from females kept in hapas and fry production will be based on the system learned both in Thailand and in the Philippines. Fry quality control will focus on the points proposed by our Hondurans HC partners.

Tilapia grow-out in cages is not practiced in Southeastern Mexico; however, based on what we have seen in Thailand and in the Philippines, we are encouraging government officers and private investors to use this system as an alternative to pond culture. This topic is very important since the majority of the soil in Tabasco is not suitable for aquaculture. There are several lagoons and water reservoirs that can be used to promote tilapia cage culture.

Finally, a very important example for us was the implementation of aquaculture in small ponds for aquarium fish trade in Kenya. This project has encouraged us to look into new horizons of small farming aquaculture in Southeastern Mexico.

The Philippines

Tilapia are warm water species that belong to family Cichlidae. In the Philippines, tilapia is one of the most popular cultured species. They are widely cultured for food in many countries in Asia. They provide the needed animal protein particularly for Filipinos. There is also a growing interest on tilapia culture. Its rising popularity as a cultured

species is due to its hardiness, resistance to disease ease of breeding, good taste and tolerance to a wide range of environmental conditions. The fish is rich in protein, vitamins and minerals and found to contain a low level of cholesterol fat and sodium.

Over the years, tilapia farming has benefited from various technological advances and innovations such as culture of monosex tilapia, preferably that of all-male population, and more recently, the use of YY technology to produce genetically male tilapia (Mair & Abella, 1997). Native to Africa, the tilapia has been extensively studied and introduced to many parts of the world as a nutritious and sustainable food source. Tremendous amount of information are available today on the biology and culture of tilapia because tilapia production from aquaculture has grown rapidly worldwide. Practices vary from country to country and even from farmer to farmer. There is a need to document these aquaculture practices for consideration by others who may want to endeavor in the culture of tilapia.

Strengths gained through participation in the ACRSP

1. Improved fertilization strategies

Based on the survey on management practices conducted in 2005 (Fitzsimmons et al., 2003), almost 85% of the tilapia operators fertilized their fishponds. Five (5) percent of them use organic fertilizers, 85% use inorganic fertilizers and 10% use both organic and inorganic fertilizers. For the type of organic fertilizers, chicken manure, either dried or processed, is the most common type of organic fertilizer used applied at the rate of 1000 to 2000 kg ha^{-1}. The frequency of application is every 2 weeks, once $crop^{-1}$, or twice $crop^{-1}$.

When using inorganic fertilizers such as ammonium phosphate (16-20-0), urea (46-0-0) or complete fertilizer (14-14-14), the recommended rate is 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$. In cases when farmers are not bothered by detailed calculation of the nutrient requirements, the rate of inorganic fertilizer application varies from 50-100 kg ha^{-1} every two weeks depending on the nutrient concentration. Fertilization is most effective only during sunny weather because fish food growth is dependent on sunlight for photosynthesis. The pond is ready for stocking two weeks after fertilization or when water shows a green color which is an indication of the richness of the water with natural food.

Some tilapia operators use both organic and inorganic fertilizers to make use of animal manures that are available on farm. The rates and frequency of application is the same when the fertilizers are used singly.

2. Improved feeding strategies

Again, based on the survey, 98 % of tilapia operators provide supplemental feeds using commercial feeds for their fishponds and 2% used formulated feeds. Almost 63% of them follow a feeding guide provided by feed companies and 27% of them used *ad libitum* feeding. Several feeding strategies are practiced such as daily feeding, 15-45 days delayed feeding and alternate day feeding. If feeding rate for tilapia are based on

percentage of their body weight, then feeding rate varies from 2-5% of total fish weight per feeding at a feeding frequencies of 2x or 3x a day.

Up to 70% of the recurring cost of production to tilapia farmers in the Philippines is incurred in the expense of purchasing and delivering commercial feeds. A few studies of the efficiency and profitability of feeding strategies available to Philippine commercial tilapia farmers have examined the production costs and market value of farm products under differing production strategies. Three such variations of feeding methods have demonstrably improved the efficiency of farm production in ponds and have increased profit margins by reducing production costs. These are delayed feeding onset of supplemental feeding, satiation feeding and alternate-day feeding strategies (Brown et al., 2000; Bolivar et al., 2004; 2006).

3. Capacity building

The CLSU College of Fisheries offers a BS degree in Fisheries with major field in inland fisheries and minor field in marine fisheries. The college is the only one in Central Luzon (Region III) that offers a BS Fisheries curriculum. The college was recognized as Center of Excellence in Fisheries by the Commission on Higher Education. This recognition is attributed partly because the college is one of the top two fisheries institutions in the country based on the performance of its graduates in the Professional Regulation Commission Board Examination for Fisheries Technologist. The CLSU Institute of Graduate Studies offers graduate degrees in Aquaculture (MS and PhD).

With these institutions in place for fisheries at CLSU, it was convenient to provide student support to deserving students both in the undergraduate and graduate programs. There have been 40 undergraduate students that have been supported either partially or in full to complete their degrees. There were a total of 7 students who have been funded to undertake their On-Job-Training in areas that were not available at CLSU, i.e. shrimp farming, shrimp hatchery, and hatchery of marine species. At least 8 graduate students went on field trip to be exposed to other culture systems. About 130 persons have attended seminars sponsored by the ACRSP at CLSU. Some students were able to attend national and international conferences because of ACRSP support where they get the necessary exposure to the fisheries and aquaculture scientific community and establish contacts and linkages.

Farmers meeting have been conducted at CLSU at part of the on-farm trials under the auspices of the ACRSP. This can also be considered as outreach since aquaculture technologies are informed to farmers.

At present there are 14 undergraduate and 9 graduate students being funded under the ACRSP. It is envisioned that these people once they graduate from the university will become extension agents, researchers, fish feed distributors, etc. so they are expected to increase the human capacity of the country in aquaculture and fisheries.

4. Pond and water management practices

Prior to the stocking of fingerlings for grow-out, the pond is thoroughly drained, cleared of obstruction, weeds and wild fishes and other unwanted organisms that may be present. The pond bottom is allowed to dry up until it cracks before refilling the pond with fresh, clean water. Liming using agricultural lime ($CaCO_3$) is applied at the rate of 500-1000 kg ha^{-1} to condition the bottom soil, when necessary. Screens are placed at the water inlets to prevent the entry of fish predators and competitors.

About 70% of tilapia operators do water exchange on a weekly, monthly, or twice per cropping depending on the condition of the pond water and availability of fresh water. Almost 36% of the tilapia operators monitored water quality parameters of their fishponds. They measure dissolved oxygen concentration, water temperature, pH and total ammonia nitrogen on a weekly, monthly, once per cropping or twice per cropping. Among the tilapia operators, 85% of them do fish sampling every two weeks to adjust on the amount of feeds.

5. Tilapia harvesting

Tilapia are harvested after 3-4 months of culture when the fish attains the desired marketable size of at least 100-120 g a piece. Current trends however, show that consumers prefer bigger sizes of 250-400 g per fish. Harvesting is preferably done at daybreak if fish are to be sold fresh in the morning. Harvesting of tilapia may be total or partial (selective). In total harvesting, the pond is drained to the half-level mark the night before. The larger fish are caught with a seine net and placed in concrete tanks with clean water to wash away the mud. After the bigger-sized fish re netted out, the water level is further lowered to facilitate the capture of the remaining fish manually that burrow into the mud. In cases when the fish have “muddy” smell or taste (off-flavor), holding them about two days in a pond or tank with flowing water will improve their quality.

Selective harvesting is usually done in ponds that are difficult to drain. Bigger-sized fish are caught by means of cast net or seine net. The larger mesh net allows the smaller fish to pass through and remain in the pond. This particular harvesting method allows stocking to be done only once. After four months, selective harvesting can be started with repeated seinings every two or three weeks.

6. Stocking of fingerlings

Stocking of fingerlings in ponds is done one week after pond preparation. While fingerlings of about 10-15 g are desirable to stock for grow-out, the widely available size of fingerlings only about 1 g or less (commonly referred by size number, i.e. size # 24, # 22, # 17, etc.). The larger the fingerlings, the faster the growth and the shorter the culture period (Guerrero, 1997).

Fingerlings used by tilapia operators include the FAC selected strain or FaST, the BFAR-ExCEL fingerlings, GST or the GENOMAR Supreme Tilapia, GIFT strain (Genetically Improved Farmed Tilapia) and the GMT strain (Genetically Male Tilapia). Fingerlings must be procured from a reliable source or produced by the culturist himself.

The stocking density depends on the management method that the farmer desired. For example, under extensive method, the stocking density ranges from 5,000 to 20,000 per ha^{-1}. With low density, fertilization of the pond will be sufficient to sustain the growth of the fish until harvest. With semi-intensive method, tilapia fingerlings are stocked at 20,000 to 40,000 ha^{-1}. Fertilization is practiced during the first two months of culture. When natural food becomes limiting with increasing fish biomass, supplemental feeds are given. Majority of tilapia growers in the Philippines practice this method. Farmers can do 1-3 croppings $year^{-1}$. Intensive culture of tilapia is done in ponds with areas of 0.25 to 0.5 ha and water depth of 1 to 1.5 meters. Fingerlings are stocked at 40,000 to 100,000 ha^{-1}. Fish are dependent on commercial feed in this method and in cases when stocking density is at the upper limit, it may be necessary to provide mechanical aeration such as paddlewheels. A daily water change of 5 to 10% of the total volume may also be required per day particularly at the later months of culture to reduce toxic wastes attributed to heavy organic loading.

Lessons learned through participation in the ACRSP's "HCPI Tilapia Exchange Project"

Most of the host countries that were visited under the Phase I of the Training and Information Exchange on Cichlids among Aquaculture CRSP Host Country Institutions opened their doors for new knowledge and experiences in cichlid aquaculture and native species. The Host Country Principal Investigators (HCPIs) who also acted as hosts, organized the in-country itineraries very well and provided opportunities for the visitors to interact.

The history on the introduction of Mossambique tilapia and Nile tilapia appeared to be similar for most countries visited. There may be variations on the production systems used by each country but the bottom line was to come-up with a production that would improve the profitability of the farmers.

The use of native cichlid species in aquaculture are particularly of interest since some of the species are used for food in one country but as an aquarium fish in another country.

It was also amazing to find tilapia farms located in a remote, mountainous area in Honduras. The farmer has a backyard tilapia pond of around 300 m^{-2} and three additional ponds of almost the same area in a nearby farm he also owns. Aside from Dr. Meyer, the group was accompanied by Mr. Ponciano Cruz, an extension agent from Danli. He was a good example of an efficient government extension agent who provides technologies to farmers even in remote areas just so the profitability of the farmer could increase using resources within the means of the farmer.

Also, an excellent example of an aquaculture system used for tilapia is the one practiced at the Aqua Corporation de Honduras in Rio Lindo. It is an intensive raceway tilapia farm and I would say that it was my first time to experience seeing such an intensive system. The farm has its own fish processing plant and they produce their own fingerlings.

In Kenya, we visited Mr. Manase Okelo, a fish farmer in Maseno, Kisumu. The farm has a newly built hatchery and uses recirculating water system. The farmer is engaged into catfish breeding (*Clarias gariepinus*). Catfish fry are used as baitfish for Nile perch

(*Lates niloticus*) caught using longline from Lake Victoria, the second largest lake in the world. He also keeps stocks of Nile tilapia but he found them slow growing so he is considering other species like *Oreochromis esculenta*. To me, this is an example of an effective outreach program since the farmer was able to build his facilities with guidance from people who had formal trainings in the universities.

Overall, the site visits were well arranged. We did not encounter any untoward incidents during those oversea travels.

Thailand

The Aquaculture CRSP activities in Asian countries except Philippines have been mainly led by the University of Michigan and coordinated by the Asian Institute of Technology (AIT). AIT is an independent international graduate institute based north of Bangkok, Thailand. Since the initiation of ACRSP program to AIT in 1987 with the appointment of an U.S. Co-Principal Investigator as a faculty member at AIT, the Aquaculture CRSP project has brought collaboration among the University of Michigan (1982-present), the University of Hawaii (1982-1995), Michigan State University (1982-1994; 2001-2003), the University of Virgin Island (2001-present), Department of Fisheries of Royal Thai Government (1982-1995), Can Tho University of Vietnam (2001-present), University of Agriculture and Forestry of Vietnam (2001-present), Research Institute for Aquaculture No. 1 of Vietnam (2001-present), Institute of Agriculture and Animal Science of Nepal (2001-present), Bangladesh Agricultural University (2001-present), and AIT (1987-present). A large number of scientists from U.S. universities and host institutions have been involved in the Aquaculture CRSP project. Aquaculture CRSP has been allowed to expand to China since early 2004. This has allowed Chinese institutions and researchers to have the opportunity to participate in the program.

Nile tilapia, *Oreochromis niloticus* Chitralada strain is the most commonly cultured freshwater fish species in Thailand today with an annual production of nearly 300,000 metric tons. Introduction of tilapia to Thailand dates back to 1960s when the Japanese emperor presented Thai King with several pairs of fish to stock in the royal Chitralada palace; hence the strain name. This is the primary stock at AIT. This stock has been maintained at AIT since the early 70s and it has been the choice of strain for almost all Aquaculture CRSP studies. Much of the early studies at AIT before the ACRSP were on the use of tilapia for waste water fed aquaculture and as a means of controlling aquatic plants. Although, production of tilapia was low during the early 80s, introduction of more intensive production system (fertilization and supplemental feeding) and availability of monosex fingerlings catalyzed the higher production levels of the late 80s and 90s. Unlike most other large scale tilapia producing counties of the region, Thailand produces tilapia primarily for domestic consumption and production level has leveled off in past several years reflected on the low retail price in the market today. Even after using semi-intensive production systems, it has remained an affordable fish for low income population.

While Thai Department of Fisheries has been the primary driver extending tilapia culture to the rural parts of Thailand, ACRSP research combined with AIT Aqua-outreach Program has played a significant role in research and dissemination of improved tilapia

culture practices especially to small scale producers. When we examined the flurry of research studies and compared with level of production, the increased production level follows the intensities in AIT-CRSP research and extension activities. This indicates the benefits of applied research of ACRSP studies resulting in increased production. Of course, while it is difficult to assign all the credit to any single entity for increased level of production in Thailand, ACRSP research has at least in part contributed to this success.

Strengths gained through participation in the ACRSP

The ACRSP contribution to small-scale tilapia culture in Thailand has been primarily in the area of pond dynamics, fertilization, and supplemental feeding.

1. Boost tilapia production over the past thirteen years

Since 1985, tilapia production in Thailand has increased from 20,000 to 300,000 tons annually. This large increase has been through collaboration with the Thai Department of Fisheries and AIT. Tilapia represents the largest tonnage of freshwater fish produced in Thailand.

2. Economically efficient pond fertilization strategies developed and implemented

ACRSP developed economically efficient fertilization strategies using a combination of organic and inorganic fertilizers that can produce up to 8,000 kg tilapia/ha/year. These strategies are currently being implemented by the Thai Department of Fisheries to improve tilapia production by small-scale farmers.

3. Improved management systems increase feed-use efficiency

Integrated systems have been developed in which natural productivity resulting from intensive pond management practices is efficiently converted into additional fish yield. No additional feed is necessary to produce this second fish crop. Modification of feeding practices has resulted in economically efficient intensive tilapia production systems.

4. Capacity Building

A large number of degree students (approximately 150 M.S. and 30 Ph.D.) as well as more than 300 short course trainees have benefited directly from the ACRSP. ACRSP expatriate researchers also teach at host country universities.

Lessons learned through participation in the ACRSP's "HCPI Tilapia Exchange Project"

The experience of sharing knowledge, practices, and tools was intended to help host country PIs understand other country/regional contexts and bring new or different technologies back to integrate into their own country, to facilitate formation of informal networks for developing future research ideas and proposals, and to share the lessons learned through visits to other countries through echo seminars presented in their home countries.

Some of the specific lessons learned include:

1) Our visits to UJAT (Mexico), CLSU (the Philippines), Zamarano (Honduras), the Fisheries Department and Moi University (Kenya) highlighted how different each site is and that the formulation of joint research proposals would present unique opportunities and challenges as a result.
2) Production technologies in each institution and respective country were consistent with the overall level of aquaculture development in that country. For example, Thailand and the Philippines are concerned about environmental impact of intensification of tilapia culture, while Honduras and Kenya are concerned about getting farmers to culture fish. Production technology in Thailand and the Philippines is quite advanced compared with Honduras and Kenya, and this is reflected in the respective institutional facilities and programs.
3) Despite contextual differences, several tilapia culture issues were found to be similar. For example, reproduction of tilapia was a concern to all. Active research to identify equivalent native species was on-going in all countries visited. Production optimization was also a universal goal at all institutions. Clearly, scientists in more aquaculturally-advanced countries (Thailand and the Philippines) could work on a number of research areas to benefit less advanced institutions.
4) All participating host country PIs have known each other formally for many years. However, it was this series of exchange visits that brought us closer together to a point where we feel we can formally and informally engage in dialogue with each other in topics related to new and innovative ideas, research proposals, and outreach/extension of knowledge in our respective contexts.
5) Hopes that a number of joint proposals would be generated following these exchange visits did not come to fruition. If conditions were established early for each PI to develop at least one proposal that uses some aspect of what was learned in these exchanges we might have generated at least 5 or more proposals—a lesson learned.
6) Echo seminars held following exchange visits were to have a multiplier effect; however, other than delivery of the seminars, the impact of this was not measured.

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