AQUACULTURE CRSP 21ST ANNUAL TECHNICAL REPORT

WORKSHOPS ON USING PRINCIPLES OF POND DYNAMICS TO OPTIMIZE FERTILIZATION EFFICIENCY

Tenth Work Plan, Pond Dynamics Research 2 (10PDR2)
Final Report

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ABSTRACT

Eight, three-day workshops were given in Bangladesh, Cambodia, Laos, Nepal, Thailand, and Vietnam during June to July 2002. These workshops focused on practical aspects of how to use principles of pond dynamics to improve pond management and optimize fertilization efficiencies for natural food production in semi-intensive aquaculture systems. The centerpiece of the workshops was learning how to apply the algal bioassay fertilization strategy (ABFS) using the simple algal bioassay test kit developed by Michigan State University (MSU) through the Aquaculture Collaborative Research Support Program (CRSP). Fifteen test kits were left at each workshop site. Nearly 150 total participants representing universities, government fisheries offices, non-profit organizations, and community farming groups participated in the workshops. Responses to the workshops have been very positive. Reports from several countries indicate that researchers and farmers alike are adopting the ABFS because it is practical and promotes economically-efficient natural food production by using a simple ecological approach to identify pond-specific fertilization requirements.

INTRODUCTION

Pond fertilization in aquaculture is intended to stimulate phytoplankton productivity in order to provide natural foods for culture organisms (Colman and Edwards, 1987; Schroeder et al., 1990). Research on pond fertilization to increase yields of planktivorous fish, particularly Nile tilapia (*Oreochromis niloticus*), has received considerable attention at Aquaculture CRSP research sites located in Southeast Asia, Latin America, and Africa (Egna, 1997). The scientific foundation for this research is the well-established, empirical positive relationship between algal productivity and the net fish yield (NFY) of planktivorous and detritus-feeding fish (e.g., McConnell et al., 1977; Almazan and Boyd, 1978; Oláh et al., 1986; Knud-Hansen et al., 1993). This relationship is quite logical because algal productivity is the energetic foundation for secondary production and detritus formation, and all three are basic and valuable food sources for omnivorous and detritivorous fish (Schroeder et al., 1990).

The five principle factors that regulate algal productivity in ponds are the availabilities of soluble inorganic nitrogen (N), phosphorus (P), carbon (C), light, and suitable water temperatures (Fogg, 1975). Pond fertilization supplies soluble N, P, and C for algal uptake and growth, while the availabilities of sufficient solar radiation and appropriate temperatures are functions of weather, pond location, and pond turbidity. Relative deficiencies in any one or more of these requirements will depress and possibly cease phytoplankton productivity until that requirement is satisfied. When such a requirement has become a limiting factor, phytoplankton growth will be controlled by the availability of that factor regardless of the concentrations of non-limiting nutrients (O'Brien, 1974). For example, N fertilization of a pond in which P availability limits algal growth will have little or no effect on algal productivity in that pond (e.g., Boyd and Sowles, 1978). To maximize fertilization efficiency, inputs of N, P, and C must neither limit phytoplankton growth nor exceed phytoplankton demands. When all algal nutrient requirements are met, algal productivity may be limited by physical factors such as unfavorable water temperatures or insufficient light availability due to algal self-shading and/or inorganic turbidity.

Since the mid-1980s, research conducted by MSU through the Aquaculture CRSP has focused on incorporating ecological principles of pond dynamics (e.g., N and P cycling, dissolved oxygen dynamics, thermal stratification, primary production and decomposition, and the role of inorganic turbidity) into pond fertilization recommendations for semi-intensive aquaculture. Pond management decisions on where to place the ponds, types of source water, pond depth and surface area, and managing pond sediments are all affected by pond dynamic considerations. In particular, understanding pond ecology promotes knowledgeable choices of appropriate fertilizers to both optimize fertilization efficiency and minimize unwanted environmental impacts (Shevgoor et al., 1994; Knud-Hansen, 1998).

In addition to studying pond dynamics, MSU also developed the ABFS to determine pond fertilization requirements on a pond- and time-specific basis (Knud-Hansen, 1998; Knud-

Hansen et al., in press). The algal bioassay is a simple, ecologically-responsive test where pond or lake water subsamples are fertilized (spiked) with algal nutrients (e.g., N, P, and C) individually and in combination. Fertilizing with the primary limiting nutrient(s) will cause algae to grow. A secondary limiting nutrient is one that becomes limiting once the primary limiting nutrient is supplied. For example, algae in pond water with no soluble N and little soluble P will grow with N added, but not with additional P. N is the primary limiting nutrient. With N added, however, the available P is soon depleted and algal growth stops. When N and P are added together, however, algal growth is much greater than with the addition of N alone. P is the secondary limiting nutrient and must be added with N to get the pond green. The ABFS also identifies co-limitation (e.g., when N and P are both primarily limiting and the addition of either N or P alone does not stimulate algal growth), and light limitation (e.g., due to high algal biomass and/or inorganic turbidity causing insufficient light availability for the algae to utilize the added nutrients). Recommended fertilization is at a full rate for primary limiting nutrient(s), half rate for secondarily limiting nutrient(s), and no fertilization if the nutrient is not limiting at all.

The ABFS has been tested under controlled and field conditions, and it has proven superior in terms of nutrient fertilization efficiencies and farm economics to standard fertilization recipes and fertilization requirements determined by computer modeling (Knud-Hansen et al., in press). Variabilities between ponds (and within the same pond over time) limit the utility of fixed-input fertilization recipes, and explain why ponds fertilized identically will give an unpredictable range of fish yields. Although both computer models and the ABFS are ecologically based, the time, costs, and level of expertise required to use computer models makes farmer adoption impractical. The benefits of the ABFS are both economical and environmental. Fertilization requirements are fine-tuned on a pond-by-pond basis, so algal productivity is maximized with the minimal amounts of nutrients added. Fish yields are more consistent and predictable, and there is minimal excess accumulation of N and P in the pond water, so environmental effects upon discharge are reduced. Furthermore, the ABFS eliminates the risk of ammonia toxicity because over-fertilization with N is impossible. In 2002, MSU developed a portable algal bioassay kit (described below) that requires no water chemistry, electricity, computers, or even literacy to use.

The activity described by this final report consisted of making about 130 algal bioassay test kits and giving three-day workshops at different institutions in South and Southeast Asia where the Aquaculture CRSP or the Asian Institute of Technology (AIT) aquaculture program or both have established formal connections. The primary objective of the workshops was to transfer existing scientific knowledge, generated through the Aquaculture CRSP, on how to improve the predictability of pond management and productivity through a practical understanding of pond dynamics.

METHODS AND MATERIALS

Workshop Locations and Dates:
The three-day workshops were given by Knud-Hansen at the following dates and locations where the Aquaculture CRSP or the AIT aquaculture program or both have established formal connections. AIT served as the "home base" between workshops at other sites:

31 May–3 June 2002	Aquaculture and Aquatic Resources Management (AARM), AIT, Pathumthani, Thailand
5–7 June 2002	Udornthani College of Agriculture and Technology (UCAT), Udornthani, Thailand
10–12 June 2002	Regional Development Coordination for Livestock and Fisheries (RDC), Savannakhet, Laos
17–19 June 2002	Faculty of Fisheries, University of Agriculture and Forestry (UAF), Ho Chi Minh City, Vietnam
20–22 June 2002	School of Agriculture Prek Leap (SAPL), Phnom Penh, Cambodia
27–29 June 2002	Research Institute for Aquaculture (RIA-1), Bac Ninh, Vietnam
3–5 July 2002	Fisheries and Aquaculture Department, Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Rampur Campus, Chitwan, Nepal
9–11 July 2002	Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

Workshop Topics:
The workshop objectives were to teach principles of pond ecology which have a direct relationship towards efficient pond management through demonstrations, presentations, and informal discussions. Incorporated within these goals was teaching participants how to use the algal bioassay test kit, and how the kit incorporates principles of pond ecology in its application. Specifically, the workshop addressed the following topics:

- Pond ecology, focusing on managing factors which control primary and secondary productivities in fertilized ponds (e.g., concepts of nutrient limitation, thermal stratification, diel variability);
- Ecological benefits and limitations of organic and inorganic fertilizers as related to pond dynamics (e.g., algal availability, costs of nutrients, and environmental impacts on pond water quality);
- Pond characteristics that affect fertilization decisions (e.g., pond location, depth, use of structures such as hapas and cages, etc.);
- Methods for determining fertilization requirements (e.g., fixed-input, water chemistry, computer modeling, and algal bioassay); and
- How to use the algal bioassay test kit to identify pond- and time-specific fertilization requirements.

All presentations were given using PowerPoint® software. Except for Bangladesh and Nepal, a translator was provided at each workshop.

Workshop materials:
The primary source material was the Aquaculture CRSP publication "Pond Fertilization: Ecological Approach and Practical Applications" (Knud-Hansen, 1998). Because this can be downloaded from the Aquaculture CRSP website, all participants had access to the book. This book also describes in detail the algal bioassay method for determining pond fertilization requirements.

The focus of the workshop was the algal bioassay test kit. Each kit contained the following:

one 30 ml bottle with N spike ingredient (NH_4Cl)
one 30 ml bottle with P spike ingredient (KH_2PO_4)
one 30 ml bottle with C spike ingredient (NaHCO3)
three 120 ml spike solution bottles for N, P, and C
two boxes of 25 mm diameter filter paper
one 25 mm paper filter punch
one explanatory manual with fertilization table
one plastic box with a hinged lid and removable tray to carry the kit components
one 1/8 teaspoon scoop
three 1 ml dispenser pipets
one Millipore Swinnex 25 mm filter holder
one extra gasket for filter holder
one 30 ml plastic syringe
one forceps
one marker pen
eight 500 ml clear plastic drinking water bottles (not included, provided by participants)

The kits provided the concentrated solutions of N, P, and C as algal nutrient spikes to be put in pond water. The dry ingredients were mixed with locally-available distilled water in the 120 ml bottles. Each kit provided sufficient dry ingredients to conduct about a thousand algal bioassay tests. Pond water was collected in locally-available 500 ml clear plastic drinking water bottles. Each pond required eight bottles for the test: seven bottles for spikes (N, P, C, N+P, N+C, P+C, N+P+C) and one bottle for a non-spiked control. After two to three days incubation under indirect sunlight, relative algal growth in the bottles was examined by visual comparison of filters (hand filtered using a 30 ml plastic syringe and a Millipore Swinnex filter holder provided in the kit; the kit also contained a steel 25 mm filter punch to make bioassay filters from locally-available paper coffee filters), and by visual comparison of water color in the bottles. There are only 21 possible filter color combinations. A chart was provided in the kit manual to determine from the specific color combination for that test how that pond should be fertilized for that week. Fertilization recommendations were based on whether a nutrient was found to be primarily limiting, secondarily limiting, or did not limit algal productivity at all. If colors were not distinguishable, then light limitation was indicated and fertilization would not be recommended.

A total of about 130 kits were assembled at AIT. The 30 and 120 ml bottles, filter punch, and kit box were purchased in Thailand. All other components were brought over from the United States. The total cost for each kit was approximately US$25. Fifteen kits were left at each workshop site. About 20 kits were left at AIT. Remaining kits were given to individual host-country researchers. The Aquaculture CRSP Project Management Office also has a kit.

Workshop format:
The general format for the workshops was as follows:

Day One (am): Opening ceremonies, remarks and introductions, workshop overview, use of the algal bioassay test kits, sampling on-site ponds (5–12 different ponds), and beginning algal bioassay analyses on pond water samples.

Day One (pm): First presentation: Pond ecology

Day Two (am): Second presentation: Fertilizers, focusing on economics and the ecology of fertilization. Beginning with the second formal workshop, we had a field trip to a local farm(s) to conduct additional algal bioassay tests. We also developed a site-specific computer spreadsheet to calculate N and P costs as a function of fertilizer costs.

Day Two (pm): Third presentation: Pond characteristics and structures which affect pond fertilization decisions.

Day Three (am): Terminate and analyze bioassays that started on days one and two. Fourth presentation:

A comparison of methods used to determine fertilization rates and requirements. The workshop ended around lunchtime after a summary of the workshop objectives and conclusions, and the presentation of workshop certificates to participants.

The Aquaculture CRSP grant provided funds for travel, housing, and per diem for workshop participants, for morning and afternoon coffee and tea breaks, for lunches, and for administrative expenses incurred by the host institution. The list of participants and affiliations for all workshops can be found in Dr. Knud-Hansen's CRSP trip report.

RESULTS

A formal workshop was not given at AIT. However, on 31 May 2002, Knud-Hansen taught the algal bioassay method to 15 AIT aquaculture students. Algal bioassays were started on Friday, and results were examined/discussed on the morning of 3 June. Workshop presentations were condensed and presented to the class on 24 June.

On 5–7 June 2002, the first Pond Dynamics/Algal Bioassay Testing Workshop was given at UCAT in Udornthani, Thailand with the assistance of Jakkapope Monkonsawad and Ratchada Mhoryadee from UCAT. Monkonsawad provided assistance with logistics and language translation, and Mhoryadee provided administrative assistance. There were a total of 22 participants representing the following institutions in Northeast Thailand: UCAT; Khon Kaen College of Agriculture and Technology; Roi Et College of Agriculture and Technology; Yasothorn College of Agriculture and Technology; Singburi College of Agriculture and Technology; Nong Khai Inland Fisheries Development Center; Udornthani Inland Fisheries Development Center; Roi Et Fishery Station; Lopburi College of Agriculture and Technology; Singburi College of Agriculture and Technology; Nakhorn Ratchasima College of Agriculture and Technology; and the Udornthani Inland Fisheries Development Center. Of the 22 participants, 12 were women. Five ponds were tested at UCAT, with four different results: one pond was N-limited, two ponds were N-limited primarily and P-limited secondarily, one pond was N-limited primarily and C-limited secondarily, and one pond was light-limited due to inorganic turbidity.

On 10–12 June 2002, the Second Pond Dynamics/Algal Bioassay Testing Workshop was given at the office of RDC in Savannakhet, Laos. Douangchith Litdamlong, Director of the RDC, provided on-site workshop coordination and support. Nick Innes-Taylor, Institutional Advisor for the RDC, also provided

valuable assistance including translating workshop presentations. There were a total of 15 participants, two of whom were women. Participants represented government fish hatchery stations from six provinces (Attapeu, Champasak, Khammouan, Salavan, Savannakhet, and Sekong province) in southern Laos and the Champasak province Technical Agricultural College. There were also three private farmers from around Savannakhet. Algal bioassays were conducted on nine ponds from an integrated farm. Seven of the ponds were N-limited, while two ponds were N-limited primarily and P-limited secondarily.

On 17–19 June 2002, the third Pond Dynamics/Algal Bioassay Testing Workshop was given at UAF in Ho Chi Minh City, Vietnam. Nguyen Van Tu, an associate professor from UAF, was the primary assistant providing both language translation and logistical and administrative assistance. The workshop was attended by 18 participants, six of whom were women. Participants came from the Research Institute for Aquaculture No. 2; Fisheries Extension Center of Ben Tre province; Agriculture Extension Center of Binh Duong province; Agriculture Extension Center of Long An province; Agriculture Extension Center of Tay Ninh province; Agriculture Extension Center of Binh Phuoc province; Department of Agriculture and Rural Development of Binh Phuoc province; Agency of Aquatic Resource Conservation of Dong Nai province; Agriculture Extension Center of Dong Nai province; Research Center of Agricultural Science and Technology, Ho Chi Minh City; Faculty of Fisheries, UAF; Urban Agriculture Sustainable Development project; and the Tropical Biology Institute. Nine ponds were sampled at UAF and four ponds at a nearby farm. Most ponds were N-limited, with a few ponds N-limited primarily and P-limited secondarily. Two ponds were primarily limited by both N and P, and a few ponds with high inorganic turbidity were light-limited. The field trip on Day 2 took workshop participants to a productive commercial fish hatchery near Ho Chi Minh City.

On 20–22 June 2002, the fourth Pond Dynamics/Algal Bioassay Testing Workshop was given at SAPL in Phnom Penh, Cambodia. Assistance was provided by Eric Meusch, Advisor to the Department of Fisheries (through AIT-AARM), Aquaculture Office in Phnom Penh, and by Hav Viseth, National Program Director, Bureau of Aquaculture, Department of Fisheries. Viseth was particularly helpful both with administrative assistance and with language translations during the workshop. There were 20 participants, four of whom were women. Participants came from the Department of Fisheries Aquaculture office; Svay Reang Provincial Fisheries Office; Takeo Provincial Fisheries Office; Kompong Speu Provincial Fisheries Office; Royal University of Agriculture Fisheries Faculty; the School of Agriculture, Prek Leap; Department of Fisheries Staff of Fisheries Domain office; and the Program for Agricultural Sector in Cambodia in Prey Veng province. Ponds were sampled at SAPL and at community ponds near SAPL. Several ponds were turbid and therefore light-limited. However, most ponds were N-limited primarily and P-limited secondarily. There was also one pond limited by both N and P primarily.

On 27–29 June 2002, the fifth Pond Dynamics/Algal Bioassay Testing Workshop was given at RIA-1 in Dinh Bang, Tuson, Bacninh. The workshop organizer at RIA-1 was Pham Anh Tuan, Deputy Director of RIA-1. Kim Van served as the language translator. There were 25 participants, nine of whom were women. Participants came from the HaTinh province Aquaculture Extension Centre; Seed Center of NamDinh province; RIA-3, NhaTrang, Khanh Hoa; HaTay province Aquaculture Extension Centre; Seed Centre of HaiPhong City; Lang-Giang Aquaculture Company from BacGiang province; CuVan Hatchery from ThaiNguyen province; HoaBinh Fishery Station from HoaBinh province; Son La Aquaculture Company from SonLa province; YenLy Hatchery in NgheAn province; DinhDu Hatchery in HungYen province; Seed Centre of VinhPhuc province; RIA-1; National Seed Centre in HaiDuong province; Seed Centre of HungYen province; Fisheries College No. 4, Tuson, BacNinh province; Fisheries University, NhaTrang, Khanh Hoa province; Ministry of Fisheries, Hanoi; and the McLinh Fish Station, VinhPhuc province. There were also up to 15 university students who audited the workshop at various times, attending the presentations and learning about how the algal bioassay test incorporates pond ecology. Ten ponds were tested at RIA-1 and five more at a nearby farm. Similar to other sites, most ponds were either N-limited, primarily N-limited and secondarily P-limited, or N and P limited.

On 3–5 July 2002, the sixth Pond Dynamics/Algal Bioassay Testing Workshop was given at IAAS at Tribhuvan University, Rampur Campus, Chitwan. Madhav K. Shrestha, professor at IAAS and research collaborator with AIT and the CRSP, coordinated workshop activities. There were 17 workshop participants, three of whom were women. Participants came from the District Agriculture Development Office, Biratnagar, Morang; District Agriculture Development Office, Inarwa, Sunsari; Regional Agriculture Research Station, Nepal Agricultural Research Council, Tarahara, Sunsari; Fisheries Research Division, Nepal Agricultural Research Council, Godawari, Lalitpur; Department of Environmental Science, Tri Chandra Campus, Tribhuvan University, Kathmandu; Post Graduate campus, Tribhuvan University Biratnager, Morang; King Mahendra Trust for Nature Conservation, Biodiversity Conservation Committee, Saurah, Chitwan; and IAAS—Rampur, Chitwan. Eight ponds were tested at the IAAS aquaculture research facility: one pond was P-limited, one was N-limited, two were primarily N-limited and P-limited secondarily, one was N and P-limited, one was light-limited, and two had insufficient algae to show a response in two days. On day two workshop participants went to a rural community (Kathar, Chitwan) where Shrestha runs an IAAS-AIT collaborative project promoting women in aquaculture. Project ponds were sampled, but most were very turbid and likely light-limited.

On 9–11 July 2002, the seventh Pond Dynamics/Algal Bioassay Testing Workshop was given at BAU in Mymensingh, Bangladesh. Md. Abdul Wahab of the Department of Fisheries Management at BAU and research collaborator with AIT and the CRSP, coordinated workshop activities with Nirmal Chandra Roy providing administrative assistance. There were 21 participants representing Department of Fisheries Management, BAU; Department of Fisheries Biology and Genetics, BAU; Upazila Fisheries office, Haluaghat, Mymensingh; Upazila Fisheries office, Bhaluka, Mymensingh; Upazila Fisheries office, Muktagacha, Mymensingh; Bangladesh Fisheries Research Institute, Mymensingh; Bangladesh Rural Advance Committee; Proshika Human Development; and CARITAS, a Christian NGO for Rural Development. Of the 21 participants, two were women. Eight ponds were tested at the BAU research facilities and seven ponds from local farmers. Three ponds were N-limited, four ponds were N and P-limited, one pond was P-limited, two ponds were N-limited primarily and P-limited

secondarily, one pond was P-limited primarily and N-limited secondarily, three ponds were light-limited due to high turbidity, and one pond had essentially no algae and did not respond to the test. After the workshop ended, Knud-Hansen gave an hour and a half lecture to five of Wahab's doctoral students on experimental design and analysis for aquaculture.

DISCUSSION

The workshops were very well received at all sites. Participants particularly appreciated the ecological and holistic approach to pond fertilization, as well as the practical utility and benefit of using algal bioassays to identify pond nutrient requirements. In the months following the workshops, Knud-Hansen has received numerous e-mails from participants asking further questions and reporting successes as they applied this new technology in their own work. The following comments from Bangladesh and Laos are particularly noteworthy.

In 2002, Wahab at BAU informed MSU that PhD students at BAU are now using the ABFS for their research (Wahab, personal communication, 20 September 2002). He also said the Bangladesh government, as well as several non-profit organizations, want to provide ABFS training opportunities to farmers. At a technology fair for aquaculture, Wahab reported that the ABFS "received the highest attention of high level government officers, NGOs, extension workers and farmers." Other academic and governmental institutions not represented at the workshop also want to learn the ABFS approach, and have expressed a strong interest in having a second workshop in Bangladesh.

In 2003, Nick Innes-Taylor at RDC wrote that at least one of the workshop participants has been using the ABFS with great success (Innes-Taylor, personal communication, 27 January 2003). This participant represents a group of ten families as part of the Community Food Production Group in Savannakhet. As Innes-Taylor reported, "They started with just three ponds, but they are now using inorganic fertilization for all 10 of their family managed ponds (total area about 2.5 ha), and have made a very 'reasonable profit' (both from the sale of 'meat' fish and the sale of fish seed - they also breed fish for sale to other farmers). People have generally been so impressed with the technique that he [the participant] has already been on local TV five times and has run a short course for about six senior Government Officials from Vientiane who heard about the success and came down to see for themselves. He has now been asked by the provincial authorities to act as a 'volunteer training centre' and has been requested to organize short trainings in the fertilization techniques for 'volunteers' from each of Savannakhet Districts (total 15 districts)."

With each successive workshop the PowerPoint® presentations were fine-tuned, digital photos were added, and the fertilization spreadsheet initiated when the second workshop was improved. The ABFS is now fully described by Knud-Hansen et al. (in press). Concepts which evolved with both the workshops and the in press publication are now incorporated in a "final" workshop presentation. Although it has taken more time than anticipated, the final workshop presentation was finally sent on a compact disc (and hardcopy) to all workshop sites in May 2003. The two main additional lessons incorporated in the final workshop production are: (1) the over-riding importance of N fertilization and (2) the filtration component of the algal bioassay test kit is unnecessary—visual comparison of bottles is both simpler and more consistent.

The ABFS can be simplified even further for farmer adoption and use. Country-specific "farmer kits" are envisioned using N, P, and C spikes made from local materials, locally-available plastic bottles, and a native language poster pictorially showing how to interpret visual comparisons. Although there have been many requests for purchasing the existing algal bioassay test kit, the long-term objective is to teach farmers how to make and use their own kits.

CONCLUSIONS

Nearly 150 aquaculture university professors, students, government extension workers, fisheries staff, farmers, and others in six southeast Asian countries now have a working knowledge of how to apply principles of pond dynamics for improving the yields and sustainablity of semi-intensive aquaculture. Each participant gained a greater understanding of how a pond works ecologically, how to use that knowledge to improve predictable fish yields with reduced economic and environmental costs, how to recognize and prevent pond conditions which will hinder fish production, and how to use simple algal bioassays to optimize pond fertilization.

ANTICIPATED BENEFITS

A primary goal of the Aquaculture CRSP is to improve the health and economic welfare of rural farmers in the tropics through the promotion of more sustainable aquaculture practices by improving pond fertilization efficiencies and fish yields in semi-intensive, warmwater aquaculture systems. The workshops promoted that goal by teaching people within the university, government extension, and NGO host country aquaculture community the principles of pond dynamics together with the application of the ABFS. The ultimate economic beneficiaries of the ABFS workshops should be fish farmers who will be able to use the ABFS approach to produce higher and more predictable yields while minimizing fertilization inputs and hence costs. Other beneficiaries include aquaculture scientists who can provide better consistency between experimental ponds, and thus reduce experimental error and variability in studies involving fertilized pond systems. The CRSP also benefits in several ways. First, it benefits from the widespread exposure and credit it has received for sponsoring the workshops. Second, the ABFS represents the first *practical* approach to pond fertilization that rural farmers can use and benefit from that actually incorporates ecological principles of pond dynamics as understood through CRSP research. And third, the Regional Plan for Southeast Asia strongly encourages strengthening current linkages with AIT and the CRSP to neighboring countries. The ABFS workshops conducted in Bangladesh, Cambodia, Laos, Nepal, Thailand, and Vietnam facilitated that goal. The workshops also provided a forum for extending scientific knowledge gained from years of CRSP research beyond the borders of CRSP host countries. The workshops helped solidify the informational and research networks necessary to best achieve the goals of the Aquaculture CRSP.

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