TECHNOLOGIES IN MANGROVE-FRIENDLY AQUACULTURE

Final Report of and Papers Presented to the
On-Site Training on Mangrove-Friendly Aquaculture
Hai Phong City, Socialist Republic of Vietnam
19-30 April 1999

Aquaculture Department
Southeast Asian Fisheries Development Center
Tigbauan, Iloilo, Philippines

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TECHNOLOGIES IN MANGROVE-FRIENDLY AQUACULTURE

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This document contains the final report of and papers presented as lecture materials, to the On-Site Training on Mangrove-Friendly Aquaculture held in Hai Phong City, Socialist Republic of Vietnam from 19 to 30 April 1999. This document replaces the Advance Copy of the Report issued in May 1999.

Fourteen experts on mangroves and aquaculture served as lecturers and resource persons. Technologies in Mangrove-Friendly Aquaculture, in general were introduced, taking into consideration the results of the Workshop on Mangrove-Friendly Aquaculture, 11-15 January 1999, Iloilo City, Philippines.

The On-Site Training was participated in by 25 participants; 20 from Vietnam and 5 from Cambodia. The conduct of the On-Site Training was an offshoot of the Project SD/AQ99-CM01 with the SEAFDEC Secretariat which also allocated the necessary funds from the Japanese Trust Fund. The Canada-ASEAN Centre based in Singapore provided funds for the participation of the trainees from the Kingdom of Cambodia.

The On-Site Training, hosted by the Research Institute of Marine Products (RIMP) of the Ministry of Fisheries, Vietnam, was coordinated by Prof. Dr. Bui Dinh Chung *for RIMP and* Mr. Yasuho Tadokoro *for AQD who also served as Chair of the On-Site Training Steering Committee.* Ms. Virgilia T. Sulit *of AQD served as Co-Chair for Administration and Secretariat, while AQD's* Dr. Jurgenne H. Primavera *served as Member for the Scientific Program and AQD's* Ms. Kaylin G. Corre *as Member for Training Matters.*

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ACKNOWLEDGMENT

On behalf of the organizers, the Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center (SEAFDEC) extends its gratitude to various offices and agencies for their cooperation and support in the organization and implementation of the on-site training in Hai Phong, Vietnam.

AQD is specifically grateful to the *Government of Japan* for the allocation of special funds for the on-site training and especially for promoting the conservation of mangrove resources in the region; to the *SEAFDEC Council* for considering the implementation of the on-site training in particular, and AQD's mangrove-friendly aquaculture program, in general; the *Government of Canada* through the Canada-ASEAN Centre and its ASEAN Canada Fund for supporting the Cambodian representatives to the on-site training; the *ASEAN Sectoral Working Group on Fisheries* and the *ASEAN Secretariat* for their support; and the *Government of Vietnam* through the Research Institute of Marine Products (RIMP) for hosting the training and providing technical and administrative support, and also through the Ministry of Fisheries for providing the Vietnamese resource persons, and the Vietnamese representatives to the training.

AQD is also grateful to the *Government of Cambodia* through its Department of Fisheries for the participation of five Cambodian representatives; the *Government of Indonesia* through the Directorate General of Fisheries, the *Government of Malaysia* through the Department of Fisheries Malaysia, and the *Government of Thailand* through its Department of Fisheries, for providing resource persons; and the *Government of the Philippines* through the Department of Environment and Natural Resources, and the Bureau of Fisheries and Aquatic Resources for also providing resource persons.

AQD also appreciated the assistance of the *SEAFDEC Secretariat* in terms of technical and administrative support; the *resource persons* for sharing their time and experiences, and for their efforts; the *interpreters* for their valuable services; and the *RIMP and AQD staff* for their tireless support. AQD also wishes to thank all those who supported the on-site training behind the scene but who may have been omitted in the abovementioned list.

FOREWORD

The Southeast Asian Fisheries Development Center (SEAFDEC), a regional treaty organization established in 1967, conducts research and development in appropriate technologies that would contribute to increased fishery and aquaculture production at sustainable levels. The Member Countries of SEAFDEC are Brunei Darussalam, Japan, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and the Socialist Republic of Vietnam. The Aquaculture Department (AQD) based in the Philippines, is one of the four departments of SEAFDEC. The other three are the Training Department in Thailand, the Marine Fisheries Research Department in Singapore, and the Marine Fishery Resources Development and Management Department in Malaysia. AQD was established in 1973 to conduct research, develop technologies, disseminate information, and train people in the farming of fishes, crustaceans, molluscs, and seaweeds for food, livelihood, and equity in the context of sustainable development.

In response to the worldwide call for the conservation and promotion of the mangrove resources in the region, SEAFDEC, with financial support from the Government of Japan, approved in 1998 the implementation by AQD of a five-year Mangrove-Friendly Aquaculture Program. This is part of SEAFDEC's effort towards the wise use of the mangrove areas without necessarily sacrificing aquaculture development.

The Mangrove-Friendly Aquaculture Program of AQD as revised in November 1999, focuses on shrimp culture in mangrove areas. It comprises research, verification and pilot demonstration, and information dissemination; and aims to: (a) assess the mangrove-friendly aquaculture technologies in the region; (b) assess pilot projects or models on mangrove-friendly aquaculture; (c) prepare manuals on recommended methodology for appropriate models or systems; (d) publish for dissemination and implementation in the region of appropriate design or system for mangrove-friendly aquaculture; and (e) transfer the technology and methodology on mangrove-friendly aquaculture to the region. The ultimate goal of the Program is to formulate the Code of Practice on Mangrove-Friendly Aquaculture for the region.

The on-site training on mangrove-friendly aquaculture conducted in Vietnam aimed to impart and exchange information on aquaculture technology emphasizing on mangrove-friendly aquaculture to the target trainees from Vietnam and Cambodia. Highly competent and qualified resource persons were tapped for the session in order to maximize the benefits that the trainees can derive from the training. AQD is indeed, very thankful to the resource persons for sharing their experiences, and for their time and efforts.

AQD is also most grateful to the Government of Japan for committing special fund for this Program, to the Canada-ASEAN Centre for supporting the Cambodian trainees, and to the Government of Vietnam specifically the Research Institute of Marine Products for hosting the on-site training at the beautiful City of Hai Phong.

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Chief
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MANGROVE-FRIENDLY AQUACULTURE PROGRAM: BACKGROUND INFORMATION

Introduction

The Mangrove-Friendly Aquaculture Program was conceived by the Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center (SEAFDEC) in response to a growing concern on the loss of mangroves in the region which has been attributed to the fast development of shrimp aquaculture. The Program which involves research, verification and pilot demonstration, and information dissemination, intends to promote the conservation and preservation of the mangrove resources in the region without necessarily sacrificing aquaculture development. The ultimate goal of the Program is to formulate the Code of Practice on Mangrove-Friendly Aquaculture for the region, which shall form part of the SEAFDEC project on the Regionalization of the Code of Conduct for Responsible Fisheries (Aquaculture Development).

The growing lobby by environmentalist groups for an embargo of farmed or trawled shrimps that are not using environment-friendly methods is beginning to be felt by the shrimp industry in the region. To cushion the impending lobby by these groups, SEAFDEC strongly promotes the conservation and preservation of mangrove resources in the region. Thus, in the 1998 Meeting of the SEAFDEC Council, the Government of Japan signified its support to the implementation of the projects on the conservation of mangroves in line with the new SEAFDEC Strategic Plan. After that Meeting, the Government of Japan decided to provide a special budget for mangrove conservation projects in relation to shrimp aquaculture and marine turtle conservation project to be implemented by SEAFDEC.

Regional Effort

SEAFDEC implements the Mangrove-Friendly Aquaculture Program of AQD under the collaborative mechanism of the ASEAN-SEAFDEC Fisheries Consultative Group. The program was conceived as SEAFDEC's solution to the problem on the alleged massive destruction of mangroves for shrimp culture development, and its contribution to the regional efforts of conserving the mangrove areas without sacrificing aquaculture development for the region's food security. The Program shall involve the Member Countries of SEAFDEC and the ASEAN.

First Workshop on Mangrove-Friendly Aquaculture

AQD convened the first Workshop on Mangrove-Friendly Aquaculture in Iloilo City, Philippines from 11 to 15 January 1999. The Workshop aimed to assess the status of utilization of the region's mangrove areas for aquaculture, identify problems encountered in such aquaculture activities, and come up with recommendations and strategies on sustainable aquaculture in mangrove areas.

The Workshop which was attended by 120 participants from the Member Countries of SEAFDEC and the ASEAN as well as from AQD, and mangrove experts from international and regional organizations, government agencies, non-government organizations, and the academe, came up with practical technologies on sustainable aquaculture in mangrove areas. Problems affecting mangrove-friendly aquaculture and strategies for sustainable aquaculture development in mangrove areas were also identified. The Workshop also came up with some characteristics on mangrove-friendly aquaculture that would possibly determine the development of its standard definition. Moreover, the Regional Working Group on Mangrove-Friendly Aquaculture was also organized in principle, during the Workshop. Representatives from the countries in the region represented at the Workshop signified their support for the establishment of such Working Group.

On-Site Training

The question of high cost and limited facilities for its regular training courses gives AQD an alternative means of training personnel of Member Countries on-site. The greater benefit of this training method is the greater number of trainees and possible participation of the private sector in the countries where the on-site training sessions will be conducted. The specific objective of the on-site training was to impart and exchange information on aquaculture technology emphasizing on mangrove-friendly aquaculture to the target trainees in lead countries. For this training, Vietnam served as the Lead Country and the trainees came from Vietnam. In support of the promotion of mangrove conservation in relation to shrimp culture, the Government of Japan committed the allocation of special funds for the Mangrove-Friendly Aquaculture Program of AQD, and particularly the on-site training in Vietnam. The Canadian International Development Authority, on the other hand, through its ASEAN-Canada Fund supported the participation of five representatives from Cambodia to the on-site training.

The on-site training was conducted at the Research Institute of Marine Products (RIMP) in Hai Phong City, Socialist Republic of Vietnam, from 19 to 30 April 1999. About 20 government officials, researchers, fish farmers, and extension workers from Vietnam attended the training. Another five representatives from Cambodia also attended, making a total of 25 participants.

Three areas of training were introduced: (a) practical technologies or wise use technologies on sustainable aquaculture in mangrove areas and the problems affecting such aquaculture; (b) aquaculture technologies on commodities of economic importance in the region and specifically in Vietnam; and (c) legal frameworks leading to future directions, policies, and regulations including the role of mangrove-friendly aquaculture on the mangrove conservation program of the national governments. Experts from the Member Countries of SEAFDEC and the ASEAN, as well as from AQD and RIMP, served as resource persons of the training. These experts were qualified in their respective fields of specialization in relation to sustainable aquaculture and mangrove-friendly aquaculture.

Future Directions

The need to improve shrimp yield from brackishwater ponds while maintaining the ecological balance in ponds and its surrounding areas, was the rationale behind the conception of the Mangrove-Friendly Aquaculture Program of AQD. As an integrated shrimp farming in mangrove areas, the Program integrates the forestry and aquaculture uses of the mangrove ecosystem, thus promoting harmony between environmental groups and the local communities who made a living out of the mangrove resources.

The Program which now focuses on shrimp culture in mangrove areas, mainly aims to develop sustainable culture technology packages for shrimp farming which are friendly to mangroves and the environment. The specific objectives are to disseminate the technology packages among SEAFDEC Member Countries and the ASEAN through actual demonstration and training; prepare position papers that can be used to shape policies to encourage the adoption of shrimp culture techniques which are friendly to mangroves and the environment in general; and to launch a multi-media information campaign to make the international market aware of the "green" culture technology that is being pursued in the region.

Research, verification and pilot demonstration runs will be pursued side by side. Research shall be undertaken to further refine techniques known to be successful. Four research areas have been identified for implementation under the Program, namely, nutrient cycles to include recycling systems and ratio of treatment per pond; "green water" using tilapia, milkfish or siganids; capacity of mangroves to absorb nutrients to include absorption mechanism and loading capacity; and probiotics and bioaugmentation to include screening of commercial products, characterization and bacterial profile, and effectivity of the products. Research shall be conducted at the facilities of AQD in the Philippines.

Verification and pilot demonstration runs on the other hand, shall be undertaken to determine whether techniques known to be successful in a particular country or area can be adopted in other countries or locations as well. Verification and pilot demonstration of improved practices shall be conducted at AQD in the Philippines for the semi-intensive and intensive commercial-shrimp farming using sustainable techniques, in Vietnam for the semi-intensive grow-out shrimp culture in mangroves, and in Thailand for the intensive shrimp grow-out using marine irrigation and recirculating systems.

Documentation will be in the form of technical papers for scientific journals as well as popular articles for trade journals, newspapers, and magazines for general circulation as well as through the Internet. Position papers shall be prepared to guide member governments on policies and regulations to make shrimp culture environmentally friendly. Any technology developed will be disseminated through regional training programs and workshops.

THE ON-SITE TRAINING ON MANGROVE-FRIENDLY AQUACULTURE

Hai Phong City, Socialist Republic of Vietnam
19-30 April 1999

THE OPENING CEREMONIES

Clockwise from top left: *Prof. Dr. Bui Dinh Chung*, Director of RIMP and SEAFDEC Alternate Council Director for Vietnam, welcoming the participants and guests to the On-Site Training; *Mr. Yasuho Tadokoro*, Deputy Chief of AQD (until May 1999) giving the Background of the Training and AQD's Mangrove-Friendly Aquaculture Program; *Mr. Panu Tavarutmaneegul*, SEAFDEC Secretary-General, officially opening the Training; and *Mr. Nguyen Ngoc Hong*, Vice Minister, Ministry of Fisheries, Vietnam and SEAFDEC Council Director for Vietnam, giving a Message.

SEAFDEC and Vietnam Officials (*above photo*), and with the participants and Guests to the Opening Ceremonies (*middle and lower photos*), for posterity

REPORT OF THE ON-SITE TRAINING ON MANGROVE-FRIENDLY AQUACULTURE: SUMMARY

Introduction

The On-Site Training on Mangrove-Friendly Aquaculture was conducted by the Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center (SEAFDEC) at the Research Institute of Marine Products (RIMP) of the Ministry of Fisheries - Vietnam, Hai Phong City, Socialist Republic of Vietnam, from 19 to 30 April 1999. A total of 25 participants and 10 observers attended the On-Site Training. Twenty of the participants came from all over Vietnam while five were from the Kingdom of Cambodia. Ten observers came from the Ministry of Fisheries - Vietnam, Hanoi and from RIMP, Hai Phong City.

Highly qualified and renown mangrove and aquaculture experts from the region, served as lecturers in the On-Site Training. The experts came from Indonesia, Malaysia, the Philippines, Thailand, and Vietnam as well as scientists from AQD and RIMP. Support staff from AQD and also from RIMP assisted in the conduct of the On-Site Training. An On-Site Training Steering Committee, chaired by the AQD Deputy Chief *Yasuho Tadokoro*, was organized by AQD for the purpose.

The Government of Japan provided special funds for the On-Site Training as part of its commitment for the conservation of mangroves in the region. On the other hand, the Government of Canada through its Canada-ASEAN Centre based in Singapore, provided financial support specifically for the attendance of the participants from the Kingdom of Cambodia.

At the Opening Ceremonies, the Director of RIMP and SEAFDEC Alternate Council Director for Vietnam, *Prof. Dr. Bui Dinh Chung*, welcomed the participants, resource persons and guests to RIMP and to the On-Site Training. The AQD Deputy Chief, *Mr. Yasuho Tadokoro*, presented the Background of the On-Site Training and the five-year Mangrove-Friendly Aquaculture Program of AQD.

The Vice Minister of the Ministry of Fisheries-Vietnam and SEAFDEC Council Director for Vietnam, *Mr. Nguyen Ngoc Hong*, commended AQD for the conduct of the On-Site Training in Vietnam. He mentioned that the training is relevant to Vietnam because much of its mangrove forests have been destroyed during the war, and recently these have been depleted due to the persistent use of mangrove trees for wood and irresponsible cutting of mangroves for aquaculture. He thanked the organizers for conducting the training, and particularly the Governments of Japan and Canada for their financial support. He commended the participation of Cambodia in the training, taking note of the interest indicated by Cambodia to join SEAFDEC.

The Secretary-General of SEAFDEC, *Mr. Panu Tavarutmaneegul*, thanked the Government of Vietnam for committing to host the On-Site Training at RIMP. He expressed optimism on the implementation of the Mangrove-Friendly Aquaculture Program of AQD especially with the support of the ASEAN Sectoral Working Group on Fisheries on the Program. He thanked the Government of Japan for its continued support for the Program and the Government of Canada for supporting the participation of Cambodia in the On-Site Training. He gave the assurance that the SEAFDEC Secretariat will extend its full support to the Program and congratulated the participants for attending the training which formed the backbone of the forthcoming activities under the Program.

Lecture Sessions

The Concept of Mangrove-Friendly Aquaculture and Wise Use Technologies in General, was discussed by *Dr. Jurgenne Primavera*, Scientist of AQD. Dr. Primavera has been working on mangroves as one of the major research projects of AQD, for the past five to ten years. She has ongoing projects on mangrove-friendly aquaculture in the Island of Panay, the Philippines. Dr. Primavera has also pioneered the broodstock development of penaeid prawns and shrimps at AQD, and has published a number of scientific papers on this topic as well as on mangrove conservation and preservation.

Dr. Primavera explained the mangrove ecosystem focusing on the taxonomy and distribution of mangroves, the various mangrove species and their functions, and the valuation of mangroves. She also mentioned the conservation and management of mangroves under the framework of integrated coastal area management, the adoption of mangrove zones and sustainable mangrove forestry, and the practice of mangrove-friendly aquaculture.

The lecture on Mangrove-Friendly Aquaculture Technology in Indonesia: Silvofishery, was presented by *Dr. Purwanto,* Head of the Division of Environment and Fishery Resources, Directorate of Fishery Resources Management of the Directorate General of Fisheries-Indonesia. Dr. Purwanto has been actively involved in the resources management projects of his country and specifically on silvofisheries. He is a member of the Indonesia's National Project Team working on fisheries management policy and planning, and information system management.

Dr. Purwanto explained that coastal aquaculture was not the main activity that caused mangrove destruction in his country. There may have been other reasons for the decrease in mangrove areas which was recorded to be about 1.0 million ha in 1982-1987, and another 0.8 million ha in 1987-1993. He discussed the concept of silvofisheries including site selection criteria, design and construction of silvofisheries models, as well as feeds and feeding mangement for the species stocked.

The Mangrove Wise Use Technologies in General: Vietnam Experience was discussed by *Dr. Do Van Khuong*, Deputy Director of RIMP. Dr. Khuong has been responsible for RIMP's science-technology and aquaculture activities, and heads the national marine fish breeding and marine fish culture research project. Dr. Khoung presented the status of aquaculture in Vietnam including the mangrove-friendly aquaculture technologies practiced in Vietnam. He offered solutions for the development of aquaculture in mangroves.

The topic on Mangrove Legal Framework (Vietnam Experience) was presented by *Dr. Vu Van Trieu*, Deputy Director General of the International Cooperation Department, Ministry of Fisheries, Vietnam. Dr. Trieu discussed the reasons for the decreasing of mangrove areas in Vietnam which was mainly due to the chemical warfare of the American army from the 60s to early 70s. Later, he mentioned that the main causes were due to the conversion of mangroves into agricultural, industrial and residential areas. He discussed strategies used by his Government to protect and develop mangrove areas sustainably.

The Philippine Legal Framework on Silvofisheries was discussed by *Atty. Annaliza Vitug*, Legal Officer of the Philippine Bureau of Fisheries and Aquatic Resources (BFAR). Atty. Vitug has been actively involved in the formulation of the 1998 Philippine Fisheries Code which was passed into law as Republic Act 8550, in March 1998. She has also been active in the Philippines' projects related to the conservation of its natural resources.

Atty. Vitug mentioned that BFAR has embarked on researches and studies with the end view of developing models for less destructive uses of mangroves. She discussed provisions in the Philippine Fisheries Code that encourage the intensification of aquaculture but minimizing its destructive effects on the ecosystem. She cited a provision in the Code prohibiting the conversion of mangroves into fishponds, the reforestation of mangrove areas and coastal zones, and prohibiting commercial fishing in the reforested areas.

Community-based Mangrove-Friendly Aquaculture: The Philippine Experience was presented by *Engr. Santiago Baconguis,* Chief of the Coastal Zone and Freshwater Ecosystems Research Division, Ecosystems Research and Development Bureau of the Philippine Department of Environment and Natural Resources (DENR). His fields of specialization include environmental management, environmental impact assessment, coastal and mangrove resources management, and many more. He has written and published a wide range of subjects from coastal zone and freshwater ecosystem management to aquaculture.

Engr. Baconguis outlined the various mangrove-friendly aquaculture systems practiced in the Philippines. He focused the discussion on the organization of community-based projects and a step-by-step procedure in starting a cooperative, which he said can be easily implemented in mangrove-friendly aquaculture situations.

Thailand's Experience on Mangrove-Friendly Marine Shrimp Aquaculture Technology was discussed by *Mr. Siri Tookwinas,* Director of the Marine Shrimp Research and Development Institute of the Department of Fisheries in Thailand. Mr. Siri has represented Thailand's Department of Fisheries in various international and national committees including those on environment impact assessment, standard evaluation of water quality criteria for aquaculture, coastal resources projects, etc. He has published a number of technical papers on aquaculture, specifically on shrimps and other economically-important aquatic species.

Mr. Siri explained that Thailand has developed the technologies for mangrove-friendly marine shrimp culture, which adopts the zero water discharge during culture period and the water recycle system. While research on biotechnology for shrimp farm effluent treatment processes are being undertaken, mangrove reforestation in the suitable areas has also been carried out by his Government.

The lecture on the Interaction Between Mangrove Ecosystem and Coastal Aquaculture was given by Prof. *Dr. Phan Nguyen Hong,* Chief of the Mangrove Ecosystem Research Division of the Centre for Natural Resources and Environmental Studies, Vietnam National University. Dr. Hong has been actively involved in projects relating to the socio-economic approaches of aquaculture.

Dr. Hong discussed the role and the potential of mangroves in the economy and nature, the role of mangroves in marine resources development, the reasons for the deterioration of mangroves, and the impacts of deforestation on shrimp pond construction,. He also discussed in general, the impacts of the conversion of mangrove areas into agricultural and industrial areas. He mentioned the need for sustainable use of mangrove ecosystems in order to rehabilitate the mangrove forests and marine product resources.

The topic on Sustainable Aquaculture and Coastal Resource Management: Framework was presented by *Mr. Renato Agbayani*, Associate Scientist and Head of Training and Information Division of AQD, and Head of the Socio-economics Section and Project Leader of the Sustainable Aquaculture and Coastal Resources Management Project of AQD. He has lectured in the regular and special training courses conducted by AQD especially on such topics as aquaculture economics and community-based coastal resource management.

Mr. Agbayani explained the conceptual framework for sustainable aquaculture and coastal resources management, from which research projects can be developed taking into consideration the interrelationship between and among the basic elements of the projects and their possible outcomes. He discussed the various strategies in aquaculture that could prevent further destruction of mangroves, such as the concept of property rights, co-management of the resources, community-based management, and mangrove-friendly aquaculture.

The experience of AQD on Aqua-Mangrove Integrated Farming: Shrimp and Mud Crab Culture in Coastal and Inland Tidal Flats with Existing Reforested or Natural Growth of Mangroves was presented by *Mr. Avelino Triño*, Researcher of AQD. Mr. Triño has written and published a number of scientific papers on shrimp and mud crab aquaculture. Mr. Triño discussed the systems for aqua-mangrove integrated farming practiced at AQD, focusing on shrimps and mud crab culture.

The topic on the Wise Use of Technologies of Important Mollusc Species from Mangrove Areas in Malaysia was presented by *Ms. Devakie Madhava Nair*, Fisheries Research Officer of the Fisheries Research Institute, Penang, Malaysia. Ms. Nair has been actively working on mollusc research specifically on the artificial propagation of oysters and developed the technology for oyster spat production. She discussed the culture techniques for the various molluscs as practiced in Malaysia.

Aquaculture of Shellfish in North Vietnam was presented by *Mr. Ha Duc Thang* of RIMP. Mr. Thang has been actively involved in mollusc research projects particularly on oysters, ark shell, abalone, scallops, and mussels. He discussed the use of rational technologies of bivalve culture in coastal and estuaries as practiced in Vietnam.

The AQD experience on Mangrove-Marine Fish Aquaculture was discussed by *Mr. Joebert Toledo*, Associate Scientist of AQD. His lecture was divided into two parts, namely; pond and pen culture, and cage culture of marine fishes. Mr. Toledo is the AQD Commodity Program Leader on Grouper and also the Project leader of AQD's research project on broodstock development and seed production of grouper.

The Scientific Fundamentals and Selection of Rational Culture Technologies for Some of the Economically Important Seaweeds was presented by *Prof. Dr. Nguyen Xuan Ly*, Director of Science and Technology Department of the Ministry of Fisheries, Vietnam. He is also an Associate Professor in Biology and a member of the Mekong River Committee of Vietnam.. He has been actively working on seaweeds research and has published a number of papers on this topic.

Field Trips

The participants and resource persons went on field trips to view the mangrove resources in Hai Phong, Vietnam. During the first field trip, the areas visited were the mangrove areas in Phu Long, Cat Hai District; the Fishing Port in Cat Ba Island; and the Mariculture Station of RIMP in the eastern part of ha Long Bay, Cat Ba Island.

The second field trip was a visit to RIMP's Research Institute for aquaculture at Do Son, a few kilometers from Hai Phong City. The participants also visited the Trung Dung and Do Son Aquaculture Farms, and the fish landing area at Do Son.

Group Presentation

The participants were grouped into four representing the three areas of Vietnam (northern, central, and southern) and Cambodia. The participants came up with strategies and recommendations for the development of mangrove-friendly aquaculture projects, which they can present to their respective offices and countries, after the On-Site Training.

While the background information presented by each group varied, similar problems and constraints were noted. Among the problems cited were sharp decrease of mangrove areas due to conversion to shrimp, fish or salt ponds; high population growth and poverty in coastal communities; lack of education of most people in coastal communities and lack of awareness on the role of mangroves in the ecosystem; and mangrove trees continuously being utilized as firewood, charcoal, or building materials. Conflicting and overlapping policies from government agencies regarding mangrove conservation, were also mentioned by the participants. specifically, they said that land tenure given is too short for the farmers to recover investments. Laws are formulated by the governments without proper consultation with the stakeholders. In addition, appropriate technology for sustainable aquaculture are not available to most farmers. The participants opined that these interconnecting problems often lead the stakeholders to chaos.

The participants from Cambodia added that although national laws were adopted, these are not adequate. The interaction during the training revealed similarities on the present state of mangrove areas as well as problems and constraints in the formulation and implementation of mangrove-friendly aquaculture activities in Vietnam and Cambodia. The organizers hoped that after the participants return to their respective assignments, they should be more equipped to prepare mangrove-friendly aquaculture programs.

Recommendations and Strategies

The participants prepared recommendations and strategies which could be presented to their respective offices and governments. Specifically, the participants from Vietnam suggested that direct management of mangrove areas be given to district and local levels. Mangrove areas used for aquaculture follow a ratio of 70% mangrove and 30% aquaculture using the modified or semi-intensive culture methods. Non-productive areas which have been converted for aquaculture should be returned to the government for replanting or rehabilitation. Education of the coastal communities on the ecology of mangroves as well as on mangrove conservation and rehabilitation, be intensified.

On the other hand, the participants from Cambodia presented a Project Development Plan on Mangrove-Friendly Aquaculture with the objectives of conserving coastal resources, promoting sustainable aquaculture, and improving the living standard of the coastal communities. The Cambodian participants expressed the hope that a similar training course be conducted in Cambodia especially when Cambodia becomes a member of SEAFDEC.

Evaluation of the On-Site Training

The participants in their evaluation of the training, were happy about the lectures and the information provided by the resource persons which they considered relevant to the mangrove conservation and aquaculture development programs of Vietnam and Cambodia. The experiences cited by the resource persons have served as lessons to them, making them confident not to repeat the unsuccessful efforts made by many countries in the region in the conservation of their mangrove resources.

The participants were also considered the training a good opportunity for them to be able to apply wise use technologies in aquaculture. They rated the over-all coordination of the training as excellent, especially with the support and cooperation of the RIMP staff headed by their Director, *Prof. Dr. Bui Dinh Chung*, and also the tireless and efficient efforts of the interpreters.

On behalf of the organizers, *Mr. Yasuho Tadokoro* presented a summary of the evaluation of the On-Site Training. He recalled that at the beginning of the training, the participants expected to learn and gain more knowledge about mangroves, the ecosystem, some sustainable aquaculture methodologies, and socio-economics of mangrove-friendly aquaculture. He was happy to note that at the end of the training, the expectations of the participants were met. However, he emphasized that the concept of mangrove-friendly aquaculture may be equated with that of "silvo-aquaculture," denoting the important relationship between mangroves and aquaculture.

Mr. Tadokoro also reiterated that in mangrove-friendly aquaculture, the culture method may not necessarily be extensive, it can be semi-intensive or intensive. It is really the wise use of modern aquaculture technologies in the mangrove areas which should be taken into serious consideration. He also noted that the group presentation of the participants clearly showed their confidence in implementing and promoting mangrove-friendly aquaculture technologies in their areas of work. He cited as an example, the Development Plan on Mangrove-Friendly Aquaculture presented by the participants from Cambodia. The plan included human resource and policies development, strengthening of law enforcement, and technology transfer and aquaculture demonstration. He commended the participants for coming up with such significant output.

Concluding Matters

Representing the participants from Vietnam, *Ms. Pham Thi Thuy* thanked SEAFDEC for conducting the training which they considered very relevant to the fisheries and aquaculture development of Vietnam. She thanked the Government of Japan for the financial support which made the training possible. She also thanked RIMP and the Ministry of Fisheries-Vietnam for giving them the opportunity to attend the very important training. She assured the organizers and her Government that the knowledge gained from the training will be applied in their respective places of work.

On behalf of the Government of Cambodia, *Mr. Khem Pona*, who represented the participants from Cambodia, took the opportunity to thank the Government of Vietnam especially RIMP for hosting the training, the Government of Japan for providing special fund, SEAFDEC and AQD for conducting the training, and the Government of Canada through the Canada-ASEAN Centre for supporting the participation of Cambodia in the training.

He mentioned that they learned so much from the experiences, knowledge and ideas on mangrove-friendly aquaculture from the other ASEAN countries. He added that the information provided by the resource persons were very useful to them in order that they these can be applied in their country using the right and proper way.

Mr. Pona expressed the hope that Cambodia will soon become a member of SEAFDEC after becoming a member of ASEAN. He also wished that AQD will conduct a similar training course in other Southeast Asian countries, especially in Cambodia. He reiterated that the training was very relevant, specifically mentioning that the experiences they learned from the lectures and the field trips will be useful in the mangrove-friendly aquaculture development of Cambodia. He mentioned that RIMP which is located in the beautiful Hai Phong City, was a very convenient and appropriate venue for the On-Site Training because of its excellent facilities.

As host of the On-Site Training, *Dr. Do Van Khuong*, Deputy Director of RIMP, considered it a good opportunity for RIMP to serve as venue of the training. He mentioned that the experience gained by him and the rest of the RIMP staff working with the renown resource persons was very valuable. He thanked the Ministry of Fisheries-Vietnam for committing to host the training at RIMP, the Governments of Japan and Canada for the financial support, and SEAFDEC and AQD for conducting the training. He offered his apology, in behalf of RIMP, for any inconvenience that the resources persons, participants, and guests must have experienced at RIMP, and at the same time expressed the hope that they enjoyed their stay in Hai Phong City.

On behalf of AQD, *Mr. Yasuho Tadokoro* expressed his profound gratitude to the resource persons, the participants, the interpreters, and the support staff for their contributions for the success of the On-Site Training. He also thanked the Ministry of Fisheries-Vietnam for hosting the On-Site Training at RIMP. He thanked the various governments in the region for sharing their expertise for the training, and the donors for their financial support.

The SEAFDEC Deputy Secretary-General, *Mr. Masao Shimomura* expressed his profound gratitude to the Government of Vietnam through its Ministry of Fisheries for making available the facilities and staff of RIMP for the On-Site Training. He commended AQD for getting the most qualified resource persons for the training. He encouraged the participants to make full use of what they learned during the training and for the Governments of Vietnam and Cambodia to take note of the recommendations and strategies formulated during the training in order that the implementation of the mangrove-friendly aquaculture in the region shall have good results.

Mr. Shimomura commended the trainees for coming up significant output as expected of them by the Government of Japan which allocated the special fund for the On-Site Training. He appreciated the financial support of the Government of Canada which enabled the participants from Cambodia to attend the training. He regretted that the total fund for the On-site Training was not enough to cover the participation of Myanmar. However, he expressed the hope that Myanmar will be able to participate in the future activities of SEAFDEC.

THE PARTICIPANTS

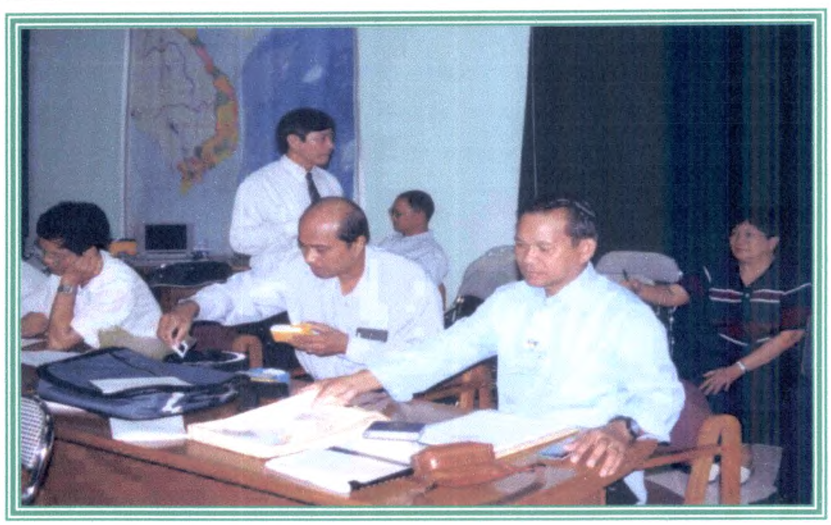
The participants in the On-Site Training, comprising 20 from Vietnam and 5 from Cambodia. Ten observers from RIMP and Ministry of Fisheries (Hanoi, Vietnam) also attended the training.

THE RESOURCE PERSONS

Resource persons from RIMP (*top photo)*, Indonesia (*middle photo*), and Vietnam (*lower photo)*

Resource persons from Thailand (*top photo*), and from AQD (*middle and lower photos*)

Resource persons from Vietnam (*top photo*) and Malaysia (*middle photo*). Lower photo (*from left to right*): D. Nair (Malaysia), Y. Tadokoro (AQD), D.V. Khoung (RIMP), B.D. Chung (RIMP), and J. Toledo (AQD)



First batch of resource persons (*top and middle photos*) receiving their Certificates of Appreciation from the organizers (RIMP and AQD), and preparing their lecture notes (*lower photo*)

WISE USE TECHNOLOGIES OF MANGROVE-FRIENDLY AQUACULTURE

LECTURE PAPERS
Presented at the On-Site Training on Mangrove-Friendly Aquaculture

Hai Phong City, Socialist Republic of Vietnam
19-30 April 1999

IMPACTS OF BRACKISHWATER POND CULTURE ON THE MANGROVE ECOSYSTEM

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I. Introduction

Thirty-five percent of the total 18 million ha of mangrove forests worldwide are found in Southeast Asia (Spalding *et al.*, 1997). Indonesia alone has 4.5 million ha followed by Malaysia with 640,000 ha (Fig.1). At the same time, the region also leads in brackishwater aquaculture, producing for example 446,000 mt of farmed shrimp or 60% of 1997 global yields (Rosenberry, 1997). This paper aims to describe Southeast Asian mangroves, the impacts of brackishwater pond culture on these ecosystems, and lessons from the region for the development of aquaculture in Malaysia.

II. Mangrove Goods and Services

Mangrove systems have three functions: information, regulatory and resource. The information function may refer to aesthetic, religious, cultural or historical aspects. For example, the premier city of Manila or *Maynila* owes its name to the species *Scyphiphora hydrophyllacea* locally called *nilad*, which grew abundantly along Manila Bay in pre Hispanic times (Merrill, 1918). What are usually referred to as services and amenities fall under the regulatory function, and may be geomorphic/hydrologic (coastal protection, erosion control and sediment trapping) or ecological (nurseries, nutrient supply/recycling and storage) in nature.

Mangrove resources (Table 1) are the most familiar among the three functions. Utilization of these forestry and fisheries products may be traditional, small-scale extraction for domestic needs (e.g. domestic food, fuel and medicines) or commercial in scale (charcoal, timber and harvest of fish, shrimps and bivalves).

A positive relationship between fish/shrimp nearshore catches and mangrove area has been documented for Indonesia (Martosubroto and Naamin, 1977), Malaysia (Sasekumar and Chong, 1987) and the Philippines (Camacho and Bagarinao, 1987). Mangrove-associated fish, crustaceans and molluscs contribute 21% (1.4 million tons) yearly to the inshore capture fisheries in the ASEAN region (Singh *et al.*, 1994). Mangrove-associated fish contribute around 30% (1.09 million tons) of annual finfish resources excluding trash fish, while mangrove-dependent prawns provide almost 100% (0.4 million tons valued at US$1.4 billion) of total prawn resources in ASEAN.

The link between fish/shrimp yields and adjacent intertidal area (Fig. 2) has been associated with the nursery function, larval trapping or retention, and trophic subsidy or 'outwelling' (Hatcher *et al.*, 1989; Chong, 1996). Because there is little evidence that the exported detritus enhances primary productivity offshore (Lee, 1995), the mangrove-fisheries connection may therefore lie in the nursery function through provision of food and shelter from predation (Hatcher *et al.*, 1989) and the lateral trapping or retention of planktonic prawn larvae in mangrove swamps (Chong, 1996).

Mangroves have declined worldwide over the last century, but especially within the last few decades in Southeast Asia. Such loss due to anthropogenic factors include overexploitation by coastal communities and conversion to settlements, rice and other agriculture, salt beds and industrial activities. But brackishwater pond culture—which dates back to at least 1400 in Java, Indonesia (Herre and Mendoza, 1929)—has also taken its toll. Most of the thousands of hectares of brackishwater ponds in the Philippines and Indonesia were carved out of mangrove swamps for milkfish cultivation. However, the recent mangrove-pond conversions in Southeast Asia have been for shrimp farming. For example, 102,000 ha of Vietnamese mangroves had been developed into shrimp ponds in 1983-1987 (Table 2).

III. Ecological Impacts of Brackishwater Pond Culture

The ecological impacts of brackishwater pond culture, whether for shrimp or milkfish crops at extensive, semi-intensive or intensive levels of farming include effluent release into waterways, chemical use, salinization of soil and water, destruction of fry bycatch, introduction of exotic species and pathogens, and loss of mangrove habitats.

A. *Nutrients, organic loading and sediments*

The water quality in high-density culture ponds deteriorates as shrimp biomass and food inputs increase during a cropping cycle. Mean levels of nitrogen, phosphorus, turbidity and chlorophyll and other water parameters in Hawaiian shrimp ponds were generally higher in effluent than in influent water (Ziemann *et al.*, 1992). Similarly, N and P levels in waste water discharged from Thai shrimp ponds were significantly higher compared to inflow water (Vorathep, 1991). Effluent water during regular flushing and at harvest accounts for 45% of N and 22% of organic matter output while sediment is the major sink accounting for 31% of N output, 84% of P, 63% of organic matter and 93% of solids (Briggs and Funge-Smith, 1994).

The quality of receiving waters deteriorates if the assimilative capacity of the environment is exceeded. Due to shrimp pond effluent loadings, levels of nitrates, nitrites, phosphorus, sulphide, turbidity and biological oxygen demand increased considerably from 1983 through 1987 to 1992 in the Dutch Canal in Sri Lanka (Jayasinghe, 1995) and water quality in Kung Krabaen Bay, Thailand significantly deteriorated over time (Tookwinas, 1998). An Australian study showed that levels of Vibrio and other bacteria were 10 times higher in shrimp pond sediments compared to mangrove sediments, and were also higher in mangrove sediments near effluent canals compared to those located 2 km away from farms (Smith, 1998).

Because sediment or sludge accumulates at the rate of 20-290 mt DW/ha/cycle in intensive shrimp ponds, their direct disposal in waterways may cause eutrophication and self-contamination in ponds through intake water (Frederiksen *et al.*, 1998). Nevertheless, sludge is largely mineral soil whose chemical composition is probably not toxic to organisms and whose removal is unnecessary, expensive and destructive to ponds (Boyd *et al.*, 1994). Neither does sediment removal reduce levels of *Vibrio* and other bacteria (Smith, 1998). Instead, sludge should be spread and compacted over the pond bottom to reduce erodibility by aerator-induced currents (Boyd *et al.*, 1994), and dried between crops to reduce *Vibrio* and bacterial levels temporarily (Smith, 1998). Alternatively, pond sludge may be collected and used in mangrove planting projects near farms (Macintosh, 1996).

B. *Chemical use*

Chemicals used in shrimp culture may be classified as therapeutants, disinfectants, water and soil treatment compounds, algicides and pesticides, plankton growth inducers (fertilizers and minerals), and feed additives (Primavera, 1993). Excessive and unwanted use of such chemicals result in problems related to toxicity in nontarget species (cultured species, human consumers, and wild biota), development of antibiotic resistance, and accumulation of residues. The antibiotics oxytetracycline and oxolinic acid were detected above permissible levels in 8.4% of 1,461 *P. monodon* sampled from Thai domestic markets in 1990-1991 (Saitanu *et al.*, 1994). From June 1992 to April 1994, Japanese quarantine stations found antimicrobial residues in 30 shipments of cultured shrimp from Thailand (Srisomboon and Poomchatra, 1995).

C. *Groundwater removal; salinization of soil and water*

Pumping large volumes of underground water to achieve brackishwater salinity have led to the lowering of groundwater levels, emptying of aquifers, land subsidence and salinization of adjacent land and waterways in Taiwan and Southeast Asia. Even when fresh water is no longer pumped from aquifers, the discharge of salt water from shrimp farms located behind mangroves still causes salinization in adjoining rice and other agricultural lands (Dierberg and Kiattisimkul, 1996). Salinization reduces water supplies not only for agriculture but also for drinking and other domestic needs.

D. *Destruction of wild fry bycatch*

Extensive farming of the giant tiger prawn, *Penaeus monodon*, also depends on natural seed that comprise only a fraction of wild fry catches. In India and Bangladesh, where ponds are stocked mainly with wild fry, up to 160 fish and other shrimp fry are discarded for every tiger prawn collected from open waters (Banerjee and Singh, 1993). Given a yearly seed collection of one billion *P. monodon* in Southeast Bangladesh, the amount of bycatch destroyed is staggering and could have major consequences for marine food webs (Deb *et al.*, 1994).

E. *Loss of mangrove habitats*

Mangrove goods and services may be produced on-site or off-site, and marketed or not. Past valuation efforts have covered only traded products because of the subsistence level of utilization of such items as traditional medicines and domestic fuel, and the difficulties in assigning monetary values to such regulatory functions as coastal protection and waste processing, thereby underestimating the true value of mangroves. Reviews of available valuation data give a range of US$6-400/ha for individual and combined forestry goods (Radstrom, 1998) and $40-5,300/ha for different fisheries products (Ronnback, 1999). But if complete systems are considered, maximum figures of $11,000/ha can be attained (Table 3). Aside from conventional market analysis, valuation tools currently available include non-market methods (hedonic pricing, contingency valuation, indirect opportunity cost), damage costs and preventive expenditure (Turner *et al.*, 1998).

Cost-benefit analysis (CBA) is also useful in comparing alternative uses of mangroves. A CBA of Fiji mangroves including interactions of ecological, economic and institutional factors at the ecosystem level gave a negative net present value (NPV) for alternative uses (Lal, 1990). That is, mangrove reclamation for shrimp ponds or rice culture did not give positive returns. In Trang Province, Thailand, maximum NPV could be generated from 35,665 ha of mangrove economic zones by retaining 61% of the entire area as mangrove forest, reforesting 10%, and allowing only 17% for wood concessions and 12% for shrimp farms (Pongthanapanich, 1996). Considering forest products and fisheries as well as services of coastal protection, shoreline stabilization and carbon sequestration, Sathirathai (1997) concluded that mangrove conversion to commercial shrimp farms in Surat Thani, Thailand was economically available only for private persons but not society as a whole.

F. *Introduction of exotic species*

The most numerous introductions of non-indigenous fish and crustacean species outside their natural range have been for aquaculture purposes (Welcomme, 1988). The potential negative effects of such introductions include degradation of host environment, disruption of host community, genetic degradation of host stock, and introduction of diseases and parasites (Welcomme, 1988). In recent years viruses, notably the Whitespot Virus (WSV) and Yellowhead Virus (YHV), have caused catastrophic multimillion dollar crop losses in shrimp farms across Asia. All save 2-3 of the 20 identified viruses in marine shrimp have been described in cultured animals (Lightner and Redman, 1998). Since 1995, WSV and YSV have appeared in cultured and wild shrimp populations in the U.S. (Nadala and Loh, 1998; Nunan *et al.*, 1998), Central and South America (T. Flegel, Mahidol University, pers. comm.). The release of untreated wastes directly into coastal waters by plants that import Asian shrimp, and international transfers of live shrimp broodstock and larvae are the probable introduction routes of these Asian viruses (Lightner *et al.*, 1997).

The introduction of parasites and diseases, competition from introduced species, loss of mangrove habitats and mortality of wild fry bycatch may all impact negatively on biodiversity.

IV. Lessons from Southeast Asia

The development of shrimp farming in the Philippines, Thailand and Vietnam has many lessons for new players in the industry like Malaysia. They include proper siting and management of culture ponds, aquaculture development and mangrove conservation within the framework of integrated coastal zone management (ICZM), and appropriate policy instruments (Primavera, 1998).

A. *Proper siting and management of farms*

In addition to such standard criteria as soil quality and tidal regime, selecting pond sites must consider the waste-absorbing or assimilating capacity of the environment. Extensive shrimp culture requires an intertidal location (for water supply) which is often associated with clearcutting of wide mangrove stands.

On the other hand, intensive systems located inland spare mangroves but jeopardize water supplies and agricultural land because of saltwater contamination. Various manuals have described proper pond operations including management of cultured stock, water and food. The processing and disposal of effluents and sediments attain greater importance as intensive culture farms increase. Aside from proper pond siting and design, methods to mitigate the impacts on receiving waters include zero or reduced water exchange in combination with sedimentation and treatment ponds, pond liners, probiotics, and sludge collection and storage (Primavera, 1998). Alternatively, mangroves can be used to treat shrimp pond effluents with high levels of solids, organic matter and nutrients (Dierberg and Kiattisimkul, 1996).

Calculations show that 2.4-7 ha and 3-22 ha of mangroves, respectively, can filter the nitrogen and phosphorus wastes from a one-ha intensive shrimp pond (Robertson and Phillips, 1995), whereas 0.04 to 0.12 ha of mangroves can absorb the dissolved inorganic nitrogen load produced by a one-ha semi-intensive shrimp pond in Mexico (Rivera-Monroy *et al.*, 1999). Waste processing is only one of the many ecological services required by shrimp farms, including food inputs, postlarval nurseries and water supply. The "ecological footprint" or ecosystem area that provides these goods and services to a one-ha semi-intensive shrimp farm in Colombia has been calculated as 35-190 times the surface area of the farm (Kautsky *et al.*, 1994).

B. *ICZM and mangrove management*

Integrated coastal zone management coordinates the interests of various stakeholders, e.g., fisheries, aquaculture, forestry, settlements and navigation to ensure the optimal use of resources, maintenance of biodiversity, and conservation of critical habitats. The expansion of brackishwater pond culture in Southeast Asia for milkfish and shrimp has been a sectoral rather than holistic exploitation of the coastal zone. This shortsighted approach to aquaculture development has caused serious socioeconomic impacts such as loss of mangrove goods and services, food insecurity, and marginalization of coastal communities (Primavera, 1997), aside from the ecological consequences earlier discussed.

Based on their ecological and economic functions, mangroves can be designated into four zones: a) preservation-conservation (for coastal protection, biodiversity, ecotourism), b) sustained yield (of forestry and fisheries products), c) conversion to aquaculture, agriculture, salt beds and other uses, and d) reforestation. Ecologists have recommended that no more than 20% of a given mangrove area be converted (Saenger *et al.*, 1983) to ponds and other uses. Consistent with the ecological footprint concept where ponds can exist side by side with mangrove areas, such recommendation can be applied to Malaysia and other countries whose swamps remain luxuriant. In the Philippines where all but a few (notably in Palawan) mangrove forests have been converted mostly to aquaculture, the solution lies in replanting of degraded areas and reverting abandoned or underutilized ponds to mangroves. This whole-scale destruction of mangroves??, especially in north and central Philippines, could be one reason local shrimp farms have not recovered from devastating luminous vibriosis; only newly-opened culture areas in the south remain productive.

Practically all countries in Southeast Asia require a coastal greenbelt whose width ranges from 20 m for Philippine riverbanks to 540 m in Indonesia (Table 3), although enforcement is inadequate (Primavera, 1995). Forming part of the preservation-conservation zone, such mangrove greenbelts and buffer zones should be retained or planted not only along shorelines and riverbanks but also between adjacent uses, e.g., shrimp pond and rice field.

Not all aquaculture requires clearcutting of mangroves. Examples of mangrove-friendly aquaculture exist either in waterways (seaweeds like *Gracilaria*; bivalves like mussel, oyster and cockles; and cages for crab and fish) or land-based (ponds and pens for crabs, shrimps and fish). These technologies, particularly integrated mangrove ponds and pens (also called aquasilviculture or silvofisheries) optimize the utilization of mangroves for both forestry and aquaculture production (Primavera *et al.*, 1999) and can be promoted in areas where mangroves are being conserved or replanted.

C. *Policy options*

The conversion of mangroves to milkfish and shrimp ponds was premised on the early belief that mangroves and other wetlands are wastelands. This is reflected in the low fishpond lease fees charged in the region; for example the $2/ha/yr charged for Philippine ponds hardly captures the economic rent of $20-127/ha/yr when these ponds culture shrimp and/or milkfish (Evangelista, 1992). The 1950s fishpond boom followed by the 1980s shrimp fever and the attendant mangrove loss in Southeast Asia have been fueled by loans from the International Bank for Reconstruction and Development, the Asian Development Bank, the FAO-United Nations Development Programme and other multilateral development agencies.

The World Bank (1989) has recommended the imposition of fees for the use of mangroves and other natural resources to levels commensurate to economic rent. Governments can impose green taxes based on the Polluter Pays principle to mitigate the environmental and socioeconomic damages from brackishwater aquaculture (e.g., correcting water quality problems and rehabilitating mangroves and other damaged landscapes), revoke early policies and withdraw subsidies used to stimulate aquaculture expansion (e.g., declaration of coastal land as public resources, loans and tax breaks for aquaculture), and require environmental planning and performance as preconditions to the approval of pond culture loans, credits and access to resources.

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Table 1. Products of mangrove ecosystem (Saenger *et. al.*, 1983)

A. Mangrove forest products		
• Fuel	Firewood (cooking, heating)	Charcoal, Alcohol
• Construction	Timber, scaffolds Heavy construction (e.g., bridges) Railroad ties Mining pit props Boat building Dock pilings	Beams and poles for buildings Flooring, paneling Thatch or matting Fence posts, water pipes. chipboards, glues
• Fishing	Poles for fish traps Fishing floats Wood for smoking fish	Fish poison Tannins for net and line preservation Fish attracting shelters
• Textiles, leather	Synthetic fibers (e.g., rayon) Dye for cloth	Tannins for leather preservation
• Food, drugs and beverages	Sugar Alcohol Cooking oil Vinegar Tea substitute Fermented drinks	Dessert topping Condiments from bark Sweetmeats from propagules Vegetables from propagules, fruit or leaves Cigar substitute
• Household items	Furniture Glue Hairdressing oil Tool handles	Rice mortar Toys Matchsticks Incense
• Agriculture	Fodder, green manure	
• Paper products	Paper of various kinds	
• Other products	Packing boxes Wood for smoking sheet rubber	Wood for burning bricks Medicines from bark, leaves and fruits
B. Other natural products		
	Fish Birds Shellfish Honey Wax Mammals	Crustaceans Reptiles and reptile skin Other fauna (amphibians. insects)

Table 2. Mangrove areas converted to shrimp farms in Asia and Latin America (Primavera, 1998)

Location	**Period covered**	**Area converted (ha)**	**Reference**
Thailand	1961-1993	65,200	Menasveta, 1997
Ho Ko Nok, Chanthaburi, Thailand	1975-1991	1,428	Raine, 1994
Vietnam	1983-1987	102,000	Tuan, 1997
Mekong Delta, Vietnam	1985-1988	60,000	Trong, 1995
Chokoria Sunderbans, Bangladesh	1967-1988	6,527	Choudhury *et al.*, 1994
Puttlam District Sri Lanka	1983-1994	1,650	Liyanage, 1995
Ecuador	1979-1985	33,000-75,000	Skladany & Harris, 1992
Honduras	1973-1992	4,307	DeWalt *et al.*, 1996

Table 3. Economic values placed on products and services of mangrove systems (after Primavera, 1997).

Country	Year	Product or service	Value (US$/ha/yr)	Reference
Puerto Rico	1973	Complete mangrove ecosystem	1,550	Hamilton & Snedaker, 1984
Trinidad	1974	Complete mangrove system Fishery products Forestry products	600 125 70	Hamilton & Snedaker, 1984
Fiji	1976	Complete mangrove system Fishery products	950-1,250 640	Hamilton & Snedaker, 1984
Indonesia	1978	Fishery products	50	Hamilton & Snedaker, 1984
	1978	Forestry (charcoal, woodchips)	10-20	Hamilton & Snedaker, 1984
Thailand	n.d.	Charcoal production	4,000	McNeely & Dobias, 1991
	1982	Fish and shrimp Forestry products	30-2,000 30-400	Hamilton & Snedaker, 1984
Brazil	1981-82	Fish (based on extent of open water)	769	Kapetsky, 1987
Malaysia	1979	Shrimp and fish (inc. estuaries & lagoons)	2,772	Gedney *et al.*, 1982
	n.d.	Fishery products Forestry products	750 225	Ong, 1982
	n.d.	Managed forest (sustained harvest)	11,561	Salleh & Chan, 1986
India	1985	Complete system (inc. fishery products, maintenance of fauna, air/water purification)	11,314	Untawale, 1986
Thailand	1996	Local uses, offshore fisheries, coastline protection	3,207-4,116	Sathirathai, 1997

[a]NPV

Table 4. Width of greenbelt/buffer zone required in Southeast Asia.

Indonesia (Soemodihardjo *et al.*, 1993)

- 200-540 (1,100) m
  width = 130 x mean spring tide

Malaysia (Chan *et al.*, 1993)

- Natmancom: 100 m pond to MHWL
- CRMP: 100 m aquaculture/tourism
  500 m housing
  1,000 m industries
- WWF-AWB (for pond sites):
  50 m riverbank
  100 m MHWL in non-mangroves, ex-mangroves
  200 m coastline with accreting shorelines, state mangroves
  400 m coastline with stable, eroding shorelines, state mangroves

Philippines (Primavera, 1995)

- 20 m strip along creeks, rivers (fishponds)
- 50 m strip fronting seas, oceans (fishponds)
- 20-50 m along riverbanks (typhoon areas)
- 50-100 m along shorelines (typhoon areas)

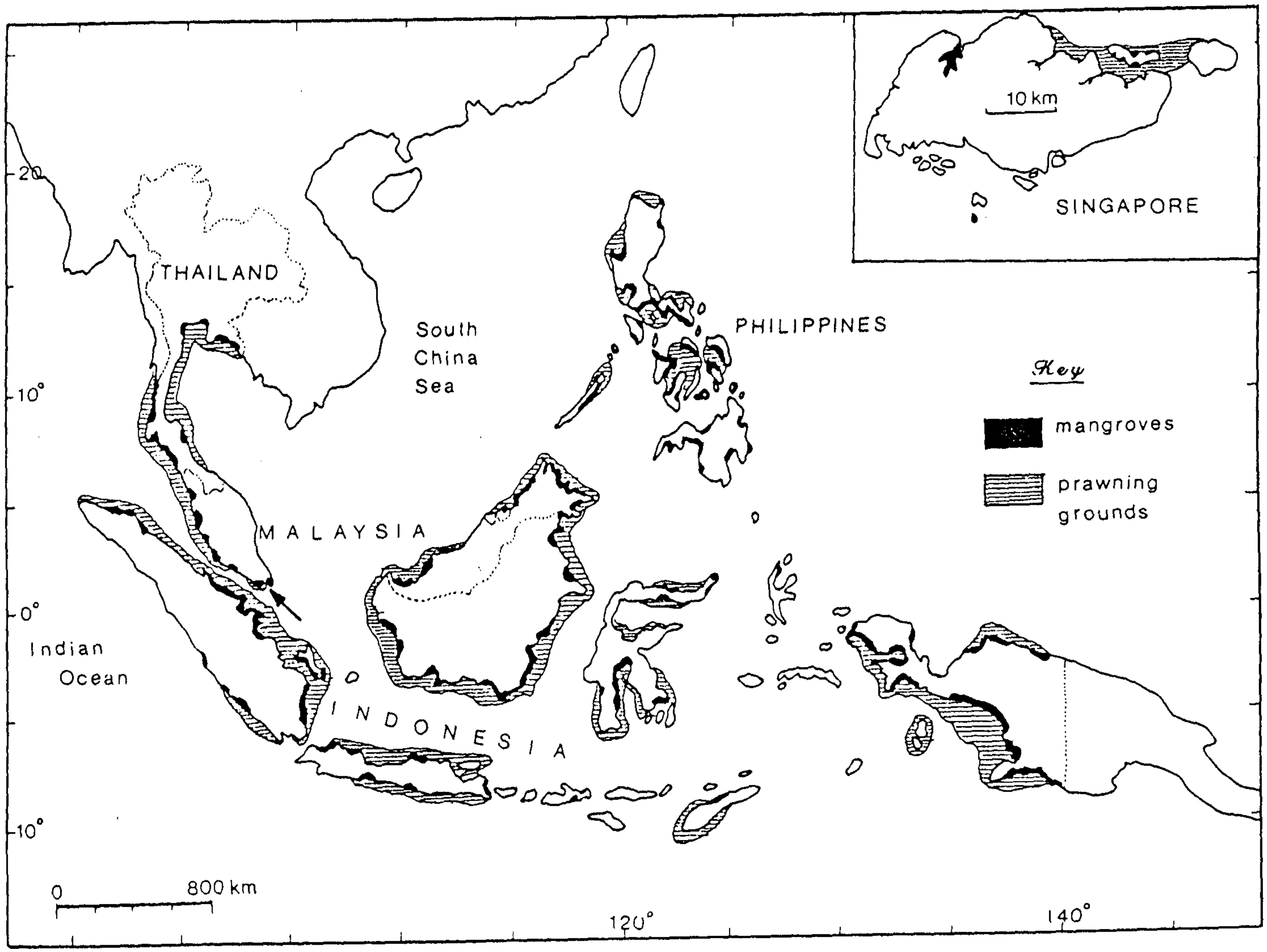

Fig. 1. Major mangrove areas and prawn fishing grounds in Southeast Asia (Chong et al., 1994).

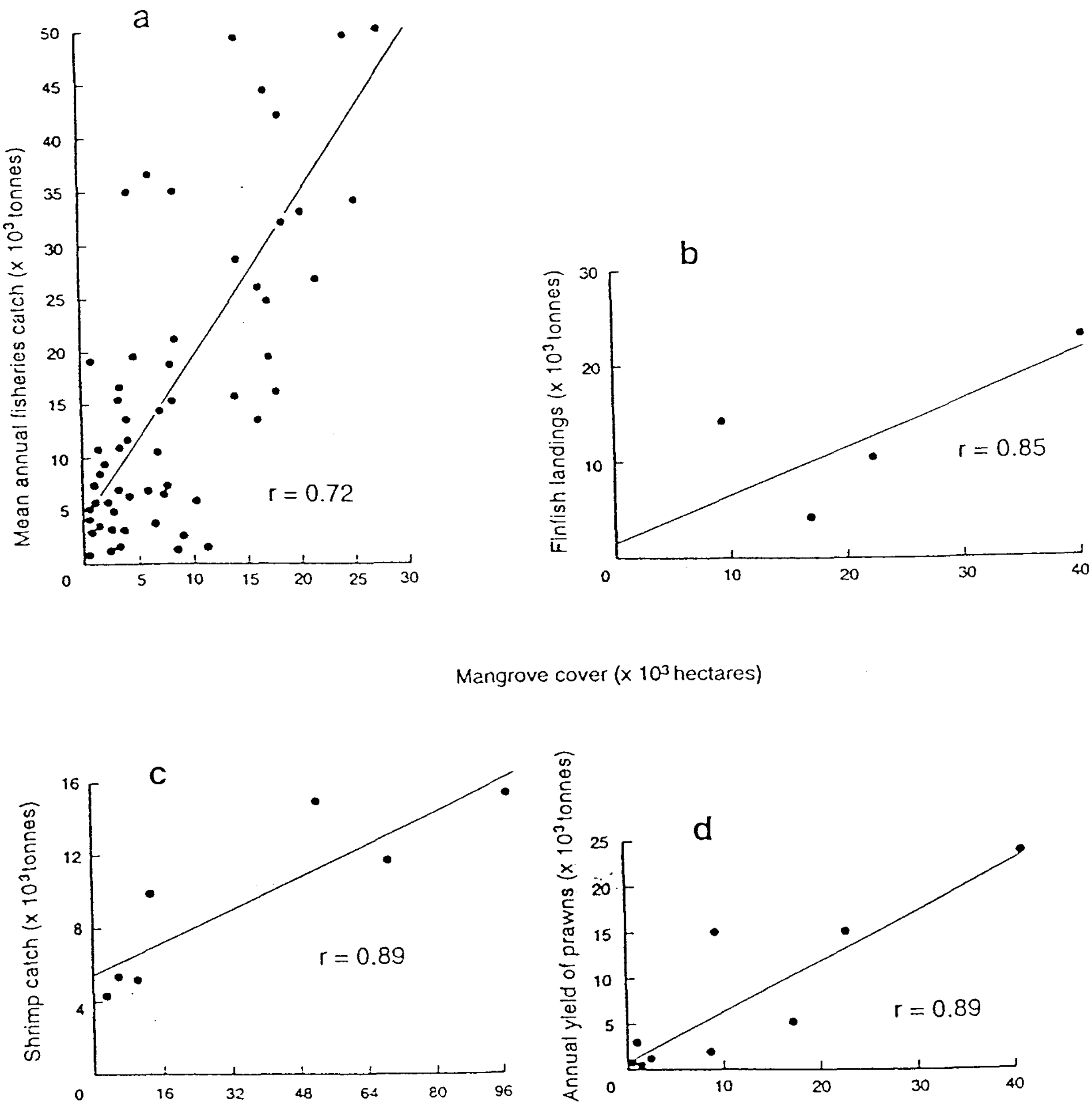

Fig. 2 . The relationship between fisheries landings and mangrove areal cover in the ASEAN region.

a) Philippines. Annual fisheries catch by province (Camacho & Bagarinao 1987)
b) Malaysia. Mangrove-dependent finfish landings on the west coast of Peninsular Malaysia (State Fisheries Statistics 1990)
c) Indonesia. Shrimp landings (Martosubroto & Naamin 1977)
d) Malaysia. Annual yield of prawns (Sasekumar & Chong 1987)

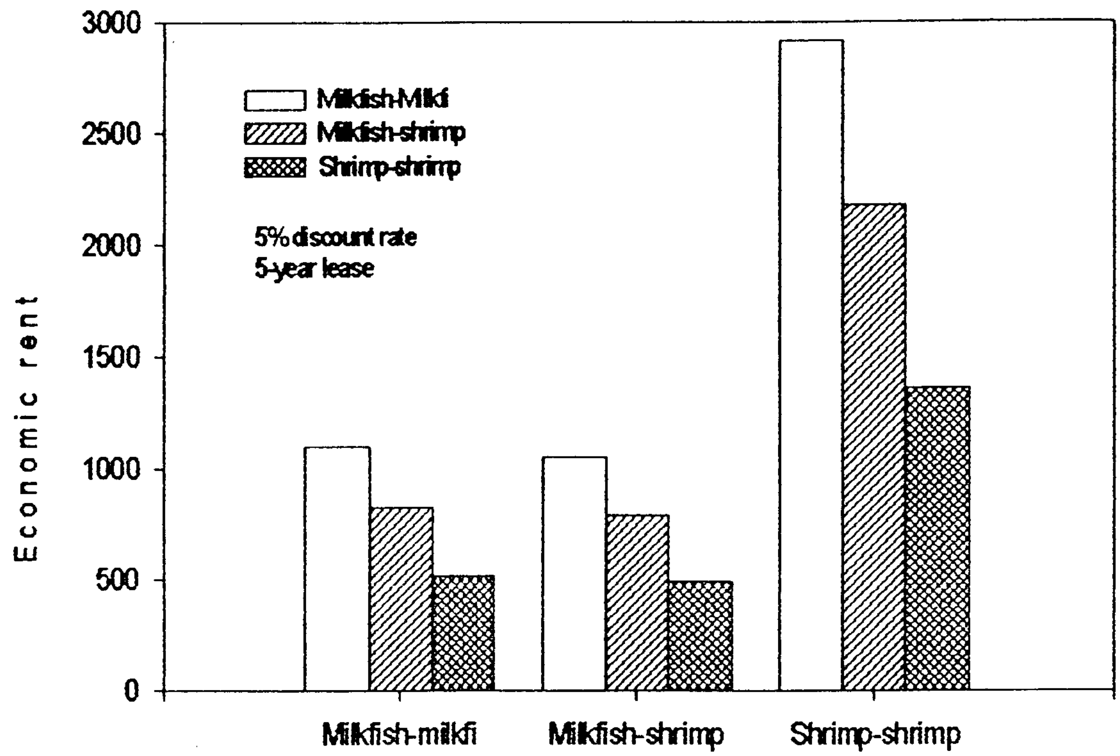

Fig.3. Economic rent (Php. peso/ha/year) of mangrove areas in Quezon, Philippines (Evangelista, 1992)

A WISE USE TECHNOLOGY OF MANGROVE-FRIENDLY AQUACULTURE IN INDONESIA: SILVOFISHERY

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I. Introduction

The area of mangrove in Indonesia decreased in the period 1982-1993 (Table 1). Coastal aquaculture, however, was not the main activity causing mangrove destruction in Indonesia. The area of mangrove decreased by about 1 million ha and about 0.8 million ha in the period 1982-1987 and 1987-1993, respectively. The area of brackishwater ponds, however, has only increased by about 40 thousand ha and about 70 thousand ha in the period 1982-1987 and 1987-1993, respectively.

Table 1. Areas of Mangrove and Brackishwater Ponds in Indonesia (in 1000 ha)

	1982	1987	1993
1. Mangrove[a]	4,251.0	3,235.7	2,490.2
2. Brackishwater ponds[b]	220.4	263.2	331.8

A. *Silvofishery*

A form of integrated mangrove tree culture with brackishwater aquaculture, in order to conserve the mangrove resource while allowing people earn incomes.

B. *Cultured Species*

Milkfish, red tilapia, sea bass, tiger prawn, mud crab; Fishes and shrimps are cultivated in canal/pond; Mud crab is cultivated in a pen on mangrove central platform area.

[a] Source: *National Strategy for Mangrove Management in Indonesia.* Office of the Minister of Environment, Department of Forestry, Indonesian Institute of Sciences, Department of Home Affairs, and the Mangrove Foundation. July 1997.

[b] Source: *Fisheries Statistics of Indonesia.* Directorate General of Fisheries 1988 and 1997.

II. Site Selection Criteria

A. *Environment Conditions*

Salinity : 15-30 ppt.
DO : >4 ppm
Water pH : 6.5 - 9

Soil texture :
For fish culture : mud, sandy-mud, sandy-clay
For shrimp culture : muddy loam

Protection : should be protected from strong wind and wave.

Pollution : should be far from industrial areas.

Security : involve the local community, to develop a community-based conservation and management system of mangrove resource.

Vegetation density : 0.2-2.5 trees/m
For fish culture : 0.2 trees/m
For shrimp culture : 2.5 trees/m
For crab culture : 2.5 trees/m

B. *Feeding Rate*

1. Sea bass culture : 5-10% of average body weight/day; Twice in a day
2. Shrimp culture : 3-10% of average body weight/day; Twice to four times in a day.
3. Crab culture : 3-10% of average body weight/day; Twice in a day.

C. *Monitoring*

1. Physico-Chemical
   DO, pH, salinity should be monitored daily
2. Security monitoring was done by the owner.
3. Stock sampling was carried out weekly.

D. *Harvest and Post Harvest*

1. Method of harvesting : total harvesting

2. Harvest size : depend on market demand;
Average size
Milkfish : 300-500 g/fish
Sea bass : 500-700 g/fish
Shrimp : 20-30 g/shrimp
Crab : 250-350 g/crab

3. Gears : Trap-net, cash-net, gill-net.

4. Packing and transport:
   a. Live fishes : Transported in the aerated container.
   b. Dead fishes : Packed in the insulated box with ice.
   c. Shrimps : Packed in the insulated box with ice.
   d. Live crabs : Tied up all legs.

E. *Economics*

1. Investment, Production Cost, Return and Profit of Aquaculture on Mangrove Area:

2. Silvofishery (in Rp. 1000)

	Milkfish[1]	Sea bass[1]	Red tilapia[1]	Shrimp[1]	Crabs[2]
Investment	540	873	523	873	46
Production cost/crop	1356	2036	1882	2077	320
Return/crop	1852	4320	2800	4950	331
Profit/crop	496	2284	918	2873	96
Annual profit	1488	4568	2754	5746	864

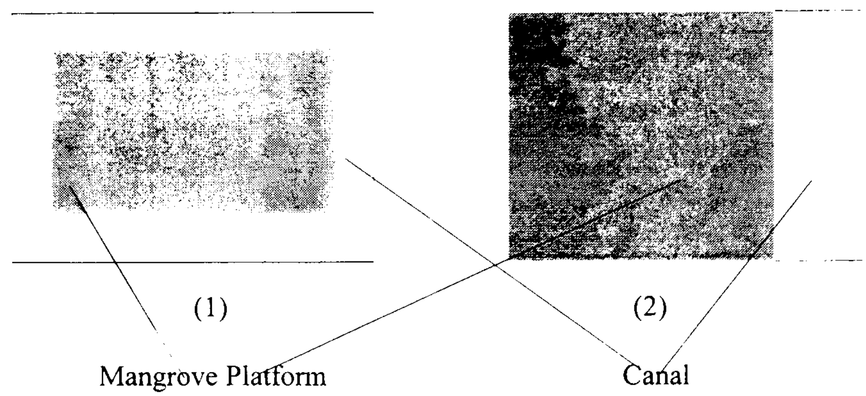
Salinity : 15-30 ppt
DO : > 4 ppm
Water pH : 6.5 - 9
Soil texture
  For fish culture : mud, sandy-mud, sandy-clay
  For shrimp culture : muddy loam, clay
  For crab culture : muddy loam
Protection : should be protected from strong wind and wave.
Pollution : should be far from industrial areas.
Security : involve the local community, to develop a community-based conservation and management system of mangrove resources.

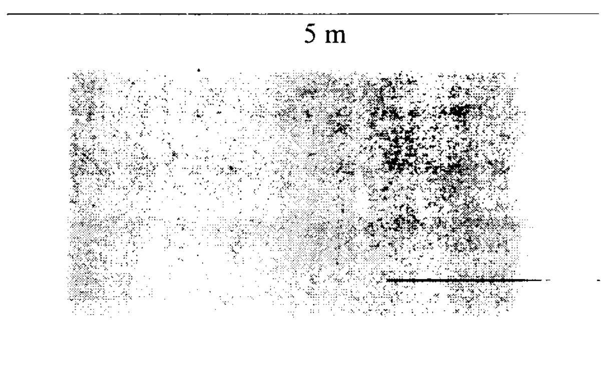
[1] Cultivation was carried out in a 1-ha pond
[2] Cultivation was carried out in a one (2.5x1.2x1.5m) bamboo cage

III. Design and Construction

A. *Basic Models*:

(1) Mangrove within the pond, and (2) Mangrove outside the pond.



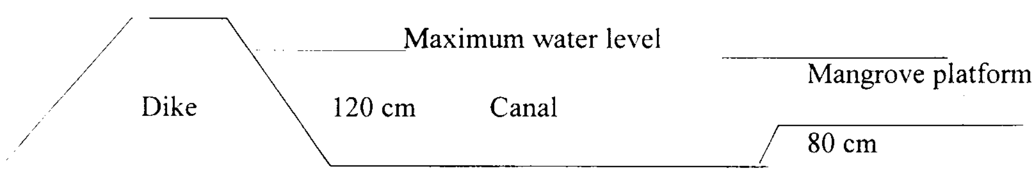


Pond sizes varied, with an average of about 1 ha.

Ratio:

Canal: 20-40%

Mangrove area: 60-80%



IV. Preparation

A. *Pond bottom drying*

Pond bottom is dried after the crop is harvested

B. *Pests and predators eradication*

Pests and predators are eradicated, by using teaseed and lime, prior to cultivation. A trap with fine mesh size or bamboo screen is operated in the gate during cultivation.

C. *Tilling of the canal bottom*

Tilling of canal bottom is usually carried out before cultivation.

D. *Fertilization*

Fertilizer is applied to increase pond productivity. This includes inorganic fertilizer, i.e. 100 kg Urea/ha and 50 kg TSP/ha, and organic fertilizer, about 500-1000 kg/ha.

V. Water Management

A. *Water exchange:*

1. For shrimp culture : 20%/day started at day 15 after fry stocking
2. For fish culture : 10%/3 days
3. For crab culture : 10-30%/2 weeks

VI. Stocking

A. *Monoculture*

B. *Stocking density*:

1. Milkfish culture : 7,500 fry/ha; size of fry = 40g/fry
2. Sea bass culture : 6,000 fry/ha; size of fry = 10 cm
3. Red tilapia culture : 8,000 fry/ha; size of fry = 10 cm
4. Shrimp culture : 15,000 fry/ha; size of fry = PL-16
5. Mud crab culture : 200 crabs/pen (2.5 x 1.2 x 1.5 m bamboo cage); size of fry = 50-70g/fry

C. *Fry production*

Fry of fish and shrimp are produced in hatchery

D. *Fry collection*

Fry of mud crab are collected from some coastal areas

VII. Feeding

A. *Type of feed*

1. Milkfish : bottom algae
2. Sea bass : trash fish
3. Shrimp : pellet
4. Crab : trash fish, meat of mollusk

B. *Source of feed and preparation*

1. Bottom algae : Naturally available
   Fertilization can increase the abundance of algae

2. Trash fish : By-catch of local fishing
   Mince the fish

3. Pellet : Supplier
   Commercially prepared

4. Mollusk : Collected from wild stocks
   Mince the mollusk

WISE-USE TECHNOLOGIES IN MANGROVE-FRIENDLY AQUACULTURE: VIETNAM EXPERIENCE

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I. Introduction

Vietnam has more than 3260 km of coastline, 112 estuaries, 12 large lagoons, bays, lagoon pools, river systems, ponds, water reservoirs, and inland hydroelectric reservoirs, which provide a great potential for aquaculture development. The potential surface water area is about 1,700,000 ha which includes small ponds and lakes (120,000 ha); water reservoirs and large water areas (340,000 ha); paddy fields for aquaculture (580,000 ha); and littoral areas (660,000 ha). In, addition, 300,000 ha of bays and lagoons in coastal areas are also suitable for aquaculture activities.

A. *Aquatic resources*

1. Freshwater fishes

About 581 species freshwater fishes are recorded, 240 of which are in the Red River Delta region, with 35 species having high economic value. In the Mekong River Delta region, 341 are recorded with 57 high-value species.

B. *Biological resources in coastal areas*

1. Fish

There are about 186 fish species, some are high-value such as grouper (*Epinephelus* spp.), amberjack (*Seriola* spp.), black kingfish (*Rachycentron canadum*), sea bass (*Lates calcarifer*), snapper (*Lutjanus* spp.), milkfish (*Chanos chanos*), striped mullet (*Mugil cephalus*). Some of these species are presently cultured such as grouper (*Epinephelus* spp.), amberjack (*Seriola* spp.), sea bass (*Lates calcarifer*), etc.

2. Shrimp

About 16 main species with high value are recorded and many of these are cultured such as the tiger shrimp (*Penaeus monodon*), white shrimp (*P. merguiensis*), Indian shrimp (*P. indicus*), taisho shrimp (*P. orientalis*), greasy-back shrimp (*Metapenaeus ensis*), yellow ringspiny lobster (*Panulirus ornatus*), and giant freshwater prawn (*Macrobrachium rosenbergii*).

3. Molluscs

According to some statistical data, there are about 690 species of molluscs found in the coastal areas. Some high-value species are cultured such as the pearl oyster (*Pteria martensii*), ark shell (*Anadara granosa*), blood cockle (*Arca granosa*), clam (*Meretrix* spp.), and oyster (*Ostrea rivularis*).

4. Seaweeds

About 90 high-value species have been identified, of which *Gracilaria* and *Sargassum* with high natural production, are being cultivated. The *Gracilaria* genus includes 13 species, the most important of which are *Gracilaria asiatica* and *G. blodgetti* which are used in the production of agar. On the other hand, *Sargassum* is used to extract alginate.

5. Mangroves

Mangrove forests are diverse ecosystem and abundant in estuaries and coastal areas. Mangroves provide not only forestry products but also habitats for marine species of high value and serve as nursery grounds for larvae of shrimps, crabs and fishes. An example of the role of mangroves in the aquatic ecosystem is illustrated in Figure 1.

The destruction and conversion of mangroves into large area extensive shrimp and fish ponds usually provide high profit only during the early years of operation. Afterwards however, the productivity usually decrease because the destruction leads to some serious effects to the natural resources and the environment. In order to solve this problem, the State recommended measures to rehabilitate the mangroves, improve farming technologies, and develop suitable and effective aquaculture systems in the mangroves areas.

This report refers to the status of aquaculture technologies in coastal areas in general. Some mangrove-friendly aquaculture systems in Vietnam are also discussed including several measures to develop aquaculture in mangroves suitably and sustainably.

II. Aquaculture in Vietnam

A. *General situation*

In almost 10 decades, aquaculture in Vietnam has developed rapidly in all three types of surface waters, namely, freshwater, brackishwater and marine water. From 1995 to 1998, aquaculture area increased at an average of 4-5%/year (597,000 ha in 1995 to 626,330 ha in 1998). In 1998, about 290,440 ha was used for brackishwater and marine water aquaculture or 46% of national total exploited area of which 225,000 ha was utilized for shrimp farming or 88% of exploited brackishwater area (Tables 1,2).

Aquaculture contributes around 30% to the national fish production as well as to the country's exports, particularly the shrimp export. In 1998, aquaculture output was 550,000 mt with total export revenue of about 400 million US Dollars or about 50% of the total export from fisheries (Table 3), accounting for 35-40% of the total export products.

The growth in aquaculture production from 1990 to 1998 is shown in Table 4, increasing from 300,850 mt in 1990 to 537,870 mt in 1998. The Mekong River Delta region is the main contributor to the national aquatic production with about 364,139 mt (1998) or 68% of total aquaculture output, followed by the Red River Delta region with its production of 69,242 mt or 13% of the total fisheries production. The products from aquaculture are mainly shrimps and freshwater fishes. For many years, finfish (mostly freshwater species) and shrimps (mainly marine species) contributed around 75% and 15%, respectively to the country's total fish production. The remaining 10% is shared by molluscs, mud crab, and seaweeds. The aquaculture of the species using various methods employs a big number of labor force. In 1998, approximately 550,00 people were employed in aquaculture which is about 15% of total labor force in fisheries. Tables 5 and 6 list the important species cultured in three types of habitats, namely, freshwater, brackishwater, and marine water.

However, the yield of the marine species is still considerably low due to the fact that Vietnam has not been successful in artificial seed production. The culture is entirely dependent on juveniles caught from the wild. On the other hand, production from freshwater aquaculture is rather high, specifically the production output from carps and tilapia culture, which is mainly for domestic consumption. Meanwhile, shrimp, crab and mollusc farming in brackishwater areas currently provide important production for export (especially the culture of shrimp, *Penaeus monodon*).

B. *Freshwater aquaculture*

Freshwater fish farming in ponds and small lakes is a traditional family farming in Vietnam which is widely practiced at the national scale. The VAC (Garden-Ponds-Livestock) farming system, integrating gardening with fish culture and animal husbandry has been developed. This system promotes the development of aquaculture in ponds and small lakes. Although freshwater fish farming area accounts for only 10% of the total aquaculture area, the yield comprises 60% of total aquaculture production.

The main freshwater species cultured in North Vietnam are the grass carp (*Ctenopharyngodon idella*), silver carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), Nile tilapia (*Tilapia niloticus*), rohu (*Labeo rohita*), and mrigal (*Cirrhina mrigal*). Recently, the culture of special high-value species such as soft shell turtle (*Palea steindachneri*), swamp eel (*Fluta alba*) and frog (*Rana sp.)* has been disseminated widely in North Vietnam, while the farming of sand goby (*Oxyeleotris marmorratus*) and giant prawn (*Macrobrachium rosenbergii*) has been developed in the South.

Fish and prawn farming in low-lying rice fields are also practiced in various provinces. In 1998, the low-lying fields area used for shrimp and fish farming was about 154,200 ha or 24.6% of the total aquaculture area. The Mekong River Delta provinces and Red River Delta region are the main areas where fish and prawn culture are integrated with rice farming.

1. Farming methods

Alternate farming of prawn + rice or rice + Nile tilapia is practiced in the Mekong River Delta where the prawn productivity was 200-300 kg/ha/yr and rice output was around 506 mt/ha/yr. Moreover, integrating fish culture with rice or rice with giant prawn is also practiced in North Vietnam where the main fish species are the common carps (*Cyprinus carpio*), Nile tilapia (*Tilapia niloticus*), mud carps (*Cirrhina molitorella*), rohu (*Labeo rohita*), etc. On the other hand, the main species cultured in the South are the silver carp, snake head, kissing gourami, and giant prawn.

Fishes are also cultured in floating cages in rivers and water reservoirs. According to the 1998 statistics, Vietnam has about 16,000 freshwater floating cages of which about 12,000 cages are installed in rivers. There are also industrial aquaculture models in large surface water areas such as in lakes and reservoirs with productivity of around 60-100 kg/ha/m^3. In the Southern provinces, the main species cultured are yellow catfish, sand goby and snakehead. Yellow catfish (*Panggasius* spp.), a high-value fish for export, is exclusively cultured in the Mekong River Delta, particularly in An Giang province where floating cage culture has been practiced for years. The cages are of varying sizes, between 100 to 150 m^3/cage. In the Northern and Central provinces, the dominant species are grass carps and common carps which are cultured in small-sized cages, about 20-30 m^3/cage. Grass carp cage culture is practiced in rivers and water reservoirs, near water inlets or outlets where water exchange in the cages is good.

In 1998, about 335,890 ha of freshwater area was used for inland freshwater aquaculture, and the total freshwater fish production was estimated at 359,000 mt (Table 3) or about 68% of total aquaculture production. Of this total, 70% were grass carps, common carps, and rohu. The Ministry of Fisheries (MoF) in 1998 estimated around 353 freshwater hatcheries in Vietnam, producing more than 6 billion fish fry/year, sufficient enough to supply the demand from freshwater aquaculture.

C. *Coastal aquaculture*

1. Production systems

Coastal aquaculture in ponds uses more than 2 ha to over 100 ha, where most of the large ponds are in intertidal areas and are used for intensive culture. Whether small or large area, each pond has only one or two gates for tidal water exchange, entry for seeds, and water level adjustment. On the other hand, aquaculture in estuaries and tidal flats is also practiced by fishermen using fish-nets or bamboo fence to round up the tidal flats for the culture of mollusc species such as clam, blood cockle, and ark shell.

Fish and mollusc cage culture in coastal areas is a relatively new activity in Vietnam. Fish cages are installed mainly in estuaries and bays where there is least impact by strong winds. Each cage is from 27 m^3 (3m x 3m x 3m) to 64 m^3 (4m x 4m x 4m), of which 6-8 cages are combined in one raft. The cages however, can be separated and moved to a safer place during the onset of typhoons.

2. Culture species

Table 6 lists the main species cultured, the culture methods and the scale of operation. The most important species cultured in marine waters are groupers (*Epinephelus* spp.), amberjack (*Seriola* spp), black kingfish (*Rachycentron canadum*), yellow ringspiny lobsters (*Panulirus ornatus),* and pearl oyster (*Pteria martensii*). Up to now, Vietnam produces only pearl oyster seeds, while marine aquaculture in general is still entirely dependent on the juveniles caught from the wild.

For brackishwater aquaculture, the dominant species are tiger shrimps (*Penaeus monodon*), white prawn (*P. merguiensis*), greasy-black shrimp (*Metapenaeus ensis*), serrated mud crab (*Scylla serrata*), clam (*Meretrix* spp.), and seaweeds (*Gracilaria* spp.). At present, only shrimp and seaweed seeds are produced in the hatcheries, but for some other species, culture is still dependent on juveniles caught from the wild.

3. Shrimp farming in brackishwater ponds

Shrimp culture is the most important industry in the coastal zones of Vietnam. Although shrimp extensive farming was recently started, it became one of the most important aquaculture practices in the early 80s in terms of area under culture, production, employment, and export volume. In 1998, shrimp farming in littoral area used about 255,000 ha or 39% of the estimated potential area in coastal zone with a production of around 80,000 mt. In Minh Hai province, shrimp farming area accounted for 50% of the total national shrimp culture area (Table 2 and Figure 3). Today, there are 1358 shrimp hatcheries in Vietnam, mostly located in the Central provinces with an annual production of about 2.5 billion PL_{15}. In general, the shrimp culture methods used are the extensive and intensive systems, utilizing small areas but low in productivity. According to the statistics of the coastal provinces, in 1998 the area for semi-intensive and intensive culture was around 30,000 - 40,000 ha.

a. Traditional extensive culture

(i) Suitable pond sites

Ponds are usually constructed in the middle zone of the tidal areas where water can be changed easily by tidal movements. The ponds are near the river mouths, mangrove areas and canals where there is abundant supply of shrimp seeds and natural food. The sites usually have favorable salinity ($\geq$ 5% in rainy season), clean water source and far from inland pollution, and the pond bottom soil is sandy-muddy.

(ii) Pond construction

Ponds are large with areas ranging from > 2.0 ha or 10-30 ha or even up to 100 ha or more. Each pond has one or two gates (the width of gates depends on the pond area) for water exchange, seed supply entry and water level adjustment. Canal systems in the ponds help water exchange, especially since the ponds are located outside the National Dike system. The pond edges are built strong enough to protect the ponds from typhoons and floods.

(iii) Management

Water exchange rely on the tidal movement and the natural seeds, food and nutrients that enter the ponds with the incoming water. Culture is for 9-10 months in the north or two months in the Mekong River Delta region (Minh Hai province). In some areas, farmers stock tiger shrimp seeds at 0.2-0.4 pc PL_{45}/m^2) in extensive ponds. Since natural food is available in the ponds, supplementary food is no longer introduced.

(iv) Harvesting

Harvesting is usually done before the onset of the new moon, because it is believed that at this time the shrimps' carapace is hard. Farmers use bamboo fish-traps to harvest the shrimps and the ponds are later dried to gather extra fishes, crabs, and seaweeds.

In 1980s, mangrove areas were converted into extensive shrimp ponds in the coastal provinces, particularly in Mekong River Delta. The model introduced is known as the shrimp-cum-forest which however, negatively affected the environment and the mangrove ecosystems. Although the productivity from such model was stable, it is largely dependent on the site of the ponds, the availability of wild shrimp seeds and the efficient water exchange in the ponds. The average production recorded was 70-250 kg/ha/yr, the maximum of which was 400 kg/ha/yr attained by some farms in Minh Hai province.

b) Improved extensive culture

This model is usually carried out in ponds about 2-10 ha and protected from predators. The farmers add more shrimps into extensive culture shrimp ponds at 1-3 pc/m^2 (2-3 cm/pc). Therefore, there are two shrimp seed sources used, from natural source and from the hatcheries.

After stocking the seeds in the large ponds, artificial food is given on the first month. During the second month, minced molluscs, trash fish, small shrimps or artificial food are given in the areas where shrimps are seen to be dense. Water in the ponds is changed more often to avail of the nutrients supply from nature. When changing water through the gates, nets and bamboo traps are installed near the gates to avoid shrimps from getting out from the ponds and to prevent predators from coming into the ponds.

The survival rate in this system is 30-60% for a culture period of 3-5 months depending on the cultured species and the natural conditions. Shrimps are harvested using bamboo traps installed in the ponds. Productivity is about 50-400 kg/ha/yr but in the Mekong River Delta, productivity has been at 500 kg/ha/yr or more. This model is now rapidly transferred to the other coastal provinces.

c) Semi-intensive culture

(i) Site selection and pond construction

Ponds may be rectangular or square, with an area of 0.5-1.0 ha. The pond bottom is flat with 0.5% drainage gates. The depth is from 1.0 to 1.4 m. In areas near river mouths, the ponds are surrounded with mud. The pond bottom is mud-sand or sand-clay and salinity is 25‰ (not lower than 5‰ during the rainy season). Seawater change is by high tide and freshwater is supplied using water pumps.

The procedure for shrimp semi-intensive culture follows:

Pond preparation ➡ Stocking of seeds ➡ Management ➡ Harvesting

(ii) Pond preparation

This includes killing the predators, draining dry the pond bottom (for 5-7 days), liming (1000-2000 kg/ha), and applying inorganic fertilizer (Urea: 20-25 kg/ha and phosphate: 10-15 kg/ha).

(iii) Management

Shrimps are fed twice a day, once in the morning and afternoon. Food may consist of minced mollusc, trash fish, small shrimps or artificial food, and rice bran. Quantity of food for each stage of shrimp in the culture pond are calculated as follows:

Stages of culture shrimp	Survival rate	Rate (%) of quantity of food based on total biomass of shrimp in the culture ponds
From PL_{15} to 5 g/pc	Estimate at 90%	30%
From 6-10 g/pc	Estimated at 80%	20%
From 11-15 g/pc	Recalculated	10%
From 16-20g/pc	Recalculated	7%
From 21g/pc or more	Recalculated	4-5%

The food in feeding trays should be regularly monitored to regulate the feeding regime for the succeeding days. From the third month, shrimp should be fed four times/day: at 6, 11,17 and 21 Hr. Water change must take advantage of high tide, changing at least 200% of the water volume of the pond during each tidal cycle. In areas where water pumps are used, water should be supplied opposite the drainage gates. During heavy rains, the surface layer of the pond water should be changed. The culture duration is three months for *P. merguiensis* and 4-5 months for *P monodon*.

(iv) Harvesting

This is done before the onset of the new moon because it is believed that at that time the carapace of the shrimps is hard. Harvesting may make use of bamboo traps within 3-4 days before drying the pond for total harvesting. The shrimp productivity in the North is from 700-1000 kg/ha/crop, in the South (Mekong River Delta) from 1500-2000 kg/ha/crop. The North is characterized by seasonal variation in temperature which allow only one or two crops/yr. In the first season, tiger shrimp (*Penaeus monodon*) is cultured from April to August. During the next season, white prawn or taisho prawn is cultured from September to November and from February to May.

The South has favorable conditions throughout the year where 2 to 3 cropping can be made. However, in poorly planned ponds, the use of waste water which is supplied to other ponds and raw food as feed, could cause pollution and diseases outbreak. This has very serious consequence to aquaculture.

d) Shrimp semi-intensive in closed systems

In order to prevent environmental pollution and the spread of diseases, the Research Institute of Marine Products developed new techniques of shrimp culture in closed system, where water is processed before this is supplied to the ponds. This model was found to be effective especially in the coastal provinces where shrimp culture is practiced.

In the semi-intensive closed system, the waste water of the shrimp ponds is poured into the mollusc or seaweed culture ponds (biological treatment) and after some time released to sediment ponds for chemical treatment. The water in the treatment ponds is used to fill up the shrimp ponds. The area for seaweeds culture and water treatment is about 50-80% of the shrimp culture pond area (Fig 4). For this system, artificial feeds should be used.

Results from this model showed that the shrimp productivity was from 1,500 2,000 kg/ha/crop in the north and 2,000-3,000 kg/ha/crop in the south. This model eliminates environmental changes and the spread of diseases

e) Intensive culture

Intensive culture requires high technical management, high investment for seeds and artificial food, pumping, and aeration. This model has been experimented by VATECH in Da Nang City in 1989 and in Thai Binh province in 1994 by a Taiwan company. The results from their projects were not stable, although the maximum yield was 4 /ha/crop in some ponds. Since the model was found not effective, both companies stopped their operations.

f) Integrated culture

This is an improved model in large ponds, from 2 to 10 ha. In addition to the number of shrimps and fish caught from the wild through the gates, farmers add tiger shrimp seeds at 02-0.5 pc/m^2 (3-4 cm/pc), crabs at 0.1-0.2 pc/m^2 (20-25 g/pc), and *Gracilaria asiatica* at 0.2 kg/m^2. In some ponds, supplemental food is added such as trash fish and small shrimps. The main food is the nutrients available in the ponds. Shrimp productivity is from 150-200 kg/ha/crop (including natural seed and stocked seeds); crabs: 100-150 kg/ha/yr; *Gracilaria asiatica*: 800-1000 dry kg/ha/yr; and fishes. Other combination adopted is integrating the culture of tiger shrimp, Nile tilapia and *Gracilaria asiatica,* a common practice in the North.

4. Crab semi-intensive culture in ponds

a. Pond construction

Ponds for crab culture, 1000-10,000 m^2 are built like the shrimp ponds but the dike's crown is fenced to prevent the crabs from escaping.

b. Stocking

Crablets are collected from the wild and stocked at 0.5-1.0 pc/m^2 or 2-3 pc/m^2 (40-50g/pc) depending on the culture season. In the North, crabs can be cultured in two seasons, the first season is from March to August while the second is from October to February. In the South, crabs are cultured all year round, but the main season is from October to February.

c. Feeding

Food for the cultured crabs are small bivalves, snails, and trash fish. The quantity of food given daily is 7-10% of the total biomass of the crabs in the ponds (if the food consists of small shrimp or trash fish) and up to 30% (for molluscs). The food is broadcast all over the pond twice a day, once in the morning and late in the afternoon.

d. Management

The quality of water in the ponds should be regularly monitored. In the rainy season if the pH decreases, lime is spread on the pond dikes at 5-10 kg/m^2. Water should be changed as often as possible.

e. Culture duration

The culture duration depends on the size of the crablets, feeding regime and culture models. If stocking is 40-500 g/pc crablets, the crabs can be harvested after 4-5 months. If the crablets intended for semi-intensive culture are smaller, the pond area can be used for extensive or improved extensive culture combined with tiger shrimp.

5. Seaweeds culture

Gracilaria culture in ponds has rapidly developed in the Northern and Central coastal provinces, particularly, from Hai Phong City to Thanh Hoa and Thua Thien Hue province. According to some algologists, 13 species of Rhodophyta are identified in the coastal zones of Vietnam, of which three are of economic value, namely, *Gracilaria asiatica, G. blodgetti* (cultured mainly in the North) and *G. tenuistipitata* (in Central) which are used to produce agar. About 3000-3500 ha of brackishwater ponds is used for *Gracilaria* spp. culture with an annual production of about 2000 dry tons/yr. *Gracilaria asiatica* is cultured in brackishwater using two models: improved extensive culture combined with brackishwater shrimp, crab and fish culture in large ponds, 2-10 ha or more producing about 500-1000 kg/ha/yr; and intensive culture in small ponds, 0.5-2.0 ha. The culture system includes many small ponds having main canal systems and separate water supply, and drainage systems which guarantee maximum water change.

In pond preparation, all harmful seaweeds and tree roots are taken out, and a layer of soft mud on the pond bottom is formed. Lime is spread on the pond bottom (2-3 mt/ha) fertilized with organic manure (8-10 mt/ha) and phosphate fertilizers (0.8-1 mt/ha). Stocking density is 500 - 600 g/m^2, spread carefully over the pond bottom. The water depth is kept at 35-40 cm in winter and 40-50 cm in summer. After 35-35 days, the stock is harvested leaving some 500-600 g/m^2. After every harvesting, supplemental fertilizers are added using the following scheme: organic manure (3-4 mt/ha) or inorganic manure (Urea: 20-30 kg/ha and phosphate: 10-15 kg/ha). Using this system, production has been recorded to increase by 2-4 mt/ha/yr.

On the other hand, from 1993, Vietnam started to develop *Eucheuma* culture in the Central coastal zone. The main species cultured are: *Kappaphycus alvarezii, Eucheuma gelatinae* and *E. denticulatus,* using either fixed culture method on mono line near sea bottom; floating frame culture method; or bottom culture in calm bays or pond with high salinity.

6. Mollusc in estuaries and tidal flats

In recent years, *Meretrix* spp. and *Arca* culture have rapidly developed in the northern and southern provinces. Fishermen use fish nets or bamboo fence to round up the sheltered areas in the estuaries or tidal flats where the ground bottom is flat, to culture *Meretrix* spp. and *Arca*. The area of each farm is about 1.0 ha. *Meretrix* and *Arca* spat are collected from the wild with a diameter of about 0.5 cm or more. The spat is spread equally at 2000-3000 pc/m^2. The bottom of the cockle culture ground should be flat, muddy and sandy: the depth at high tide 2-3 m. On the other hand, *Meretrix* spp. ground culture areas are near the estuaries with a salinity range of 10-25‰, while *Arca* culture ground have higher salinity at 20-30‰.

The natural food for the *Meretrix* spp. and *Arca* is phytoplankton and after 4-6 months of culture, partial harvesting may be done followed by total harvesting. The productivity from this method is over 10 mt/ha/crop. Vietnam's total production of *Meretrix* and *Arca* in 1998 was about 115,00-120,000 mt.

7. Pearl oyster cage culture

In Vietnam, pearl oyster is cultured in coastlines to produce pearl. All over the country, 21 companies mainly located in Quang Ninh and Khanh Hoa province, are engaged in this industry. In the North, *Pteria martensii* is the dominant species while in Central Vietnam, *Pinctada maxima* is cultured. The pearl oyster seeds are produced in hatcheries and at the same time spat are also collected from the wild.

Raft culture is a typical method used in pearl oyster farming in sheltered bays. The pearl oyster raft is about 30-50 m^2, with water depth of 4-6 m. Generally, pearl oyster farms are located in the calm bays or straits with clean water and high salinity (20-30‰). Pearl oyster cages are rectangular or square shaped (40x 60x 15 cm) or a frustum of a cone (bottom and upper diameter: 30 and 25 cm; height: 15 cm). Each cage can contain 20-25 pc pearl oysters which are suspended from rafts or long line using synthetic ropes. In producing the pearl, a mantle piece from a donor oyster is grafted into the gonad of the recipient oyster, along with a spherical nucleus.

8. Marine cage culture

Marine fish cage culture in Vietnam has been developed in recent years. Based on the statistics in 1998, there was a total of 2,590 floating cages. Generally, cages are rectangular or cubic with volume from 8 to 75 m^3, cage size is 2 x 2 x 2 m or 3 x 3 x 3 m. Cage is made of synthetic net (mesh size: 2a=1 cm) and tied to wood frame with a buoy system as floats. The shape of the cage bottom is fixed by a square frame. The position of the cage bottom is at least 1.0 m from the sea bottom. The size of cage for commercial culture is 3 x 3 x 3 m or 4 x 4 x 4m (mesh size: 2a=3 cm), water current: 0.2-0.5 m/s, and salinity at 18-35‰.

The main species cultured are grouper (*Epinephelus* spp.), snapper (*Lutjanus* spp.), black kingfish (*Rachycentron canadum*), seabream (*Sparus latus*), yellow ringspiny lobster (*Panulirus* spp.). However, seed supply is still dependent from the wild. Fingerlings (50 g/pc) are stocked at 40-60 pc/m^3. Minced trash fish is given twice a day (morning and afternoon) at about 10% of the weight of cultured fish. After 2-3 months of culture, the weight of fish should be more than 150 g/pc.

Grouper fry, 150-180 g/pc is stocked in cages at 20-25 pc/m^3. The main food is trash fish and minced mollusc, feed once a day at 1700 Hr at 5% of the weight of the cultured fish. Culture facilities are checked and cleaned regularly to avoid the accumulation of harmful organisms. Harvest can be done after 5-8 months when the weight of the fish reaches 600-1500 g/pc.

III. Consequence of Shrimp Extensive Ponds to the Mangrove Ecosystem

Before 1990, the conversion of mangroves to shrimp extensive ponds took place only in the coastal provinces, particularly in the Red River Delta and the Mekong River Delta. This activity had caused serious problems to the natural resources and the environment.

A. *Reduction of biodiversity resources*

Resource reduction has taken place mainly in extensive ponds because of the deforestation and conversion of mangroves to large shrimp pond areas. Due to the absence of gates, the water in the ponds could not be easily changed making the environment heavily polluted and reducing the number of species in the ponds. Researchers P.N. Hong and L.D. An (1992) showed that the quantity of phytoplankton and benthos, used as food by shrimps, had also reduced relatively two years after the construction of shrimp ponds specifically in the western derelict land of Ca Mau. This has been brought about by the rapid growth of *Oscillatoria* and when the plant dies covering the pond bottom., this is accumulated as H_2S and NH_4 through some chemical processes, which are toxic to the cultured species. Research results of the Research Institute of Aquaculture II showed that the degradation of the environment and the reduction of organisms content, are common in shrimp ponds in Ben Tre province.

B. *Increase in the area of barren land*

Deforestation and conversion of mangroves to shrimp ponds or agricultural production farms led to the increased area of waste and barren land. Shrimp extensive ponds may be profitable in the early years but afterwards the productivity may decrease and make the area less productive. Moreover, large ponds are difficult to manage especially the change of water by tide, thus, in many cases, the environment becomes deteriorated. According to the statistics of Minh Hai Forestry Department, from 1993 about 86,037 ha of mangroves was destroyed of which 20,000 ha was converted to farms for agriculture production. Due to shortage of freshwater, the land has degraded and become unusable for farming, an example of a barren waste land.

C. *Speed up siltation and erosion*

Mangroves act as fence protecting the coastal dike systems. Due to the destruction of mangroves, typhoons and big waves had caused erosion and flood over a vast areas. This is a critical problem for many provinces, including those in the coastal areas such as Nam Dinh, Tra Vinh Tre and Tien Giang province.

D. *Land and water pollution*

Due to the large area of the ponds which makes it difficult to change water, H_2S and NH_3 contents derived from tree leaves, roots, and other poisoning matters, also increased. The ratio of Fe_2O_3/FeO also increases as well as the SO_4^{2-} content, due to the drying of the pond and oxidization (N.V. Cu, 1990). This can be expressed using the following reaction:

$$FeS_2 + O_2 + H_2O \Rightarrow Fe^2 + SO_4^2- + H^+ + OH^{-2}$$ or

$$Fe^2 + SO_4^{2-} + O_2 + H_2O + K^+ \Rightarrow KFe_3(SO_4)_2(OH)_6 + H^+ + SO_4^{2-}$$

As a result, the once natural and nutrient laden land becomes a sulfate waste land, which is not suitable for the culture of aquatic species.

E. *Spread of diseases*

In some culture ponds, water could be affected with diseases due to microorganisms and fungi. It should be noted that the shrimp diseases outbreak in recent years have not been completely solved. Measures to prevent diseases were not applied thoroughly, thus, adversely affecting the productivity. Diseases had spread widely in shrimp extensive culture ponds in Ho Chi Minh City, Ben Tre and Minh Hai province, posing danger to the other pond areas in the country.

IV. Mangrove-Friendly Aquaculture

Mangrove-friendly aquaculture is an integrated mangrove tree culture with aquaculture. It is an approach of conserving and utilizing the mangrove ecosystem, while maintaining the economic benefits. Over the past ten years, many aquaculture models under silvo-fisheries received financial support from various sources, in order to protect the mangrove forests. In this report, some models applied in Vietnam, are briefly introduced for reference.

A. *Mangrove-friendly aquaculture models*

1. Mollusc culture

Carithides eingulata culture started in 1995 using a simple culture technique where mangrove area of about several thousands m^2 is fenced and stocked with hundreds of the mollusc seeds. After 4-6 months without feeding, when the weight of the stock is more than three times the stocking weight, the molluscs are harvested.

Cockle and clam culture is done in flat ground bottom which is muddy and sandy near the mangroves. The culture is simple but could give high benefits. Cockle and *Meretrix* culture are now developing rapidly in the Mekong River Delta provinces and the Red River Delta region.

2. Crab cage culture (*Scylla serrata*)

A model developed in 1990 involves cages made of bamboo or wooden frames 1.2m x 2m x 5m, with buoys all around to make the cages float, making sure that about 4/5 of the cage is under water. The stocking rate is 40-50 pc/m^3 and fresh food consisting of trash fish and small shrimps, is given. After 20-25 days, the stocks may be harvested.

3. Yellow ringspiny lobster (*Panulirus ornatus*) cage culture

This model adopted in Can Gio (Ho Chi Minh City), is similar to the crab cage culture with stocking density of 50 pc/cage and food is dependent on the sea organisms. The lobsters are cultured from July to February in cages which are mainly located at the edge of the mangroves near the sea.

4. Greasy grouper (*Epinephelus tauvina*) culture in ponds

Groupers are cultured in small ponds with an average area of 200 m^2 and stocked with 30-40 pc/pond. When the weight is about 200-300 g/pc, fresh food such as trash fish and small shrimps are given. After 5-6 culture months, the fish weighing about 600-700 g/pc, are harvested.

5. Shrimp (*P. monodon*) culture in ponds

Shrimp is cultured in small ponds, from 500 to 2000 m^2 at 5 pc/m^2. In the Mekong River Delta, shrimp can be cultured in two crops per year. Average productivity is 800-1200 kg/ha/crop. This is the shrimp culture model under the mangrove forests, which if properly planned will not affect the mangroves.

Aquaculture under mangrove forests is unavoidable, but the established aqua-silviculture principles must be followed. The need for proper techniques in seed production for each species and proper planning of the mangrove areas, should therefore be considered.

B. *Silvo-fisheries model*

1. Culture ponds consisting of mangroves

Many regions in the Mekong River Delta, such as Ngoc Hien, Minh Hai and some areas in Ben Tre province invested in silvo-fisheries specifically in *Rhizophora apiculata* and *Bruguiera* spp. forests. A model has been developed to control water and ensure the natural condition of the mangrove areas using gates and canal systems. Gates were constructed in such as way that during the high tide there is enough water for the mangroves and at the lowest tide, water level must be 50 cm in the canal system. It is necessary that a separate water supply and drainage systems be provided (Figure 5 and Figure 6). The ratio of culture pond and mangrove area is 1:4 and in any case, the farming pond area should not be over 30% while the mangrove area is 70%. The main culture species of this model is tiger shrimp (*Penaeus monodon*) and white prawn (*P. merguiensis*), using the improved extensive culture system.

2. Mangroves including culture pond

A model of a 10 ha mangrove including a culture pond which can be managed by a family, makes use of a suitable area where small-scale shrimp ponds and seaweed culture farms (Fig 7) can be constructed. The total farm area is 10 ha to be managed by one family, which can be divided into shrimp culture pond, 4 or 2 ponds = 2 ha; seaweed and fish culture pond combine with waste water treatment pond 7000 m^2; water treatment pond 3000 m^2; and mangrove area with crab culture by net or cage 7 ha. This model could also be adopted in the culture of shrimp in closed-system in mangrove areas with a ratio of 3:7 ha culture area to mangrove area. Tiger shrimp is stocked at 10-12 pc/m^2 (3-4 cm/pc). After four culture months (in the North from March to July), shrimp production is from 1000 to 1500 kg/ha/crop and *Gracilaria* production is 2500-3000 dry kg/ha/year. Additional produce may consist of fishes, crabs and molluscs.

3. Shrimp culture in closed-system in high tide areas

To ensure the existence and maintain a renewable mangrove ecosystem, and prevent environment pollution and the spread of shrimp diseases, this model has been adopted in high tide areas near mangroves or in the National Dike system. The total area utilized is 2.0 ha, 1.0 ha of which is for shrimp culture pond, 0.5 ha for *Gracilaria* spp. culture, and 0.3 ha. to 0.5 ha for water treatment (Fig. 8).

The depth of shrimp culture pond is 1.2 m, the main species stocked is tiger shrimp at 10-12 pc/m^2 (3-4 cm/pc), and cultured for four months. In this model, shrimp production was about 1000-1500 kg/ha/season while *Gracilaria* production was 3000 dry kg/ha/yr. This model which was implemented at the Research Institute of Marine Products has been transferred to some coastal provinces in the North.

V. Aquaculture Development in Mangrove Areas

A. *Seed production*

Except for the shrimp seeds, other species seeds are caught from the wild, causing some difficulty for aquaculture development in mangrove areas. There is therefore a need to carry out a study on artificial seed production of marine fishes (e.g. groupers, sea bass, seabream), crabs and molluscs (*Meretrix, Arca*). Moreover, there is also a need to improve the quality of shrimp seeds for culture. The State is also encouraged to grant some capital through loans to help improve the techniques in seed production for aquaculture development and management at the national or local level.

B. *Improved culture techniques in mangroves*

Mangrove environment has some advantages and disadvantages for shrimp culture. In order to get high productivity, suitable sites for ponds should be targeted where change of water volume by tidal movement is possible. Farmers must be provided with capital and taught the proper techniques to convert the areas once used for extensive culture into improved extensive and semi-extensive culture areas.

A separate water supply canal and drainage system must be constructed to minimize pollution. The shrimp culture pond system should also have a water storage pond while siltation and treatment ponds should form part of the waste treatment system. Moreover, crab and fish cage culture can also be located in the canal systems of the mangrove area.

The ratio of aquaculture area to mangrove area must be kept at 1:3. Arrangement for technical training course on silvo-fisheries should be made for the fishermen. The training may be aimed at attaining high productivity, and at developing environmentally sound and sustainable aquaculture in mangrove areas.

C. *Socio-economic and population management in mangrove area*

Mangrove as a vital resource serves as sanctuary for fishes and other marine animals. However, mangroves have long been exploited by people from the localities and other places who deforest and convert mangroves to shrimp culture ponds. In many cases, the local people even give up their traditional jobs to do extensive shrimp farming. If this continues, the mangroves will also be continuously destroyed including the marine resources. Some solutions to the outstanding problems were therefore identified to include the following:

1. Equal policy of handing land, forest and surface water to farmers for culturing marine products in order to recover the mangroves;

2. Provision of capital and promotion of technical culture using silvo-fisheries model in small areas;

3. Establishment of an education program on mangroves and mangrove resources protection in schools; and

4. Improving the methods of population control and community management plan to formulate suitable socio-economic models.

Table 1. Estimated aquaculture resources in Vietnam (in ha)

STT	Regional Resources	Esti. Potential (EP) (ha)	Esti. usable Areas (ha)	Estimated area exploited 1985	1994	1998
1	**North Mount/Midland**					
	Freshwater area	149,626	116,250	50,200	55,620	59,088
	Brackishwater area	28,000	20,135	2,500	12,055	12,565
	Total	165,624	136,380	52,700	67,675	71,653
2	**Red River Delta**					
	Freshwater area	83,062	77,866	42,700	51,229	52,977
	Brackishwater area	72,652	43,420	4,200	11,218	18,115
	Total	155,714	121,286	46,900	62,447	71,092
3	**North and South central coast**					
	Freshwater area	123,000	54,607	24,500	28,839	33,079
	Brackishwater area	70,430	55,632	8,100	19,972	21,481
	Total	193,430	110,234	32,600	48,811	54,560
4	**Central Highlands**					
	Freshwater area	85,000	38,000	2,500	4,235	9,612
	Total	85,000	38,000	2,500	4,235	9,612
5	**South-East Area**					
	Freshwater areas	105,565	60,500	25,000	53,880	40,145
	Brackishwater area	28,510	13,230	3,500	7,593	5,455
	Total	134,075	73,730	28,500	61,473	45,600
6	**Mekong River Delta**					
	Freshwater area	504,000	270,000	139,600	63,613	142,989
	Brackishwater area	460,410	282,000	48,700	237,739	232,824
	Total	964,410	552,000	188,300	301,352	373,813
	Total					
	Freshwater area	1,041,253	617,223	284,500	257,416	335,890
	Brackishwater area	660,002	414,417	67,000	288,577	290,440
	Grand Total	**1,700,178**	**1,031,630**	**351,500**	**545,993**	**626,330**

Table 2. Potential and status of freshwater, brackishwater and marine area for aquaculture (As of 1998)

Regions	Freshwater												Brackishwater and marine area		
	Total Freshwater area			Small ponds and lakes			Water Reservoirs			Low-Lying fields			Coastal areas, Bays, Lagoons		
	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)
North mount. Midland	149,626	116,250	59,088	30,000	30,000	18,000	80,315	65,482	30,825	31,314	20,765	10,236	28,000	20,135	12,565
Red River Delta	83,062	77,866	52,977	42,000	42,000	32,897	15,631	15,631	9,740	25,431	20,235	10,340	72,652	43,420	18,115
North and South Central Coast	123,000	54,607	33,079	13,000	10,000	9,765	110,000	42,107	21,235	7,000	2,500	2,079	70,430	55,632	21,481
Central Highlands	85,000	38,000	9,612	5,000	3,000	1,210	70,000	35,000	8,402	—	—	—	—	—	—
South-East Area	105,565	60,500	40,145	10,000	8,000	4,850	65,000	40,000	28,540	32,000	12,500	6,755	28,510	13,230	5,455
Mekong River Delta	504,000	270,000	192,989	20,000	20,000	15,974	—	—	208	484,225	250,000	124,837	460,410	282,000	232,824
Grand Total	1,041,253	617,223	335,890	120,000	113,000	82,696	340,946	198,220	98,977	579,970	306,000	154,217	660,002	414,417	290,440

Table 3. Main results of aquaculture, Vietnam (1995-1998)

Order	Items	Units	Annual Results				Note
			1995	1996	1997	1998	
I	Aquaculture areas	Ha	597,000	600,000	606,000	626,330	
1	Freshwater area		380,000	370,000	346,000	335,890	
2	Brackishwater area		217,000	270,000	270,000	290,440	
II	Aquatic Productivities	Ton	459,950	411,000	509,000	537,870	
1	Freshwater productivities		370,128	348,649	342,622	359,000	
2	Brackishwater productivities		89,820	92,351	166,378	178,870	
III	Export	Million USD	200	250	300	400	
IV	Employment	Person	422,500	457,634	500,000	550,000	

Table 4. Total aquaculture production (Unit: mt)				
	1986	**1990**	**1994**	**1998**
North Mount./Midland				
Total	14,336	20,919	24,115	32,375
% of Grand Total	6.16	6.95	6.08	6.04
Red River Delta				
Total	31,090	37,810	44,200	69,242
% of Grand Total	13.21	12.57	11.15	12.92
North and South Central Coast				
Total	14,630	21,250	27,237	37,710
% of Grand Total	6.23	7.06	6.87	7.04
Central Highland				
Total	1,330	2,550	6,280	4,624
% of Grand Total	0.57	0.85	1.58	0.86
South-East Area				
Total	10,930	22,610	17,430	27,780
% of Grand Total	4.65	7.51	4.39	5.18
Mekong River Delta				
Total	162,520	195,711	277,057	364,139
% of Grand Total	69.21	65.04	69.90	67.96
Grand Total	**234,836**	**300,850**	**396,319**	**535,870**

Table 5. Main freshwater aquaculture species, Vietnam

Scientific Name	English Name	Vietnamese Name	Culture Method	Culture Volume
Anabas testudineus	Climbing perch	Ro dong	RF, NS	Low
Aristichthys nobilis	Bighead carp	Me hoa	P, R, HS	Low
Catla catla	Catla	Catla	P, HS	Low
Cirrhina mrigal	Mrigal	Mrigan	P, HS	High
Cirrhina molitorella	Mud carp	Troi ta	P,R, HS	Medium
Clarias macrocephalus	Walking catfish	Tre vang	P,T, NS, HS	Low
Clarias gariepinus	African catfish	Tre phi	T, HS	Low
Clarias hybris	Catfish hybrid	Tre vang lai	P.T. HS	Low
Ctenopharyngodon piceus	Grass carp	Tram co	P, R, FC, HS	High
Cyprinus carpio	Common carp	Chep	P, HS	High
Helostoma tenmincki	Kissing gourami	Mui	P, HS	Low
Hipophthapleichth molitrix	Silver carp	Me trang	P, R, HS	High
Milopharyngodon piceus	Snail carp	Tram den	P, R, HS	Low
Labeo rohita	Rohu	Rohu, Troi an do	P, R, HS	Low
Leptobarbus hoeveni	Slender carp	Chai	P, RF, NS	Low
Fluta alba	Swamp eel	Luon dong	T, NS	Low
Notopterus notopterus	Featherback	That lat	RF, NS	Low
Ophiocephalus striatus	Snake head	Loc	P, RF, NS	Medium
Ophiocephalus micropeltes	Snake head	Loc bong	FC, NS	Medium
Oreochromis niloticus	Nile tilapia	Ro phi	P, RF, HS	High
Osphronemus gourami	Giant gourami	Tai tuong	FC, P, HS	Low
Oxyeleotris marmorratus	Sand goby	Bong tuong	FC, P, NS, HS	Medium
Panggasius bocourti	Yellow catfish	Basa	FC, NS, HS	High
Panggasius hypophthalmus	Catfish	Tra nuoi	P, NS, HS	High
Barbus gonionotus	Silver carp	Me vinh	P, FC, RF, HS	High
Puntius altus	Tinfoil carp	He vang	P,FC,RF,NS,HS	Low
Trichogaster pectoralis	Snakeskin gourami	Sac ran	RF, NS	Medium
Pelodiscus sinensis	Soft-shell turtle	Baba tron	T, P, NS	Low
Palea steindachneri	Soft-shell turtle	Ba ba gai	T, P, NS	Low
Rana spp	Frog	Ech dong	T,P, NS	Low
Macrobranchium rosenbergii	Giant prawn	Tom cang xanh	P, RF, NS, HS	High

P: Pond; **RF**: Rice field; **T**: Tank; **FC**: Floating cages; **R**: Reservoirs; **NS**: Natural Seed; **HS**: Hatchery Seed

Table 6. Main marine and brackishwater aquaculture species in Vietnam

Scientific name	English Name	Vietnamese Name	Culture Method	Culture Volume
Marine aquaculture				
Epinephelus spp.	Grouper	Mu, Song	FC, NS	Low
Lutjanus spp.	Snapper	Hong	FC, NS	Low
Seriola sp.	Amberjack	Cam, Bo bien	FC, NS	Low
Rachycentron sp.	Crab eater	Bop, Gio	FC, NS, HS	Low
Hippocampus spp.	Sea horse	Ca ngua, Hai ma	T, P, NS,HS	Low
Pteria sp.	Pearl oyster	Trai ngoc	P, NS	Low
Haliotis sp.	Abalone	Bao ngu	Intertidal rock	Low
Holothuria sp.	Sea cucmber	Hai sam	Infra-littoral	Low
Panulirus sp.	Lobster	Tom hum	P, NS	Low
Brackishwater aquaculture				
Penaeus monodon	Tiger shrimp	Tom su	P, HS	High
Penaeus merguiensis	Banana shrimp	Tom bac the	P, NS, HS	Medium
Penaeus indicus	White shrimp	Tom the do duoi	P, NS	Low
Penaeus semisulcatus	Green shrimp	The ran	P, NS	Low
Penaeus japonicus	Kuruma shrimp	Tom he nhat	P, NS	Low
Penaeus orientalis	Taisho shrimp	Tom nuong	P, NS	Low
Metapenaeus bevicornis	Yellow shrimp	Bac nghe	P, NS	Low
Metapenaeus ensis	Endeavour	Dat, Rao	P, NS	Medium
Scylla serrata	Mud crab	Cua xanh, Cuabien	P, BC, NS	Medium
Pisoodonophis boro	Brackishwater eel	Lich su	BC, NS	Medium
Lates calcarifer	Sea bass	Chem, Vouc	P, FC, BC,NS	Low
Bostrichthys sinensis	Grobia	Ca bop	T, P, NS	Medium
Sparus latus	Sea bream	Ca trap	T, P, NS	Low
Siganus guttatus	Spine foot	Dia	FC, NS	Low
Arca granosa	Blood cockle	So huyet	Tidal flats, NS	Medium
Anadara antiquata	Ark shell	So long	Tidal flats, NS	Medium
Meretrix spp.	Clam	Ngao, Ngheu	Tidal flats, NS	High
Ostrea rivularis	Oyster	Hau cua song	Estuaries, NS	Medium
Artemia	Artemia	Artemia	SP	Medium
Gracilaria spp.	Seaweed	Rong cau chi vang	Lagoon, P, NS	Medium
Kappaphycus alvarezii	Seaweed	Rong sun	Bays, NS	Low

FC: Floating Cages; **T**: Tank; **BC**: Bottom Cages; **NS**: Natural Seed; **HS**: Hatchery Seed; **SP**: Salt Pan

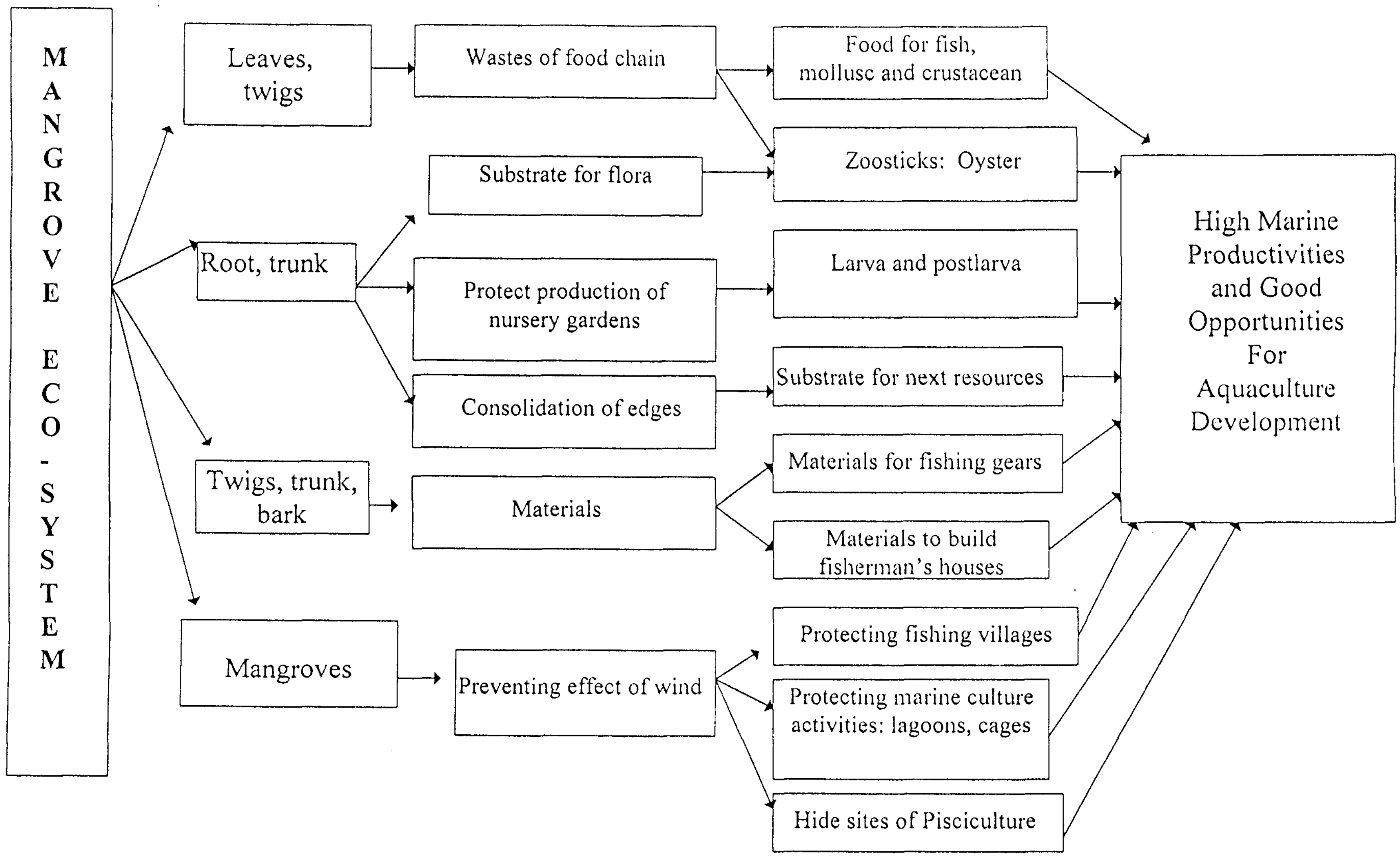

Fig 1: Functions of mangrove in relation to aquatic resources (Kapetsky, 1996)

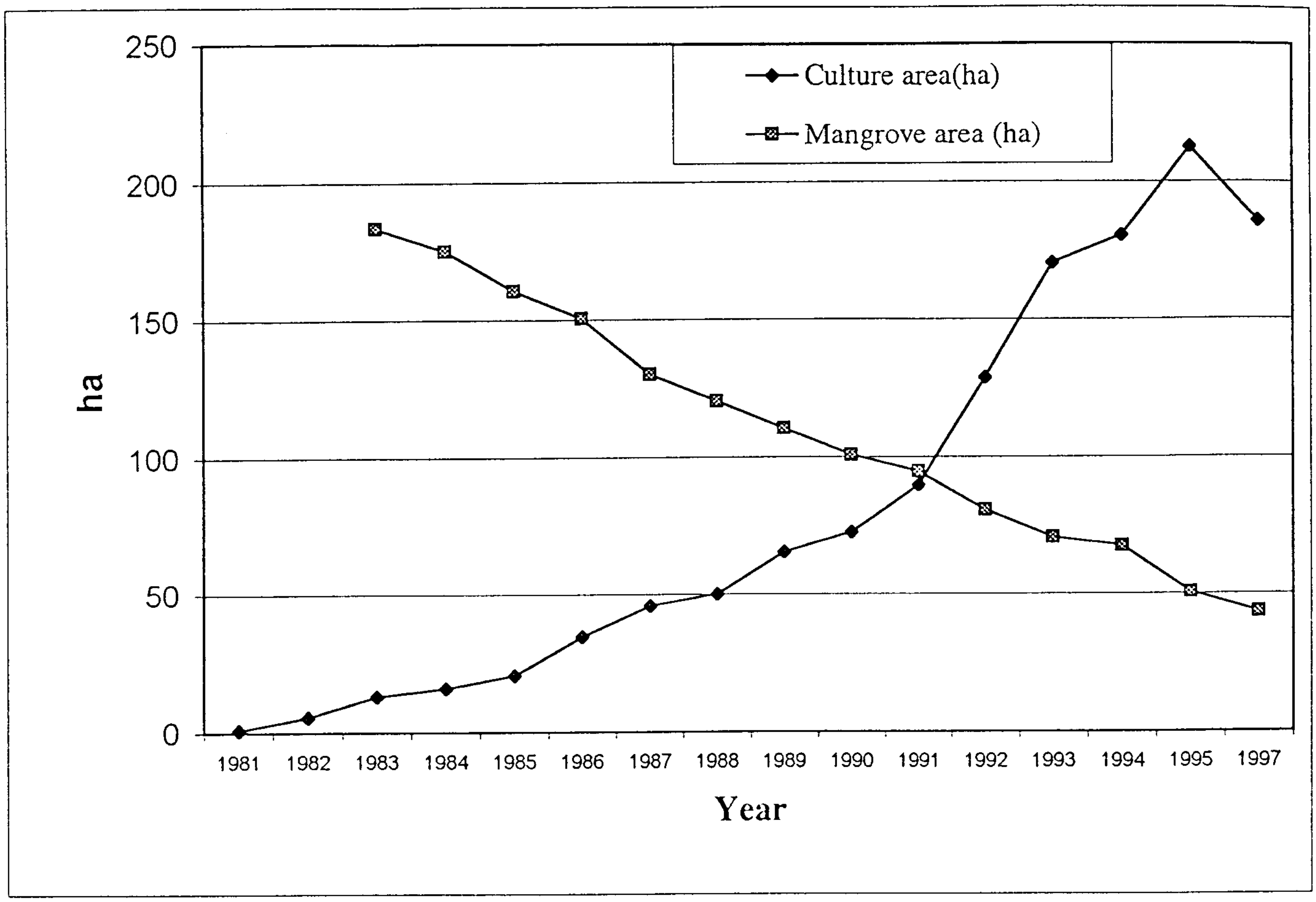

Fig 2. Interactive relationship between shrimp expansion and mangrove reduction (Mekong River Delta, in ha)

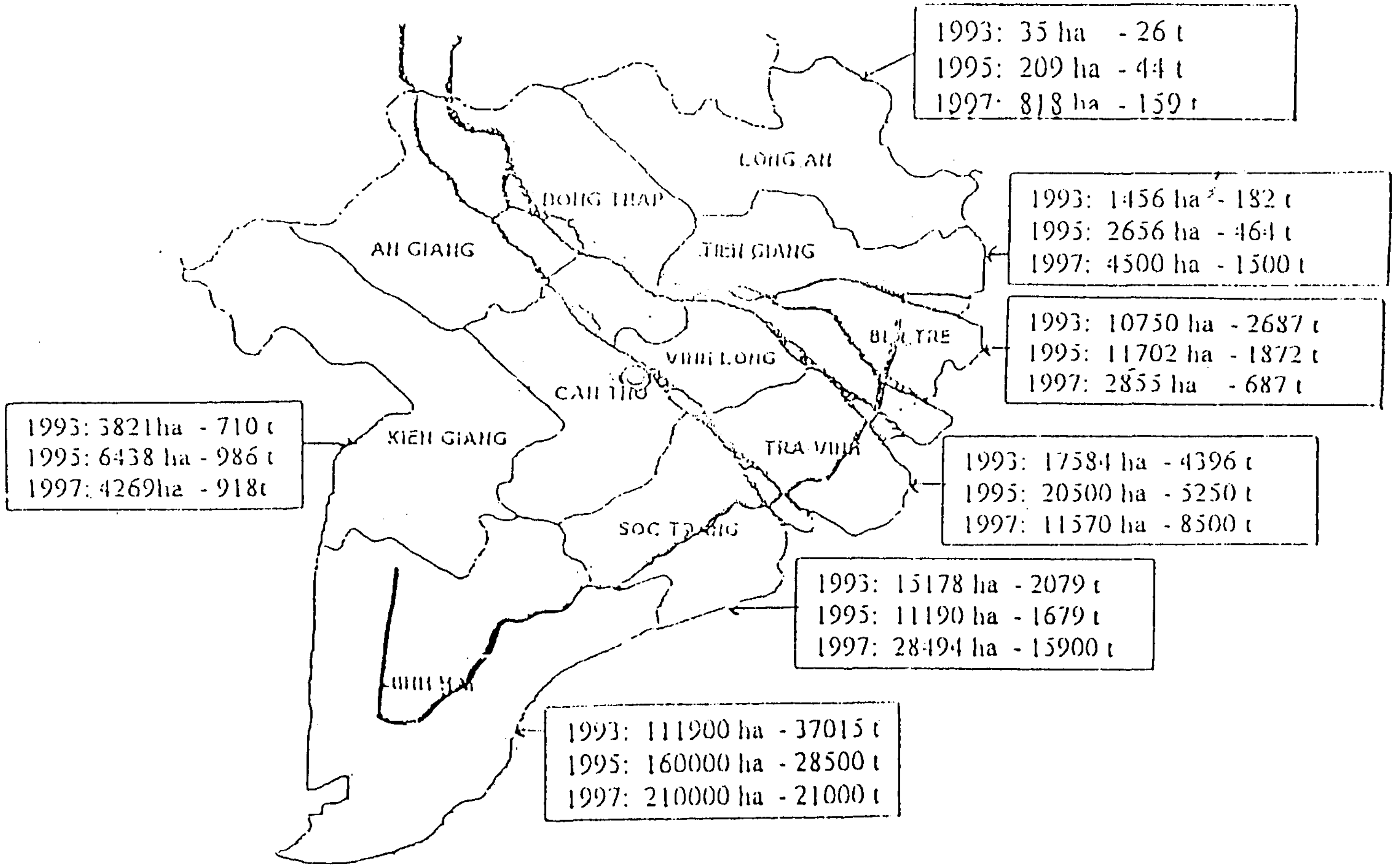

Fig 3. Evolution of shrimp farming in the Mekong River Delta, Vietnam (1993-1997)

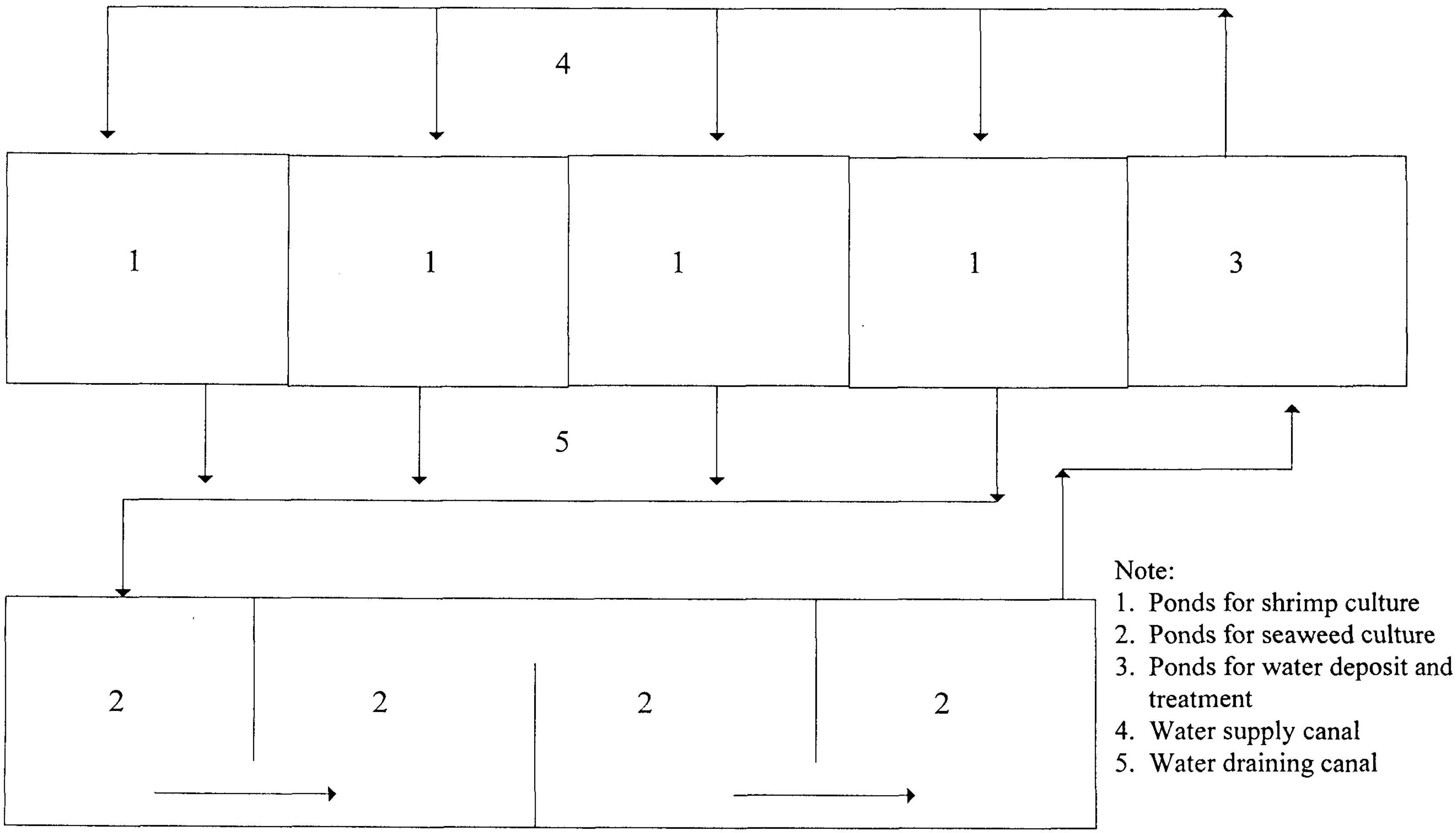

Fig 4. Model of shrimp culture ponds in a closed system

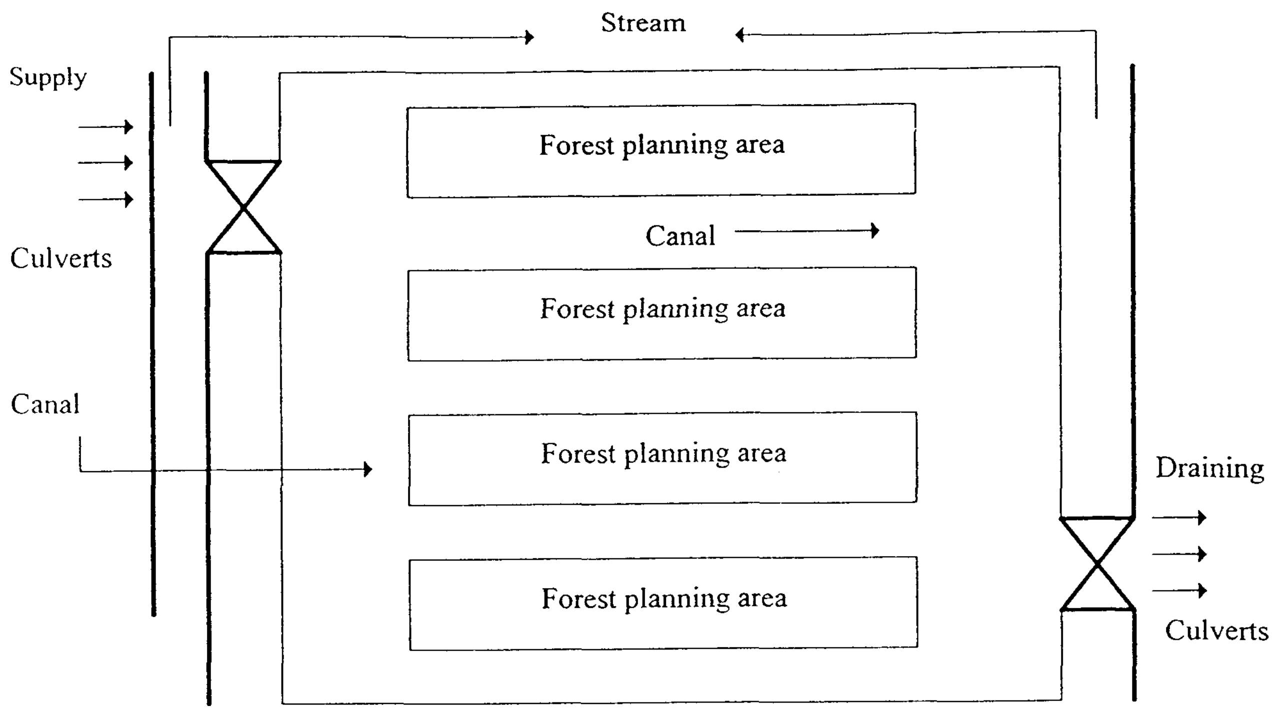

Fig 5. Model of a shrimp culture system with canals for shrimp culture (improved extensive) between mangrove forests in Minh Hai Province

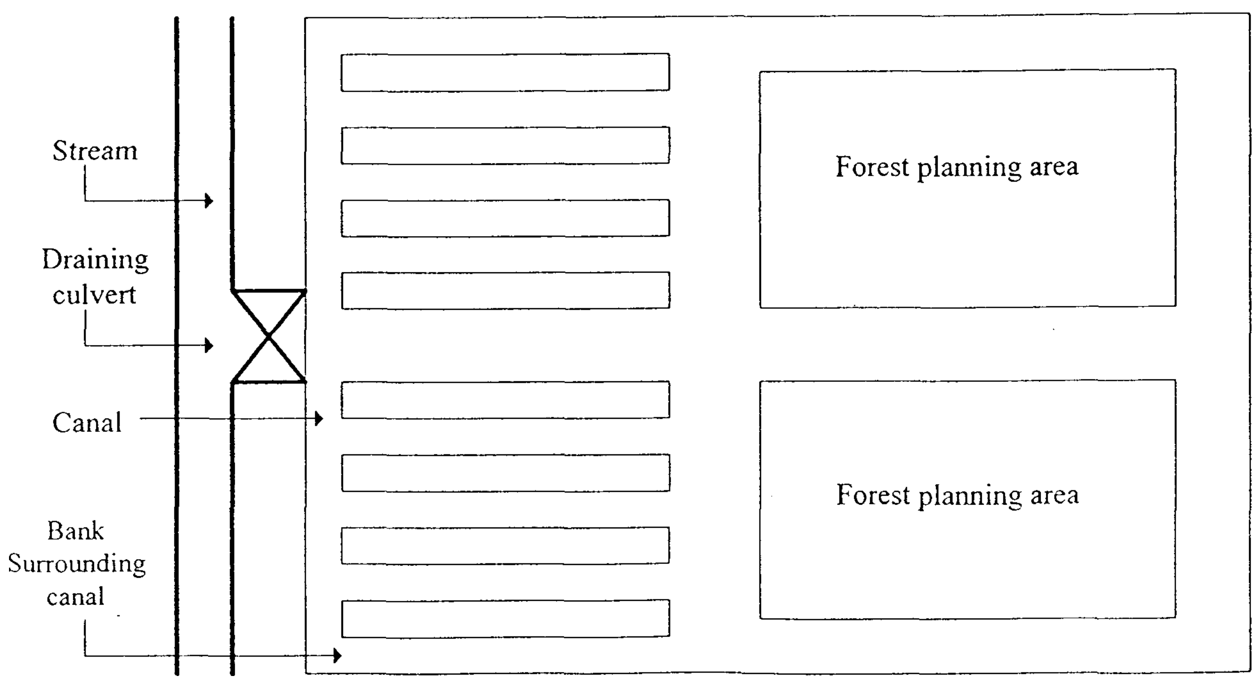

Fig 6. Model of a fishery-forestry area in Minh Hai Province

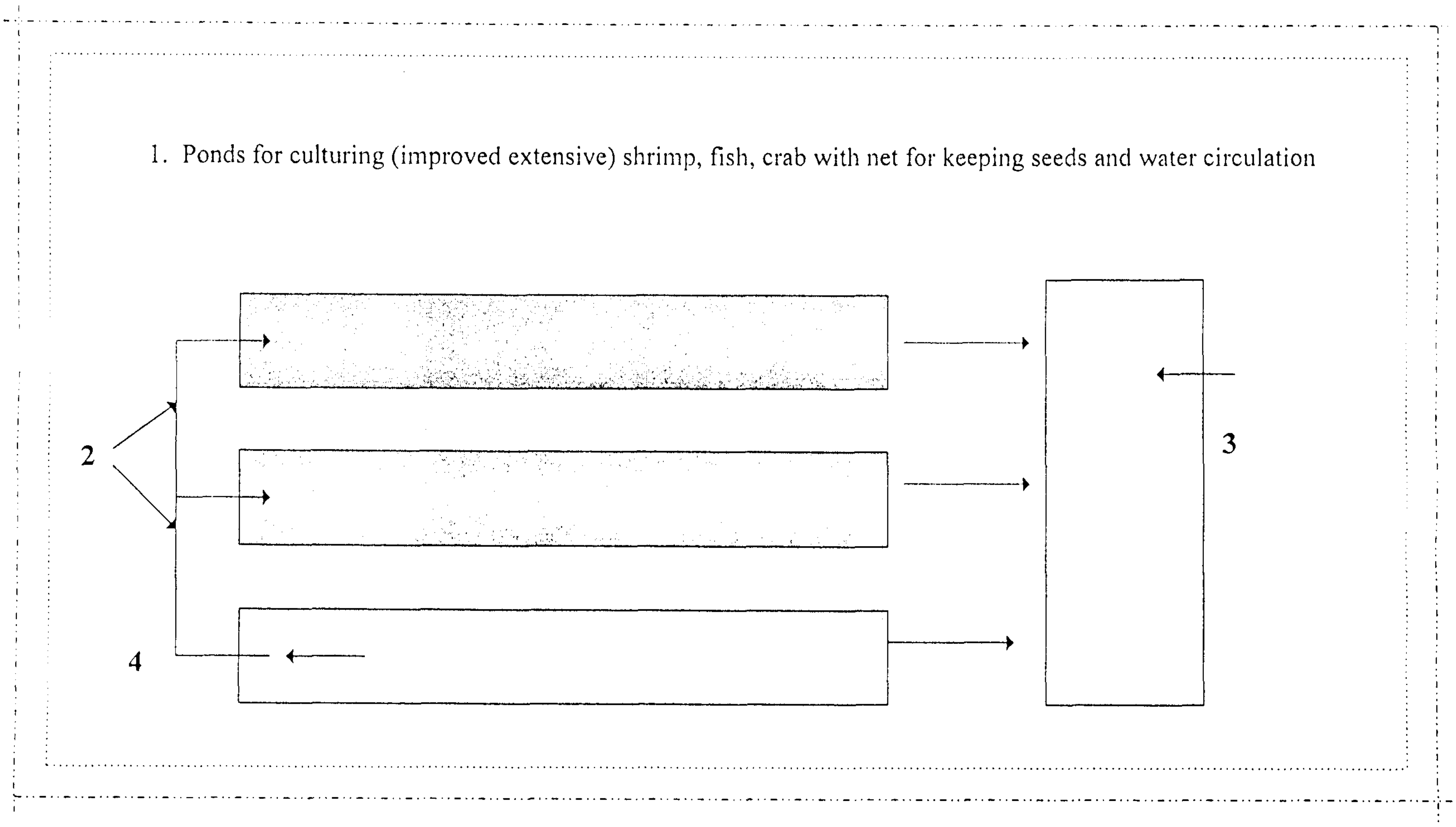

Fig 7. Model of mangrove-friendly aquaculture

Total area: 10 ha, including (1) ponds for culturing (improved extensive) shrimp, fish, crab with net for keeping seeds and water circulation; (2) shrimp semi-intensive culturing ponds, 4 ponds with 5,000 m^2 per pond; (3) ponds for culturing molluscs or fish for biological water treatment; and (4) ponds for water treatment about 3,000 m^2

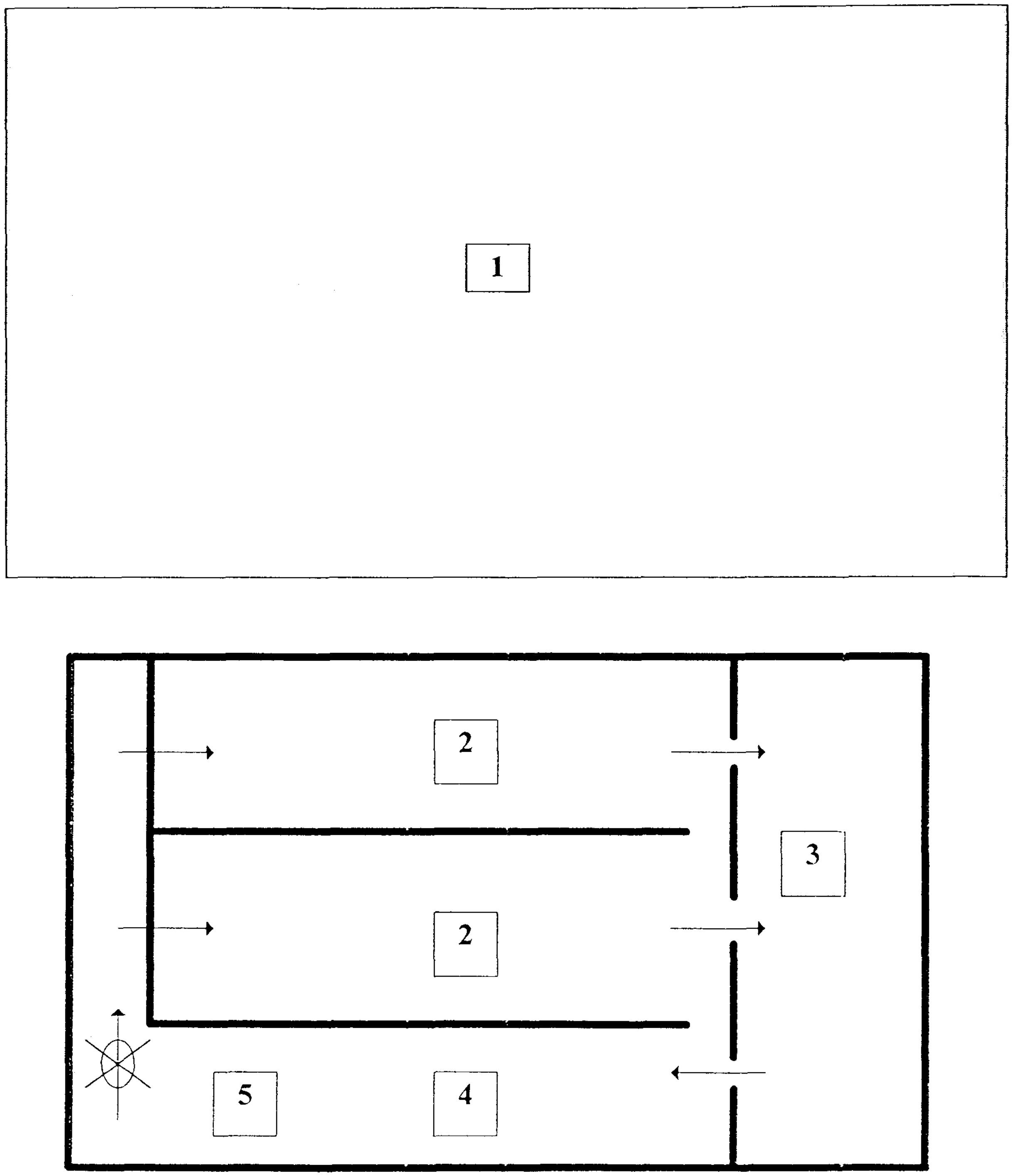

Fig 8. Model of shrimp culture in closed system with water treatment

Note: (1) Mangrove forest; (2) Ponds for shrimp culture; (3) Ponds for seaweed culture, (4) Treatment ponds using chemical; (5) Water pump

LEGAL FRAMEWORK FOR MANGROVE-FRIENDLY AQUACULTURE: VIETNAM EXPERIENCE

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I. Status of Mangroves in Vietnam

In 1943, there was about 400,000 ha of mangroves in Vietnam with two large forest areas in: Ca Mau peninsula (200,000 ha, among which 150,000 ha was virgin forests) and Rung Sat (Bien Hoa and Ho Chi Minh City) with 40,000 ha. Due to many reasons, the mangrove areas have decreased considerably and in 1983, only 252,000 ha of mangroves was recorded.

With different geographical and climatic conditions, the mangrove areas in the long coastline of Vietnam can be divided into four zones, namely, Northeast Coastal Area, Bac Bo Delta Coast, Central Coast, and South Coast (Fig. 1).

Zone I: Northeast Coastal Area from Ngoc Cape to Do Son Cape

The division of the Northeast Coastal Area is complex and creates many off-shore gulfs and estuaries with many protected islands which help reduce the effects of winds and storms. The main rivers usually very steep and with powerful flow carrying all the alluvia to the sea. Muddy substrata with sand and clay are deposited and formed, which are suitable to the growth of mangrove species. The annual rainfall is high (over 2500 mm) and the rainy season is from April to October with some rains in the dry season (20-25% of the annual precipitation). Mangroves in this area also benefit from an even and abundant source of freshwater.

This area has mountains which are near the sea. Population density is quite low, and coal is available so that the need for firewood is not critical. This is one of the reasons for the less destruction of the forests until 1970. In recent years however, mangrove forests were partly converted into agriculture lands and shrimp ponds, where more than 5000 ha of forests have been destroyed to produce rice, but the yield has been very low due to lack of freshwater. Thus, the program on increased rice production failed in many localities in the area. Farmers were then encouraged to have their land areas converted into shrimp ponds. The lack of suitable technology and investment, however, resulted in very low the economic efficiency of the shrimp ponds.

Zone II: Bac Bo Delta Coastal Area from Do Son Cape to north Lach Truong Cape

This zone is situated in the sedimentation area of Thai Binh River and Red River and their tributary systems. The sediments are abundant and rich in nutrients, forming large accretions both in the estuary and along the coast.

However, the area is not protected because of the absence of mountains or islands. Hence, many mangrove species do not grow very well except some brackishwater species which grow in sanctuary area.

Moreover, strong human impacts such as building dikes to create new lands on the sea and destruction of forests for shrimp culture, resulting in the reduction of the mangrove forest areas. In addition, erosion and typhoons have broken down many sea-dikes, causing severe damage and considerably diminishing the quantity of marine organisms (adults as well as larva) in the mangrove ecosystem.

In recent years, a program on the planting of buffer trees to protect dikes had attracted the people's attention. As a result, in the coastal areas of Thanh Hoa, Nam Ha, and Thai Binh provinces, more than 2000 ha of mangroves have been replanted. Records showed that there had been a significant increase in population of marine organisms, particularly molluscs, on the tidal flats with abundant mangrove trees.

Zone III: Central Coast, from Lach Truong to Vung Tau Cape

This is a narrow strip of land, and except for the northern part from Dien Chau (Nge An) northwards, the coastal area runs parallel with the Truong Son Ridge. The rivers are short and the slopes have minimum alluvium quite inadequate to form coastal swamps. On the other hand, the coastal area is also sloping and cannot retain the scanty deposit of alluvia, and this zone is within the typhoon path and is strongly influenced by monsoons.

From Hai Van pass southward, the climate becomes favorable due to the absence of a cold monsoon. In this area, the mangroves improve in species diversity. However, over-exploitation of the mangroves for firewood, timber and shrimp ponds, has also destroyed the resources.

Zone IV: South Coast, from Vung Tau Cape to Ha Tien

This zone is situated in the sedimentation area of Me Kong River and Dong Nai River systems. The topography is flat, low with an intricate net of rivers and channels with much alluvium, rich in nutrients, and plenty of freshwater supply during the rainy season. The dry season lasts for six months while saline water intrudes deep inland because of the high tidal amplitude and strong winds. The average annual temperature is high with small fluctuation amplitude and the area is not within the typhoon path.

The southwest monsoon and sea current from the Indian Ocean and Eastern Sea bring in seeds from the equatorial countries, facilitating the growth and extensive distribution of mangroves. The trees are of the largest size and the tree communities are also the richest. Marine resources are abundant in the area, among these are many valuable species of crabs, oysters, penaeid shrimps, etc.

II. Reasons for the Decreasing of Mangrove Areas

A. *The Chemical War of the American Army*

It has been recorded that the Chemical War in Vietnam from 1962 to 1971, destroyed 104, 939 ha of mangrove areas, of which 52% was in Ca Mau Cape, 41% in Rung Sat, and the remaining in some western provinces of the South. Ca Mau Cape used to have the largest mangrove forest areas in the country before the said Chemical War.

B. *Conversion to agricultural areas*

After the war, population growth was rapid and due to lack of food, people in many localities cleared the mangrove areas in order to build dikes to encroach the sea for agricultural use. Large amount of money and effort were spent, but the idea was a failure because there was not enough freshwater. The yield from agriculture was too low or in many cases, nothing could be harvested from the inputs.

C. *Over-exploitation for timber, firewood and charcoal*

After the war, coastal people also returned to their native places. Together with the mass migration from other provinces to the mangrove areas in the South, the demand for building timber, firewood, and charcoal had greatly increased. The increasing exploitation of the Forestry Agencies while the resources continued to decrease, also exhausted the forest resources.

At one point, the people in the communes of Vien An Dong and Dat Mui, Ngoc Hien district built family kilns to produce charcoal for sale to the other provinces. This effort destroyed many valuable forests including the mangrove forests that were newly-planted after the war.

D. *Conversion to residential areas*

In recent years, the conversion of mangrove areas into towns, industrial zones, and ports also contributed to the narrowing of the mangrove forest areas. Nam Can Town in Minh Hai province is a typical example. After 10 years of establishing it into a mangrove area, the town's population had increased 10 times, resulting in many houses and establishments gradually replacing the areas which once supported dense mangrove forests. In Quang Ninh province, the development of Ha Long City also destroyed all the mangrove forests at Coc 3, Coc 5, and Coc 8.

In the economic development of the coastal areas, infrastructures such as dams and roads were constructed in some localities such as the Cam river, the road joining Dinh Vu and Phu Long islands in Hai Phong, and the road to Hoang Tan island in Yen Hung, Quang Nin. Although these structures facilitate land and water transportation, they caused adverse effects on the environment especially the mangrove ecosystem.

E. *Conversion to shrimp ponds*

The prospect of a big benefit from shrimp export while the marine catch yield continued to decrease, had encouraged the government and many local authorities to promote shrimp farming through out the country. Thus, the natives and state bodies cleared vast mangrove forests (at Thai Binh, Nam Ha, Ninh Binh) and converted these into natural extensive shrimp ponds. In some provinces such as Minh Hai, forest clearance for shrimp farming was carried out not only by the natives but also by people migrating either legally or illegally from the other parts of the country. Since 1991, thousands of people from Ca Mau town built embankments on the new accretion southwest of Ca Mau tip in order to build shrimp ponds and houses intended for long-term residence.

According to some statistical data, the extent of brackishwater shrimp ponds, which was 50,000 ha in 1981, increased to 120,000 ha in 1987. Ca Mau and Bas Lieu provinces which have the largest areas of mangroves, were the most affected places with most forests destroyed in order to construct ponds to culture shrimp. Shrimp farming in 1980 and 1981 made use of only 4000 ha, but this was increased 20 times in 1992 to 80,000 ha. Every year, Ngoc Hien district loses an average of 5000 ha mangrove forests to shrimp aquaculture.

From 1982 to 1986, the Thai Thuy District (Thai Binh province) converted only 668 ha of planted mangrove forests to shrimp ponds. Generally though, most of the protected forests in Tien Hai district (Thai Binh) and many dike-protecting mangrove forests in Hai Phong, Ninh Binh were also cut down for shrimp ponds.

III. Protection and Development of Mangroves and Fishery Resources

Understanding the importance of protecting forest lands which include mangroves and swamplands, many laws and policies have been promulgated from the 80s up to the present. These include . the Land Law (1993 amended in 1999); the Law on Forest Protection and Development (1992); Decree 327 of the Prime Minister for Regreening of Bare Lands (1992 to 1995); Decree 556 for Protecting Forests and Regreening of Barelands (1996 to 1997); Decree 776 for Providing Infrastructure and Planning support for Allocating Land for Holdings Establishment Adjoining the Coastal Full Protection Zones; the Law on Environmental Protection (1994); the Decree on Fisheries Resources Protection and Development (1989); the Law on Fisheries (will be in effect from the year 2000); and Instruction 01/1998/CT of the Prime Minister dated 2/1/1998 for Banning of Illegal Fishing Instrument Including Use of Toxic Chemical. Electric Impulse. Dynamite. These laws and policies strongly protect mangroves and fishery resources. as well as support the development of mangrove-friendly aquaculture technology.

IV. Governmental Commitment on Conventions and Treaties

The Government of Vietnam is a member of many international conventions and treaties relating to the protection of mangroves and fisheries resources. These include the RAMSAR Convention, Biodiversity Convention, Convention on Climate Changes, CITES Convention, and the United Nations Convention on The Law of the Sea (UNCLOS).

V. Government Strategies

From the 90s, the Government Vietnam has developed strategies for sustainable development and protection of the environment. Some plans and programs directly relating to mangrove-friendly aquaculture, include the National Plan for Environment and Sustainable Development for the Period 1991-2000; the National Biodiversity Action Plan (1995); the Tropical Forest Action Plan (1992); the National Programme Number 327 for Implementation of The Decree 327 for Regreening of Bare Lands and Mangrove-destroyed Areas Development for Aquaculture; the National Programme Number 776 for Providing Infrastructure and Planning Support for Allocating Land for Holdings Establishment Adjoining the Coastal Full Protection Zones; the National Programme for Five Million Hectare Reforestation; and the National Programme on Off-shore Fishing (1997) for Reducing of Coastal Over-fishing.

The National Programme on Exporting Fisheries Products (1999) was also developed in order to improve post-harvest technology, processing technology and to increase the value added fisheries products instead of exporting raw material or semi-products. In addition, the National Programme on Aquaculture (1999) for sustainable development of mariculture, brackishwater water culture and freshwater culture was developed with the objectives of increasing the total production, increasing export, decreasing coastal fishing efforts, protection of the environment, generating more jobs and poverty reduction.

VI. Existing Project on Coastal Wetlands Protection and Development

Vietnam has the experience on coastal wetland protection through the WB/DANIDA Project on Coastal Wetlands Protection and Development in Southern Mekong Delta Province of Ca Mau, Bac Lieu, Soc Trang and Tra Vinh. After three years preparation by the experts from the World Bank, DANIDA, the Ministry of Agriculture and Rural Development, the Ministry of Fisheries and local authorities of four provinces, the completed Project Document was presented in April 1999 to the Prime Minister of Vietnam for appraisal and approval.

The objective of the Project is to re-establish the coastal mangrove wetland ecosystems and protect sustainably their aquatic nurturing and coastal protection functions. The progress of this objective will be measured and monitored based on the minimum land losses to and maximum land gain from the sea through reduced erosion and increased accretion; the decline in barren areas in the protection belt; and the increased coastal and near shore marine productivity.

In order to achieve the above objective, a full protection zone (FPZ) and an adjoining buffer zone (BZ) comprising a 467 km long coastal protection belt will be established in the project area. In the FPZ, mangroves will be reforested, economic activities and settlement will be limited, and inhabitants whose economic activities cause a threat to the sustainability of the mangrove ecosystems will be resettled. In the BZ, the development of diversified and sustainable farming techniques and social support services would be intensified to improve the income and livelihood status, specifically for the poorest segments of the coastal population who exercise the main incursion pressure on the FPZ.

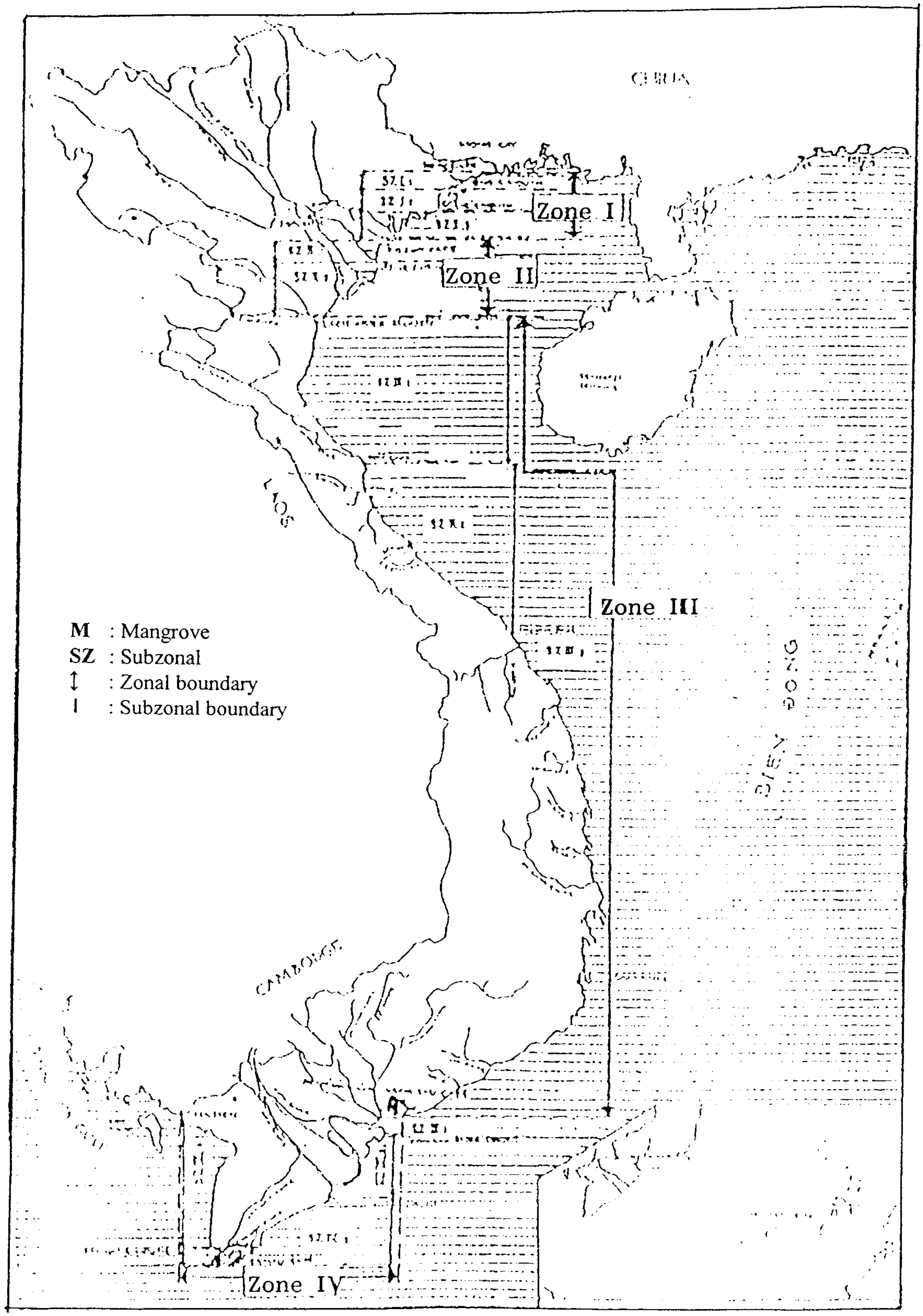

Fig. 1 Geographical distribution of mangroves in Vietnam

THE PHILIPPINE LEGAL FRAMEWORK ON SILVOFISHERIES

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I. Introduction

Three decades ago, mangroves dominated the Philippine coastline that stretched some 17,460 kilometers. It has since joined the expanding list of the country's most exploited natural resources. In 1965, the total mangrove areas of the country covered about 4500 km^2 (Barut et al., 1997). Ten years later, the number drastically fell to approximately 2500 km^2 (Bureau of Forest Development, 1984).

To date, only 139,735 ha remain (NAMRIA), 1990), accounting for 2.2% of the total forest cover (BFD, 1990). The reduction represents 70% of the 1920 figures. Of the estimated remaining mangrove forests, approximately 75% are second growth and only 5% are old growth which are mostly located in Palawan, while the remaining mangroves are found mainly along the seashores or brackishwater areas of Regions IV (Southern Luzon), IX (Western Mindanao) and X (Northern Mindanao), comprising 85% of the total mangroves (Mangrove Technical Review Committee, 1994).

Statistics showed an alarming rate of mangrove denudation due to various uses. The Philippines is losing an average of 4572 ha of mangrove forests annually, the lowest depletion was from 1920 to 1950 at 2499 ha annually while the highest was from 1950 to 1972 at 6685 ha annually. The latter period coincides with the rapid growth in aquaculture that entailed large-scale conversion of mangrove areas into fishponds (Mangrove Technical Review Committee. 1994).

A SPOT survey made by the National Mapping and Resource Information Authority (NAMRIA) showed that 95% of presently existing fishponds were formerly mangrove areas developed between 1952 to 1987. Mangrove conversion to fishponds as the main cause of destruction has consistently been reported (Zamora 1990; Primavera 1991), and such conversion accounts for an estimated 60% of the total destruction. Other development causes are charcoal and firewood production, expansion of human settlements, and mangrove area conversion for commercial or industrial purposes and also for the construction of coastal roads, dikes, bridges, saltbeds, wharves, and docks.

Although optimum mangrove utilization was the "order of the day" during the period 1952 to 1987, mangrove conservation was no longer a far-fetched idea. Persons from the academe were already sounding off the alarm button and pointing to the mangrove' multifarious and vital roles, principally, as nursery and spawning grounds of various animal species, as protection for coastal zones, as repository of rich genetic resources for scientific research, and as sanctuaries for wildlife.

The low perception of the true worth of mangroves due to the fact that their most important benefit is their indirect contribution to fish growth (Francisco, 1992), and the notion that denuded mangrove areas are suitable for fishponds and other aquaculture purposes, were simply too hard to dismiss. Thus, there was much clamor for the conversion of more mangrove swamplands into fishponds (Guerrero III, 1977). At one point, it had been the unwritten policy that mangrove swamps were far less productive when left alone than when exploited.

Heightened global environmental awareness, the aftermath of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) and the 1992 Rio Declaration, was translated to policy shifts at the domestic level. From optimum utilization, there was felt a compelling necessity to preserve the remaining mangrove forests and to explore alternative aquaculture systems.

Environmentally benign aquaculture technologies emerged and scientists realized that mangrove forests and other wetlands are not optimal sites for aquaculture ponds (Boyd, et al., 1998). This development and the passage of the 1998 Philippine Fisheries Code embodying some concepts in Agenda 21 such as sustainable development and sustainable aquaculture, and in other international treaties and protocols on the environment, represented the dawning of a new era in Philippine aquaculture.

II. Historical Overview of Laws, Rules and Policies on Silvofisheries

The earlier forms of regulation concerning mangroves can be traced to Republic Act. No. 4003, "An Act to Amend and Compile the Laws Relating to Fish and Other Aquatic Resources of the Philippine Islands and for Other Purposes," enacted on December 5, 1932. Section 63 in Article IX (Inland Fisheries) of the Act made available tracts of public forest land for fishpond purposes. Regulations governing the issuance of fishpond permits and/or leases on public forest lands were contained in Fisheries Order No. 60 dated June 29, 1960.

There were few restrictions on inland fisheries which included those under forestry laws that consisted mainly of reservations of strips of mangrove areas for coastal protection; and those enumerated under Section 64 of Act No. 4003 prohibiting the obstruction of free navigation of streams adjoining or flowing through the fishpond area, obstruction or interference in the passage of people along such streams or the banks thereof, and the impedance of the free flow and ebb of the tide to and from the interior of the swamps. It is obvious that these prior laws had set the stage for the massive conversion of mangroves and swamplands into fishponds.

Section 63 further specified that permits or lease entitling the holders thereof, for a certain stated period of time not to exceed twenty years, to enter upon definite tracts of a public forest land to be devoted exclusively for fishpond purposes, or to take certain fishery products or to construct fishponds within tidal, mangrove and other swamps, ponds and streams within public forest lands or established forest reserves, may be issued or executed by the Secretary of Agriculture. The issuance however, is subject to the restrictions and limitations imposed by the forest laws and regulations to such persons, associations or cooperation as are qualified to utilize or take forest products under Act. No. 3674. Renewal may be granted, however the combined period of the original lease and its renewals shall not exceed 50 years.

The concept of managing the mangroves surfaced mainly in the seventies with the issuance of Presidential Decree (PD) 389 or the Forestry Reform Code of the Philippines on February 5, 1974. Section 33 of the law mandated the Bureau of Forest Development (now the Forest Management Bureau) to develop a management plan for swamplands and mangrove forests, designed to increase public benefits in the form of developments including the establishment of fishponds. On the other hand, Section 37 (j) of the law allowed the cutting of mangroves through the issuance of mangrove timber licenses for a term of four years over an area, the size of which was left to the discretion of the Department Head. Evidently that time, management of mangroves under the law veered heavily on the side of the exploitation of the resources rather than on its conservation.

Section 33 of PD 389 specified that the Bureau, in consultation with other appropriate agencies shall jointly develop a management plan to increase the public benefits derived from swamplands and mangrove forest but in no case shall the development obstruct or impede waterflow of streams and rivers. Strips of mangrove forest bordering numerous islands protecting the shoreline, the shoreline roads and coastal barrios, from the destructive force of the sea during high winds and typhoons, must be kept free from artificial obstruction so that flood water will flow unimpeded to the sea to avoid flooding or inundation cultivated areas in the upstream. All mangrove swamps aside from coastal protection forests, shall be established as permanent forest and shall be managed under the principle of sustained yield.

The seventies however, saw the repeal or amendment of Act. No. 4003 and PD 704 or the Fisheries Decree of 1975 issued on May 16,1975, supplanted Act No. 4003, while PD 705 of the Revised Forestry Code promulgated on May 19,1975, amended PD 389. PD 705 still subsists while PD 704 has been recently repealed by the 1998 Philippine Fisheries Code.

One of the policies underlying the enactment of PD 705 or the Revised Forestry Code is the multiple use of forest lands. Multiple use is defined as the harmonized utilization of the land, soil, water, wildlife, recreation value, grass, and timber of forest lands. The law also released to and placed under the administrative jurisdiction of the Bureau of Fisheries and Aquatic Resources (BFAR), mangrove and other swamps not needed for shore protection and suitable for fishpond purposes. Those areas released to BFAR that were not utilized or which had been abandoned for five years from the date of release, were reverted to the category of forest land.

The law also segregated certain mangrove areas needed for forest purposes. As specified in the law, these are areas which even if they are not below 18% in slope, are needed for forest purposes and may not therefore be classified as alienable and disposable. This includes strips of mangrove or swamplands at least 20 m wide along shorelines facing oceans, lakes and other bodies of water; and strips of land at least 20 m wide facing lakes. The law also dictated the use of the seed tree system as the silvicultural or harvesting system for pine or mangrove forests. It maintained swamplands and mangrove forests for coastal protection, which areas cannot be alienated or subjected to clear-cutting operations.

The Fisheries Decree or PD 704, on the other hand, amplified the meager provisions of Act No. 4003 on inland fisheries. The principal policy of the law was the acceleration and promotion of the integrated development of the fishing industry and the maintenance of the optimum production of fishery resources through proper conservation and protection.

PD 704 put a stop to the sale of public lands suitable for fishpond purposes, exempting those fishpond sales patents already processed and approved as of November 9, 1972. Fishpond leases over public lands were granted for a period of 25 years, renewable for another 25 years over 50 ha in case of individuals and 500 ha for associations and corporations. In 1979, regulations governing fishpond lease agreements covering public lands were issued through Fisheries Administrative Order No. 125.

BFAR was also given the mandate to issue licenses for the operation of fishpens for a period of five years renewable for another five years over 10 ha in case of individuals and 50 ha in case of associations, partnerships, cooperatives or corporations. However, it was the municipal or city council which granted fishery privileges such as the operation of fish corrals, oyster beds, and fry gathering under a new segment on municipal fisheries.

The 70s further witnessed the adoption of a Philippine Environmental Policy through Presidential Decree No. 1151 and the Philippine Environment Code or PD No. 1152, both dated June 6, 1977. The decrees instituted specific management policies and prescribed environment quality standards. Fisheries and aquatic resources shall be rationally exploited and mangrove areas, marshes and inland waters, coral reef areas and islands serving as sanctuaries for fish and other aquatic life, shall be maintained. Finally, the 70s ended with the issuance of landmark regulations aimed at preserving certain areas of the public domain from any form of commercial exploitation, occupancy or use. Letters of Instructions No. 917 and 917-A issued on August 22, 1979, and September 7, 1979, respectively, declared certain areas including mangrove forests as wilderness areas or greenbelts. Mangrove forests designated as wilderness areas or greenbelts should not be less than 25% of the total mangrove forest areas of any given locality. LOI 917 also specified that mangrove forests essentially needed in foreshore protection, the maintenance of estuarine and marine life, including special forests which are the exclusive habitats of rare and endangered Philippine flora and fauna, are likewise declared wilderness areas.

The sale of public lands suitable for fishpond purposes was allowed under Republic Act No. 193 approved on June 16,1948. Section 1 thereof states that "Marshly lands and lands under water bordering on shores, or banks of navigable lakes or rivers which are covered by subsisting leases or leases which may hereafter by duly granted under the provision of Commonwealth Act No. 141 and are already improved and have been utilized for farming, fishpond or similar purposes for at least five years from the date of the contract of lease, may be sold to the lessees thereof, under the provisions of Chapter 5 of the said Act as soon as the President, upon the recommendation of the Secretary of Agriculture and Natural Resources, shall declare that the same are not necessary for the public service.

It will be observed that these prior laws were not specific to mangrove areas and were lumped with other forestry or fishery activities. Efforts at substantive and focused legislation, gained impetus only in the 80s. The first regulations, which specifically addressed mangrove forests, were issued in 1980. Special Order No. 178 reorganizing the Philippine National Mangrove Committee (NMC) created under Special Order No. 309, series of 1976, mandated said committee to formulate and establish a comprehensive and integrated national mangrove program that would rationalize and re-orient all planning and management procedures.

The Committee formulated guidelines to serve as basis for identifying areas to be declared as preservation and conservation areas, and recommended measures for the proper allocation and disposition of mangrove areas (National Mangrove Committee , 1986). Results of the research and survey activities undertaken by the NMC, especially with the use of modern remote sensing technology, formed the basis of Presidential Proclamation (PP) Nos. 2151 and 2152 issued in December 29, 1981. The proclamations set aside areas as mangrove forest reserves. PP 2151 declared certain areas with an aggregate area of 4326 ha as wilderness areas, which were withdrawn from entry, sale, settlement, and exploitation of whatever nature or forms of disposition subject to existing recognized and valid private rights. On the other hand, PP 2152 declared the entire province of Palawan and certain parcels of the public domain totaling 74,267 ha as Mangrove Forest Reserves, to be withdrawn from use, occupancy or other forms of disposition.

Subsequently, Proclamation No. 2409 was issued on March 28, 1985, recalling certain areas in Bohol from the scope of PP 2152. Rules to implement PP Nos. 2151 and 2152 were issued, such as Department of Environment and Natural Resources (DENR) Administrative Order No. 8, series of 1987 which indicated that the government would no longer entertain applications for licenses, leases or permits of any kind involving mangrove swamps and other parcels of the public domain designated as Mangrove Swamp Forest Reserves, whether such applications were new, renewal or extension. Thus, all pending applications falling under these areas were immediately denied.

To abate the rampant conversion of mangrove areas into fishponds, MNR Administrative Order No. 3, series of 1982 was issued prescribing a revised guideline on the classification or zonification of forest lands for fishpond purposes. The Order declassified lands of the public domain previously classified as alienable or disposable to areas merely zonified and delineated as areas suitable for fishpond development . Forest lands zonified as such were placed under the administrative jurisdiction and management of BFAR. Applications for leases can only be entertained by BFAR after the Ministry of Natural Resources (MNR) had declared the areas covered by the lease as available for fishpond development.

To enhance the protective capability of the mangroves, Department Administrative Order No. 42 was issued on September 10, 1986 expanding mangrove forest belt areas from the original 50 m to 100 m strip inward along shoreline fronting oceans, seas and other water bodies in storm surge and typhoon areas in fifteen provinces, and from 20 m strip river bank protection to 50 m on both sides of the river. For mangrove areas already converted to fishponds, the operators were obliged to affront tidal flats fronting their areas to at least 50 m. This was followed by DENR Administrative Order No. 76 or the "Buffer Zones in Coastal and Estuarine Mangrove Regulations" on November 23, 1987, establishing buffer zones in coastal and estuarine areas consisting of strips of 50 m in all mangrove or swampland areas throughout the country fronting seas, oceans and other bodies of water, and 20 m on both sides of river channels or banks. Mangrove or swamplands classified and zonified as alienable or disposable for fishpond development, whether or not covered by applications for fishpond development which were not yet developed were reverted to the category of forest lands. For areas converted into fishponds through a Fishpond Lease Agreement (FLA), lessees were required to affront the tidal flats fronting their respective areas to at least 50 m and the area along river channels or banks to at least 20 m.

The regulations issued in the 80s and PD 705 formed the nucleus of the mangrove regulations. However, there were still many aspects of mangrove regulation and management that were not covered. It was only in the 90s when policies on mangrove utilization and management finally became entrenched.

III. Existing Legal Framework on Silvofisheries

The country's fundamental law enunciates the policy that the State shall protect and advance the right of the people to a balanced ecology in accord with the rhythm and harmony of nature. It also declared that all natural resources including mangroves and swamplands are owned by the State and except for agricultural lands, all other natural resources shall not be alienated.

The different branches of government primarily through laws, rules and regulations carry out these major policies. The legislative branch enacts laws while the appropriate departments in the executive branch in exercise of the delegated legislative powers, promulgate regulations. In case of mangrove regulations, the delegated legislative power used to be centralized in one agency, which is the former Department of Agriculture and Natural Resources. This department was eventually divided the Ministry of Agriculture and Food (MAF) and MNR. Until 1984, MNR was the sole directly responsible for the overall management of the country's mangrove resources. The said ministry had supervision and control of both the Bureau of Forest and Development (BFD) and BFAR. In 1984, Executive Order No. 967 transferred BFAR to MAF and downgraded it from a line bureau to a staff bureau. BFAR however, retained its administrative jurisdiction over mangrove areas that have been classified, zonified and declared by MNR as available for fishpond development under MAF.

This has been the trend ever since, but a major reorganization effected under Executive Order No. 292 dated July 27, 1987, has indicated that the management responsibilities of the mangrove resources should continue to be shared by the Forest Management Bureau (FMB), the Ecosystems Research and Development Bureau (ERDB), and the Protected Areas and Wildlife Bureau (PAWB), all under DENR, and BFAR under DA. It was specified that FMB has jurisdiction over mangrove areas, ERDB over mangrove research and the development of ecologically sound technologies while PAWB and the Protected Areas and Wildlife Division in DENR Regional Offices have jurisdiction over mangrove areas or island proclaimed, designated, or set aside pursuant to a law, presidential decree, presidential proclamation or executive order as mangrove reserve, fish sanctuary, wilderness area or strict nature reserve and which are integral components of protected areas under Republic Act 7586 establishing the National Integrated Protected Areas System.

While the functions of FMB includes recommendation of policies and/or programs for the effective protection, development, occupancy, management, and conservation of forest lands and watersheds, including the grazing and mangrove areas, ERDB's functions include the formulation and recommendation of an integrated research program relating to Philippine ecosystems and natural resources, and the generation and development of technologies relevant to the sustainable uses of Philippine ecosystem and natural resources. ERDB practically absorbed the powers and functions of the Forest Research Institute and the National Mangrove Committee which had been abolished earlier.

On the other hand, BFAR continues to exercise management and administrative jurisdiction over areas released by DENR as available for fishpond development because PD 705 and its rules and regulations vesting such jurisdiction, have not been repealed. Its jurisdiction remained unaffected even under the 1998 Philippine Fisheries Code. In fact, the latter law further deepened the conflict in jurisdiction between DENR and BFAR.

Consequently, shared management responsibilities that included the common power to make rules and regulations on mangrove areas resulted in fragmented mangrove regulations that reflected disparate policies. However, attempts at unification or synchronization of policies by the different agencies were executed in joint administrative orders. These joint administrative orders and the administrative orders, circulars and other issuance separately issued by DENR and DA-BFAR and laws enacted by the Legislature, constituted the existing Philippine legal framework on silvofisheries.

A. *DENR rules and regulations on silvofisheries*

In 1990, DENR came up with a comprehensive mangrove regulation as the Department Administrative Order No. 15 dated February 01, 19909, establishing the rules governing the utilization, development and management of mangrove resources pursuant to PD 705. The Order incorporated three principles of mangrove management, namely, sustained yield, multiple use, and social equity.

Sustained yield management refers to the principle of continuous production of forest products to achieve an approximate balance between growth and harvest at the earliest practicable time. The resource is managed in a manner that it would provide sustainable harvest with economic returns while naturally renewing itself or with minimal assistance. Multiple use management, a concept already laid down in prior forest laws, is the management and utilization of the forest's various renewable resources so that these could best contribute to the long-term socio-economic development of the country. The scheme applies to the utilization of an area in combination with more compatible uses.

An embodiment of the multiple-use principle implemented by DENR through ERDB is the system that harmoniously combines mangrove forests with aqua-silviculture or agri-nipa silviculture. Aqua-silviculture is a multiple-use system that promotes a harmonious co-existence between fishery species and mangrove tree species in a semi-enclosed system while providing coastal protection and maintenance to the ecosystem. The area chosen for aqua-silviculture can also be optimized for aesthetic, recreational or educational purposes. While growing harvestable products such as timber and fishes, the mangrove ecosystem maintains its other ecological functions with minimal disturbance.

The social equity principle involves giving direct access of coastal families to the mangrove resource. Coastal dwellers are given the opportunity to benefit and create livelihood enterprises while protecting the mangrove forest from further degradation. The scheme encourages non-invasive sea farming of fishes, shrimps, crabs, and clams under the mangrove canopy.

Moreover, existing mangrove stands are managed by community groups through suitable management systems under tenurial schemes such as the Mangrove Stewardship Agreement (MSA), Community Forestry Management Agreement (CFMA), and Forest Land Management Agreement (FLMA) (Mangrove Technical Review Committee, 1994). It is from these three principles that silvofisheries had taken off, mainly through the technology development and research activities of ERDB. Nevertheless, not one provision on silvofisheries or aqua-silviculture can be found in the main body of the Administrative Order No. 15.

However, substantive provisions of the Order prohibited the granting or renewal of mangrove timber license or any kind of permits that authorize the cutting and/or debarking of mangrove trees for commercial purposes in areas covered by Fishpond Lease Agreement (FLA) and those outside the mangrove plantations. Cutting of trees within FLA areas is not allowed unless a permit is secured from DENR. In any case, the trees cut in these areas shall be turned over to the DENR for disposition through public bidding.

Conversion of thickly vegetated mangrove areas into fishponds was also no longer be allowed and mangrove swamps released to BFAR which are not utilized or have been abandoned for five years shall revert to the category of forest land. Estuarine mangroves which are predominantly, if not totally vegetated with shrubs shall no longer be disposed for fishpond development as such areas still contribute to the productivity of the nearby marine ecosystem, hence should be extensively rehabilitated, and applications for use of these areas shall be returned to the applicants immediately. Fishpond development was no longer allowed within mangrove forestry reserves and wilderness areas. If government opts to revert legally acquired productive fishponds within such areas, the operator would be justly compensated. Fishpond development shall only be allowed in denuded areas, which have been zonified as suited for such activity.

In lieu of fishponds, the Order prescribed several alternative modes of mangrove utilization including the establishment, development and management of Communal Mangrove Forest by community people under the concept of community-based forest management following a management plan approved by DENR. Another option is the conduct of sustainable activities indicated in an approved management plan that excludes fishpond development, saltworks and paddy cultivation under a Certificate of Stewardship Contract awarded to individuals, communities, associations or cooperatives covering mangrove areas except in wilderness areas.

Mangrove plantations are however, allowed to be established in denuded or sparsely vegetated mangrove forest lands, and alienable and disposable areas through an approved permit covering 50 ha for corporations, cooperatives and associations and 10 ha for individuals. Mangrove plantation developers may be allowed to cut the planted trees within their plantations through clear cutting by strips system for personal or commercial purposes after securing a permit from DENR. Lastly, in case of naturally grown mangrove forests, silvicultural practice that combines seed-tree method and planting is still permitted provided that in the course of harvesting, at least 40 trees per hectare, spaced regularly over the area are retained. The Order also provided for the periodic assessment of mangrove resources with the involvement of non-government organizations. Results of such assessments shall be interpreted by the National Mapping and Resource Information Authority (NAMRIA).

Memorandum Circular No. 5 dated March 8, 1990, was issued to implement the aforementioned Administrative Order and provide guidelines for the cutting of mangrove trees within FLA areas which among others required a cutting permit from DENR, a performance bond from the lessee equivalent to the estimated value of the mangrove timber gathered, and the retention of buffer zones. However, the cutting of mangrove trees was prohibited under Republic Act 7161 which became effective on October 29, 1991. Basically a revenue law that dealt with increase in forest charges and other fees levied on forest products and activities, the law became a stumbling block for the implementation of the tenurial arrangements for mangrove utilization. DENR has yet to issue a policy statement to resolve this conflict. Specifically, Section 4 of RA 7161 stated that "except for all mangrove species whose cutting shall be banned, there shall be collected forest charges on each cubic meter of firewood cut in forest lands, branches and other recoverable wood wastes of timber."

A joint DA-DENR General Memorandum Order No. 3 issued on October 31, 1991, represented an inter-agency attempt to consolidate and unify management policies on mangroves. The joint order prescribed the guidelines for the rational utilization of mangrove forest lands which have been released for fishpond development. It mandated the automatic reversion to the administration of the DENR, portions of fishpond areas that are undeveloped or vegetated with mangroves and fishpond areas found unsuitable for fishpond purposes by joint DA-DENR teams, as well as fishpond areas not covered by FLA applications within five years from release thereof to BFAR. The order also laid down the requirement of an environmental impact study and statement for fishpond operations or the application of PD 1586 and DENR DAO 34 series of 1991.

Other related rules included DAO 16 dated April 02, 1993, providing guidelines for the implementation of the Forestry Sector Project which aims to reverse the process of upland and mangrove forest denudation. In addition, DAO 23 dated April 27,1993, established the Coastal Environment Program specifying that activities related to protecting, conserving and rejuvenating coastal resources that include coastal forests or mangroves and other beach vegetation, shall be undertaken. DAO 96-29 dated October 10, 1996, integrated and unified all people-oriented forestry programs in line with Executive Order No. 263 or the Community-Based Forest Management Strategy. The order declared among its policies, respect for the rights of indigenous peoples to their ancestral domains. Active and transparent community participation and tenurial security were the key strategies adopted. Tenurial instruments under the Order which included the Community Based Forest Management Agreement (CBFMA), Certificate of Stewardship Contract (CSC), and Certificate of Ancestral Domain Claim-CBFMA, superseded all prior tenurial arrangements.

B. *1998 Philippine Fisheries Code*

Republic Act 8550 also known as the Philippine Fisheries Code of 1998 took effect on March 22, 1998. The law's underlying policies are the attainment of food security; limited access to fishery and aquatic resources; rational and sustainable development, management and conservation of Philippine fishery and aquatic resources; protection of rights of fisherfolk; support to the fishery sector; and integrated coastal area management.

The Fisheries Code also included the granting of privilege to the private sector to utilize fishery resources under the basic concept that the grantee is not only a privileged beneficiary but an active participant and partner of the government in the sustainable development, management, conservation, and protection of fishery and aquatic resources. The Fisheries Code is probably the first Philippine law that uses the term aquaculture, although it is still silent on silvofisheries.

Since it is logically inferred from the policy of sustainable development that sustainable aquaculture is also one of the objectives of the Fisheries Code, it is assumed that within the category of sustainable aquaculture falls the concept on silvofisheries. This definitely became a big improvement over PD 704 that had provisions only on fishponds and fishpens under a section on inland fisheries.

The chapter on aquaculture in the Fisheries Code, is particularly significant for its pro-environment and social justice provisions. The preferential right bestowed to qualified fisherfolk cooperatives and associations as well as small and medium enterprises on the granting of FLAs clearly exemplified the latter. In addition, the 'environmental provisions on aquaculture begin with the requirement on the preparation of a detailed Environmental Impact Statement (EIS) and securing of an Environmental Compliance Certificate (ECC) for any development activities or projects including fishponds.

Under the law, there is an injunction for fishpond lessees to provide facilities that will minimize environmental pollution such as settling ponds and reservoirs, and non-compliance leads to the cancellation of the lease agreement. Lessees are likewise prohibited from undertaking any construction that will obstruct any defined migration path of migratory fish species. DA through BFAR, has also been mandated to formulate incentives and distinctive for sustainable aquaculture practices.

The most relevant provision relative to silvofisheries can be found in section 47 of the Fisheries Code, instructing BFAR to formulate a code of practice for aquaculture that outlines general principles and guidelines for environmentally sound design and operation to promote the sustainable development of the industry. Environmentally sound design and operation are broad enough to include silvofisheries in its scope.

The development of the Code of Practice for Aquaculture shall be made through a consultative process with the DENR, the fishpond workers, FLA holders, fishpond owners, fisherfolk cooperatives, small-scale operators, research institutions, and other potential stakeholders. BFAR has been encouraged to consult with specialized international organizations in the formulation of the said code of practice.

It should be noted that the Philippines is a signatory to the international Code of Conduct for Responsible Fisheries which became effective on October 31, 1995. It is therefore very logical that the principles embodied therein be incorporated in the country's code of conduct for aquaculture. One of the general principles of the international code is the production and rehabilitation of all critical habitats in marine and freshwater ecosystems such as wetlands, mangroves, reefs, lagoons, nursery, and spawning areas.

The pertinent provisions of the international Code on aquaculture oblige States to promote responsible development and management of aquaculture, including an advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best available scientific information. States should also produce and regularly update aquaculture development strategies and plans to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities.

The Fisheries Code also promotes the reversion of all abandoned, undeveloped or underutilized fishponds to their original mangrove state. At least 25% but no more than 40% of bays, foreshore lands, continental shelf or any fishing ground shall be set aside for the cultivation of mangroves to strengthen the habitat and the spawning grounds of fish. Within these areas, no commercial fishing should be allowed. These areas are the so-called fish refuge or sanctuaries established by the Fisheries Code in addition to all other marine fishery reserves, fish sanctuaries and mangrove swamp reservations already declared or proclaimed by the Philippine President or legislated by the Congress of the Philippines.

The Fisheries Code also provided that at least 15% of the total coastal areas in each municipality shall be identified based on the best available scientific data in consultation with BFAR. These areas shall be automatically designated as fish sanctuaries by the local government units and the concerned Fisheries Aquatic Resource Management Councils (FARMCs).

Further bolstering the protection and preservation of mangroves, section 94 of the Fisheries Code penalizes the further conversion of mangroves into fishponds or for any other purposes with imprisonment of six years and one day to twelve years and/or a fine of eighty thousand pesos and rehabilitation or restoration of the area or compensation for the restoration of the damage. This penal revision and the earlier law, RA 7161, prohibiting the cutting of mangrove trees reflected so far, the most protective policy adopted by the government concerning mangroves.

The Fisheries Code also prescribes the registration of fish hatcheries, fish breeding facilities and private fishponds with the local government units. In fact, all the provisions on aquaculture and the other requirements found elsewhere in the Fisheries Code are applicable to private fishponds. As specified, the provisions in the Code shall be enforced in all lands devoted to aquaculture, or businesses and activities relating to fishery, whether private or public lands.

The coverage of silvofisheries may be expanded to include all other fishery activities that do not entail destruction of mangroves, such as sea ranching, mariculture and construction of fish pens, traps, corrals or fish cages. These activities are now strictly regulated under the Fisheries Code. Construction shall only be undertaken within established zones designated by the local government units after the corresponding licenses have been secured. The grant of such privileges in municipal areas is exclusively for the benefit of the municipal fisherfolk and their organizations.

On the other hand, not over 10% of the suitable water surface area of all lakes and rivers shall be allotted for aquaculture purposes like fish pens, fish cages and fish traps. Stocking density and feeding requirement shall be controlled and determined by its carrying capacity. However, two years after the effectively of the Fisheries Code, or by the year 2000, fish pens or fish traps shall no longer be allowed in lakes.

IV. Conclusion

One of the factors that led to the birth of silvofisheries is the preservation of the mangrove ecosystem, one of the critically significant and vital ecosystems that characterize the country's environment. The discussion on past and present legislation and policies on mangroves and fishery resources had shown the gradual transformation of a mind-set concerning mangroves. From marshy and malodorous wastelands, mangrove are now highly regarded for their true worth, as manifested in laws and policies on rational and sustainable utilization of mangrove, fishery, and other aquatic resources. These laws and policies are constantly evolving, although there is still a need to establish a concrete and substantive law on silvofisheries. Some policies on silvofisheries may be currently in place, particularly at DENR, but these have not been rationalized so far. At BFAR for example, there is a lingering perception that silvofisheries is only for the small-scale operators therefore limiting the undertakings and activities on silvofisheries to experimental activities. However, when the Code of Practice for Aquaculture that enjoin the use of sustainable aquaculture practices and environmentally sound design and operation, becomes a reality, then silvofisheries may finally find its own anchor.

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COMMUNITY-BASED MANGROVE-FRIENDLY AQUACULTURE: PHILIPPINE EXPERIENCE

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I. Introduction

Mangrove ecosystems throughout the Philippines are presently under threat by a variety of agents, a fact that is well known to all who have the occasion to consider the issue. In most cases, the basis of many activities which threaten the remaining mangrove stands is mainly for simple economic gain. Such exploitation may either be direct as in the case of fuel-wood gathering, charcoal production, and timber extraction or indirect as in the case of the release of the mangrove swamp areas for fishpond or real estate development.

The economic advantage associated with each type of exploitation has in the past been counted as a socially valuable contribution to the human community. In recent years however, a rising chorus of voices has been heard questioning the nature of such advantage and has indeed asserted that the various forms of exploitation represent the net cost to society.

Mangrove has various uses and values that have not been accounted for by traditional economics (Harger, 1982). Mangroves continue to provide the basic needs of man as well as intangible multiple benefits that influence man and his environment.

At the component level, mangroves are sources of food, firewood, poles, foundation piles, and raw materials for the manufacture of glue, dye, charcoal, tea, tannin, and resin. Mangroves also provide adhesive materials for plywood manufacture, honey, sugar, medicine, roofing and thatching materials, charcoal, vinegar, dissolving pulp, rayon, and livestock forage and feed supplement.

At the ecosystem level, mangroves provide essential spawning grounds that permit the reproduction of some species of fish and shellfish and at the same time serve as nursery for some offshore shrimps and fishes. Mangrove ecosystems are highly productive entities that contribute a major share of the energy requirements in the offshore ecosystems where a close dependence between mangroves and fishery productivity exists.

The contribution of mangroves to nearshore fisheries is supported by studies that show a positive relationship between a mangrove area (r=89), the total length of mangrove-lined rivers (r=96), and shrimp catches (Martosubroto and Naamin, 1977, Staples et al., 1985). A positive correlation between Philippine municipal fishery catches and existing mangroves (r=72) has also been documented by Camacho and Bagarinao (1987).

During the past decade and concurrent with the rise in population, was the increase demand for agriculture, aquaculture, and industrial development. Consequently, areas originally dominated by mangrove forests have been cleared for fishpond development. In 1967, mangrove forests totaled 418,990 ha, but after fifteen years this was reduced to 239,387 ha (BFD, 1984).

At present, the remaining total mangrove area in the Philippines is only 120,500 ha (EMB,1995). The reduction represents 73% of the mangrove area at the start of the century. The SPOT survey in 1988 revealed that 95% of the present fishpond areas were derived from mangroves between 1952 to 1987.

Unwise exploitation may eventually lead to loss of genetic biodiversity in the mangrove ecosystem (Serrano and Fortes, 1987). A point may be reached wherein future generations will be deprived of this unique environment. In order to redress this deteriorating scenario, planned changes must be implemented to arrive at coastal development within the concept of sustainability. This implies the need for development of strategies and/or alternative land uses for coastal areas that will provide for regeneration and at the same time satisfy the needs for human survival.

The government believes that by addressing the needs of the local communities, the people will join hands to protect and manage the very source of their livelihood. With this objective, the Community-Based Forest Management (CBFM) Program was created on July 19,1995 when the President of the Republic of the Philippines signed Executive Order No. 263 adopting the Program. The CBFM Program is a national strategy to ensure the sustainable development of the country's forestlands, resources and providing mechanisms for its implementation. The rules and regulations for the implementation of EO 263 is contained in the DENR Administrative Order No. 96-29.

II. Mangrove-Friendly Aquaculture

Mangrove-friendly aquaculture is a system whereby mangrove species with aquaculture and fisheries production harmoniously co-exist for the sustainable benefit of nearby communities without hampering the ecological functions of the mangrove ecosystem. Two community-based systems have been developed: aqua-silviculture and agri-nipa-aquaculture (ANA).

A. *Aqua-silviculture*

Aqua-silviculture (roughly translated as aquaculture or fish production under the forest trees) is a multiple-use system that promotes a harmonious co-existence between fishery species and mangrove tree species in a semi-enclosed system while providing coastal protection, maintenance to the ecosystem, and livelihood for the surrounding communities. The fish-mangrove inter-cropping system is also a compromise to solve conflicting interests between the forestry and fishery sectors, and the local communities. In this system, fish is cultured in the deeper part of the pond while mangrove species are planted in the shallow portion.

Thus, the aqua-silviculture technology promoted a peaceful co-existence between fish ponds and mangroves. It is a typical example of a multiple-use system of management which is now recommended and adopted as a community-based management of the mangrove forest ecosystem. The technology is expected to facilitate the reversion of the now abandoned and unproductive or denuded and open areas to their productive condition, since a portion of the areas will be utilized for brackishwater aquaculture development. This can also be tapped as an additional source of income for the mangrove-dependent population.

In the Philippines, the ratio of mangrove plantation to open pond area is 70:30 or 80:20, that is 70 to 80 percent is devoted to mangrove trees which is usually at the center of the pond, and 20 to 30 percent which comprises the deeper portion is devoted to fish production. Water is controlled in such a way that the whole pond including the plantation is covered with water during high tide. In addition to the growing trees, the system also increases the farmer's income from aquaculture production, and sale of mangrove propagules and other mangrove products.

1. Areas for aqua-silviculture development

Areas considered for aqua-silviculture development are those open and denuded mangrove areas with settlers; unproductive and abandoned fishponds; areas under Presidential Proclamation 2152 which have been fully or partially developed prior to the effectivity of such proclamation; and those A & D (titled or private lands) areas whose owners are willing to adopt the new technology. The planting of mangrove species in the aqua-silviculture system should consider the site requirements of the trees which include soil and sediment characteristics, water salinity, seedling development and tidal inundation; as well as silvi-cultural techniques and objectives regarding the management of the forests.

2. Forestry and mangrove development

Mangrove species suitable for aqua-silviculture which are economically important should be used. With respect to the mangrove soil utilization, some considerations in intensifying aqua-silviculture should include the following:

a. The first five years

During this period of pond utilization when the plants are still in the seedling or sapling stage, the pond can be utilized intensively from 3 to 5 years. This period can therefore be devoted to fish production and for repayment of investment. Starting on the third year, the plants may have already produced propagules that could be sold. The main activities therefore that can be carried out during this period are: maintenance of dikes, fertilization for algae production, protection of plants from pests and diseases, control of predators, and replanting.

b. The next six to ten years

After 5 to 10 years, the mangrove seedlings shall have reached the sapling stage (2-10 cm diameter) or tree stage (> 10 cm in diameter) with 5 m or more in height. The trees in the pond should be pruned or thinned depending on the quality of the mangrove trees, to allow sunlight to penetrate the pond. This is necessary for the production of food for the species cultured in the ponds. The pruning and thinning may be utilized for firewood or for low cost housing materials while the leaves may be used as forage for livestock or organic fertilizer. The trees are considered mature from the 15th year onward.

3. <u>Fisheries and fish production</u>

The development of aqua-silviculture should be intensified to a maximum level of production by considering silvi-culture and mariculture requirements.

a. Plantation establishment

The rows of mangrove species should be planted in the east-west direction. This is to allow full sunlight to penetrate the pond bottom for production of natural food for the cultured species.

b. Pond engineering

This includes layout and pond construction, layout and canal system construction, and floodgate and control system.

c. Pond Management

This includes preparation of pond bottom for algae production, water regulation (quantity, quality and regimen); pond fertilization (organic and inorganic); pest, disease, and predator control; fry and fingerling gathering and/or production; and stock management (fish, shrimps, crabs, etc.)

4. <u>Aqua-silviculture establishment</u>

In selecting sites for aqua-silviculture, the following conditions should be considered:

a. Tidal inundation classes;
b. Water quality assessment of pond water and surroundings (physical and chemical parameters);
c. Soil analysis and nutrient status;
d. Pollution (soil, water, air [acid rain]); and
e. Availability of planting materials.

Planning is essential in the stage of implementation and the factors to be considered include the duration of implementation; availability of labor; and budget. Specific plans should also include the following:

a. Pond compartmentalization;
b. Pond bed drainage;
c. Diking and/or use of nets and low dikes;
d. Canal systems; and
e. Location of guardhouse, watchtowers and floodgates.

As to the tidal classes in the aqua-silviculture site, the height of the dikes should be based on data of exceptional high tide or flood and astronomical high tide. Dikes should not be reached by both tides and floods, otherwise extra use of nets will have to be resorted to.

B. *Agri-nipa-aquaculture*

One of the technologies being tested and known to have a positive effect in the coastal areas is aqua-silviculture (Baconguis, 1991) which harmonizes the planting of mangrove trees with fish production. The technology however limits income generation to only fish production during the first seven years of operation, since harvest of planted mangrove trees can only be done on the eighth year.

An alternative which is considered a variation from aqua-silviculture is the agri-nipa-aquaculture(ANA). This is a sustainable land use system which combines the planting of nipa and agricultural crops with fish production in suitable areas.

C. *The impact of aqua-silviculture and agri-nipa-aquaculture*

The implementation of aqua-silviculture and agri-nipa-aquaculture in the coastal areas of the Philippines is in response to the environmental and socio-economic factors.

1. <u>Environmental factors</u>

a. Coastal degradation

The aqua-silviculture or agri-nipa-aquaculture technology will help rehabilitate the denuded mangrove, nipa and mudflat areas. Nipa and mangrove forests help stabilize coastal areas and protect rural coastal communities from strong winds, typhoons, and storm surges such as tsunamis.

b. Coastal pollution

In the implementation of aqua-silviculture or agri-nipa aquaculture, the coastal dwellers become aware of the effects of pollution on aquaculture, hence, communities will be vigilant in protecting their environment from pollutants.

c. Enhanced wetlands as wildlife habitat

The establishment of the nipa and/or mangrove forest harbors wildlife species that are also economically and ecologically beneficial.

d. Rehabilitation of degraded and/or abandoned fishponds.

All mangrove areas are potential acid sulfate soil sites. When fishpond location is inadequately designed or their is no freshwater source, acid sulfate soils will develop in two to three years. Consequently many fishponds become unproductive after three years. Milkfish for example, will not grow normally and shrimp will not survive under these conditions. With mangroves and nipa palms at the center of the pond, the farmer will still have some income even if fish production is minimal.

2. Socio-economic factors

a. Creation of job opportunities

The construction of ponds with its canal system and appurtenances, and planting of mangroves, nipa and agricultural crops create job opportunities. Inhabitants in and nearby areas will be hired as laborers, caretakers, and fry gatherers. Other income prospects will also come later either from fry gathering or supplying fingerlings or from selling fish and vegetables. Family members without regular jobs can therefore be involved in these productive endeavors.

b. Equity of natural resources

Many will benefit from the resources in areas where the management of aqua-silviculture or agri-nipa-aquaculture project is community-based undertaking or through cooperatives and/or associations. Equal distribution of the benefits will accrue to each member.

c. Increased income

Generally, income of coastal dependent communities will increase because fish with nipa and mangrove products will be harvested for additional income. If properly managed, producing agricultural crops, shellfish, molluscs, mud crab, small livestock, honey bees, etc. can also be integrated within the system. An example is the growing of passion fruit which has a good market potential and a good source of fruit juice and vitamins for the resource-poor coastal families.

d. Availability of low-priced animal protein

The culture of economic species in the ponds will also provide increased production of food for domestic consumption as well as for export.

e. Foreign exchange potential

Shrimp culture in the Philippines has gained popularity and the export potential of shrimp is still high. Nipa also yields industrial products with export potential such as high grade alcohol for industries, etc.

d. Availability of products

In the implementation of agri-nipa-aquaculture through community-based management, many products will be available for the poor coastal communities.

e. Community awareness

Technology dissemination and community awareness on the sustainable utilization of coastal areas, will be introduced to the communities.

III. The Community Based Forest Management (CBFM) Program

"People first and sustainability will follow" sums up the concept of the CBFM Program. The government believes that by addressing the needs of the local communities, they will be encouraged to protect and manage the very source of their livelihood. CBFM came into being on 19 July 1995 when the President of the Republic of the Philippines signed Executive Order (EO) No. 263 adopting community-based forest management as a national strategy to ensure the sustainable development of the country's forestlands, resources and providing mechanisms for its implementation. The rules and regulations for the implementation of EO 263 is contained in the Department of Environment and Natural Resources Administrative Order (DAO) No. 96-29. The objectives of the CBFM Program include promoting sustainable management of forest resources; social justice and improved well-being of local communities; and strong partnership among local communities and the Department of Environment and Natural Resources (DENR).

A. *Scope of CBFM*

CBFM applies to all areas classified as forest lands, including allowable zones within protected areas not covered by prior vested rights. The Program integrates and unifies all people-oriented forestry activities of the Integrated Social Forestry Program (IFSP), Coastal Environment Program (CEP), and Recognition of Ancestral Domains.

B. *Features of CBFM*

1. Security of tenure

The Community-Based Forest Management Agreement (CBFMA) entitles forest communities to use and develop the forest land and resources for a duration of 25 years, renewable for an additional 25 years.

2. Social equity

Social justice is a basic principle underlying CBFM in granting forest communities tenure and comprehensive right to use and develop the forest resources.

3. Technical assistance

DENR and Local Government Units (LGUs) provide technical assistance to CBFM participants to help them attain sustainable forest management.

4. Investment capital and market linkage

CBFM helps participants access investment capital, identify markets, and build marketing capabilities.

C. *Who can participate in CBFM*

The main participants of the program are local communities including indigenous people represented by their People's Organization (POs) and Traditional Tribal Councils (TTC) whose members are actually tilling portions of the area to be awarded, or are traditionally using the resources for all or substantial portion of their livelihood, or are residing in or adjacent to the areas to be awarded.

1. Roles of DENR and Local Government Units (LGUs)

A strong DENR-LGU partnership is vital to the success of the CBFM Program. DENR and LGUs, in active collaboration with other sectors, work together to help strengthen local forest communities in managing the forest resources. The DENR and LGU partnership in CBFM has resulted in substantial LGU financial support for forest land use planning, community mapping, community organizing, technical training, and IEC. Thus, the DENR and LGU collaborate in order to identify potential CBFM sites, plan forest land uses with communities, and endorse and issue CBFMAs; organize and prepare CBFM communities for a CBFMA; provide technical assistance and skills training for CBFM communities; and monitor progress and environmental impact of CBFM activities.

2. Roles of the People's Organizations (POs)

The People's Organizations join DENR and the LGU in making a forest land use plan and prepare a Community Resources Management Framework (CRMF) including the POs Mission and Objectives. The POs also represent the interest of their forest communities, and help protect and maintain the forestlands entrusted to their stewardship.

IV. CBFM in Mangrove Areas (DAO No 98-10 March 4, 1998)

Pursuant to PD 705 as amended, otherwise known as the Revised Forestry Code of the Philippines, EO 263 entitled "Adopting CBFM as the National Strategy to Ensure the Sustainable Development of the Country's Forestland Resources and Providing Mechanisms for its Implementation and its Implementing Rules and Regulations" embodied in DAO 96-29, guidelines were issued for the establishment and management of CBFM within mangrove areas.

A. *Objectives*

Community-Based Forest Management Projects shall be established in mangrove areas in order to promote equitable access to natural resources, help in the socio-economic upliftment of local communities, and encourage their participation in the conservation, rehabilitation, afforestation and management of mangrove forests.

B. *Establishment and management of CBFM Projects*

The establishment and management of CBFM Projects in mangrove areas shall be in accordance with DAO 96-29 and other policies issued on CBFM. Provided, that in case the mangrove area is within a protected area, the management of the same shall be in accordance with the provisions of RA 7586 and its implementing rules and regulations. Provided further, that participants to CBFM Projects shall be organized and issued Community-Based Forest Management Agreement (CBFMA) consistent with relevant provisions of DAO 96-29.

C. *Cutting or harvesting and utilization within CBFM areas*

Cutting or harvesting of mangrove species shall not be allowed provided that these are planted by the CBFMA holders themselves and that the harvesting operations are included in the affirmed Community Resource Management Framework or Ancestral Domain Management Plan. Harvesting is also allowed provided further that replanting of the area harvested shall be undertaken within six months after harvesting operations, and provided, finally that the harvesting operations, shall be closely monitored by the CENRO/PASU concerned.

V. Cooperative

A cooperative is a business organization owned collectively by members who share its profits and benefits. Upland farmers and coastal communities are encouraged to form a cooperative citing the benefits that they can derive from it. These include motivation of the members to work and help each other; provision of cheap goods and services, and loans that can be availed of by the members; encouragement for members to save and invest their earnings for their own good; and provision of opportunities for members to own and manage the cooperative.

A. *Starting a cooperative*

1. Gather information to determine if there really is a need to start a cooperative
2. Suggest to community members that they will start a cooperative.
3. Form a committee who will organize the cooperative
4. Call a general meeting of prospective members of the cooperative. During the meeting the following issues will be discussed:

    a. Will member's expenses be lessened with the establishment of the cooperative?
    b. Will income in marketing of products be higher if there is a cooperative?
    c. Will the community members gain experience and knowledge with the establishment of the cooperative?

5. If a decision is arrived at to form a cooperative, formulate the cooperative's constitution and by-laws.
6. Elect the cooperative's officers
7. Assign tasks to cooperative members for management of the cooperative
8. Prepare the following papers to register the cooperative
    a 4 copies of economic survey
    b. 4 copies of Articles of Incorporation
    c. 4 copies of By-Laws
    d. Registration fee payable to the Cooperative Development Authority (CDA)

9. Register the cooperative with the Cooperative Development Authority

VI. Concluding Remarks

Mangrove is one of the critically significant ecosystems that characterize the Philippine environment. Although considered a minor contributor to the whole system because it occupies a very small portion of the total forest cover of the country, for economic reasons it is also of paramount importance to Filipinos in many ways, especially to those living in the coastal areas. The mangrove area in the country has been reduced s by 73% from the 1918 figures, thus, impairing its economic and ecological role.

In order to remedy this deteriorating scenario, planned changes must be implemented to arrive at coastal development within the framework of sustainability. This necessitated the development of strategies and alternative land uses for coastal areas that will provide for regeneration and at the same time satisfy the needs for human survival.

This paper discussed two mangrove-friendly aquaculture technologies that will not only protect the coastal and mangrove ecosystem but could also increase the income of the coastal communities not only from the forest products but also from fish, shellfish, and crab production. Moreover, the technologies will not only serve as livelihood but also help in promoting the conservation of biodiversity.

The creation of Executive Order (EO) No. 263 adopting CBFM to ensure the sustainable development of the country's forestland resources could be one of the solutions. With the empowerment of the people, the communities will be encouraged to join hands to protect the very source of their livelihood. Thus, sustainable forestry development is expected to be attained.

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MANGROVE-FRIENDLY MARINE SHRIMP AQUACULTURE TECHNOLOGY: THAILAND EXPERIENCE

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I. Introduction

The intensive marine shrimp farming has just developed in the past decade. Since 1991, Thailand has become the leading country for exporting marine shrimp product from aquaculture in the world market. In 1998, the yield was around 234,000 mt and the average production rate was 3324 kg/ha. Thailand has developed technologies for mangrove-friendly marine shrimp culture including the zero water discharge during culture period and water recycle system which have been adopted by the shrimp farmers. The research on biotechnology for shrimp farm effluent treatment processes has also been conducted both by the concerned government agencies and private shrimp farms. Mangrove reforestation in suitable coastal areas has also been carried out.

Thailand has had the experience on coastal aquaculture for a long time. It has a huge flood plain, long riverine stretch, natural lagoon, estuarine, and brackishwater areas along the coastal line, on the Gulf of Thailand and Andaman Sea with approximately 2600 km of shoreline. Shrimp farming has been practiced on traditional or extensive methods in the coastal land area for nearly three quarters of a century. Shrimp fry were accidentally trapped in salt beds and paddy fields near estuarine areas. Originally, wild shrimp fry either enter during tidal water exchange or are intentionally gathered from the wild and stocked directly in ponds. Production depends on the seasonal abundance of wild fry which fluctuates widely year by year.

In 1973, Thailand successfully spawned and partially reared larvae of *Penaeus* spp., such as *P. monodon* and *P. merguiensis* (Tookwinas, 1993). This was in response to the efforts of the Department of Fisheries (DOF) which encouraged the production of additional seedstock from hatcheries for stocking in extensive ponds. Later, the semi-intensive marine shrimp farming system was adopted with the addition of supplemental feeds.

In the past decade, intensive farming technology for *P. monodon* has been developed and practiced in Thailand, making the area for marine shrimp farm expand tremendously to 74,942 ha in 1995. At present, shrimp farming in Thailand can be classified into three categories: intensive, semi-intensive, and traditional or extensive. As a result, the shrimp production reached 234,000 mt in 1998 (Table 1).

II. Farming Method

Marine shrimp farming system can be classified into three or four categories depending on the intensity (Tookwinas, 1993): extensive (traditional), semi-intensive, intensive, and super-intensive shrimp farming systems. Each type is classified in terms of the area and stocking density.

Extensive shrimp farming system or the traditional method is characterized by irregular shapes and size of ponds from 5 to 10 ha. Semi-intensive shrimp farming system is improved over the extensive farming system, where ponds are normally rectangular in shape of about 1-6 ha, and the stocking density is about 5-10 PL/m^2. On the other hand, the pond size for intensive farming system varies from 0.16-1.0 ha and the depth is approximately 1.5-2.0 m. The pond shape can be either rectangular or round with stocking densities ranging from 20 to 50 PL/m^2 and requires high financial and technical inputs. Artificial aerator used may be the paddlewheel which is either electric or diesel motor-driven, while another common practice makes use of oxygen injection.

In this system, shrimps are fed nutritionally complete artificial diet. Cropping is 2x/yr with an average survival rate of about 60-90%, and production can be as high as 12,500 kg/crop. However, problems on disease and environmental pollution occurring with this system are much greater than the other two farming systems.

Super-intensive shrimp farming system is the most organized system of shrimp farming. In Thailand, few farms are operated by converting the semi-intensive farm and/or intensive farm to super-intensive farm. However, this system would require very high financial and technical inputs. Although the pond construction scheme is the same as that of intensive system, the stocking rate is much higher at about 100 PL/m^2, but production is about 20,000 kg/ha/crop.

According to the survey of NACA/ADB (Tookwinas, 1995), it was estimated that most of marine shrimp farms in Thailand are either intensive or extensive farms. There are no semi-intensive marine shrimp farm at present, while most of the extensive farms are located at the inner areas of the Gulf of Thailand, Chanthaburi, Eastern Thailand, and Nakon Sri Thammaraj in Southern Thailand.

III. Culture and Production

The suitable coastal area for intensive marine shrimp farming depends on many factors and criteria, including water salinity and source, soil quality, and socio-political factors. The suitable average water salinity the whole year should range from 10 to 32 ppt. The texture of soil should be mud or muddy sand in order to reduce water seepage and prevent water losses in the ponds. The soil pH should be around 7-8 (Tookwinas, 1993).

Due to the development of the technology of intensive farming since 1985, the culture area of marine shrimp in Thailand has expanded very rapidly from 4939 farms in 1985 covering about 40,769 ha to 26,145 farms in 1995 with a total area of 74,942 ha as can be seen in Table 1 and Fig. 1.

The production per culture area has also increased from 388.7 kg/ha in 1985 to 3596.7 kg/ha in 1994. However, the yield, culture area and number of farms have decreased in 1996 and 1998. The shrimp farm areas which are located along coastal provinces of the country has shifted from the Inner Gulf of the Thailand and Eastern part to the Southern part both west coast of the Gulf and the Andaman Sea, due to the pollution in the Inner Gulf area. Most of shrimp farmers are small operators with farming area categorized into four scales: 0.16-1.6 ha. (78.7%), 1.6-8.0 ha. (18.8%), 8.0-32.0 ha. (2.20%), and more than 32.0 ha (0.3%) (CP Aquaculture, 1994).

Table 1. Marine shrimp farming in Thailand Area Number of farms and production (1985 - 1998)

Year	Number of farm	Area (ha)	Yield (mt)	Production (kg/ha)
1985	4,939	40,769	15,840.56	388.7
1986	5,534	45,368	17,885.83	394.2
1987	5,899	44,770	23,566.47	526.4
1988	10,246	54,778	55,632.84	1015.6
1989	12,545	71,165	93,494.50	1313.7
1990	15,072	64,060	118,227.05	1830.0
1991	18,998	75,332	162,069.69	2151.4
1992	19,303	72,796	184,884.32	2539.8
1993	20,027	71,887	225,514.30	3137.1
1994	22,198	73,247	263,445.96	3596.7
1995	26,145	74,942	259,540.54	3463.2
1996	22,913	69,463	229,000.00	3296.7
1997	21,000	69,120	219,000.00	3168.4
1998	22,500	70,400	234,000.00	3323.9

Source : Fisheries Statistics (1998)
Data in 1998 is estimated.

Farmed shrimp is the third largest export commodity of Thailand (Export Production Department, 1997). In 1996, the total export was 161,461 mt (Table 2) valued at 43. 4021 million Baht. Thailand exports shrimps to many countries, especially to Japan, U.S.A.. EU, Singapore, Hong Kong, and Australia.

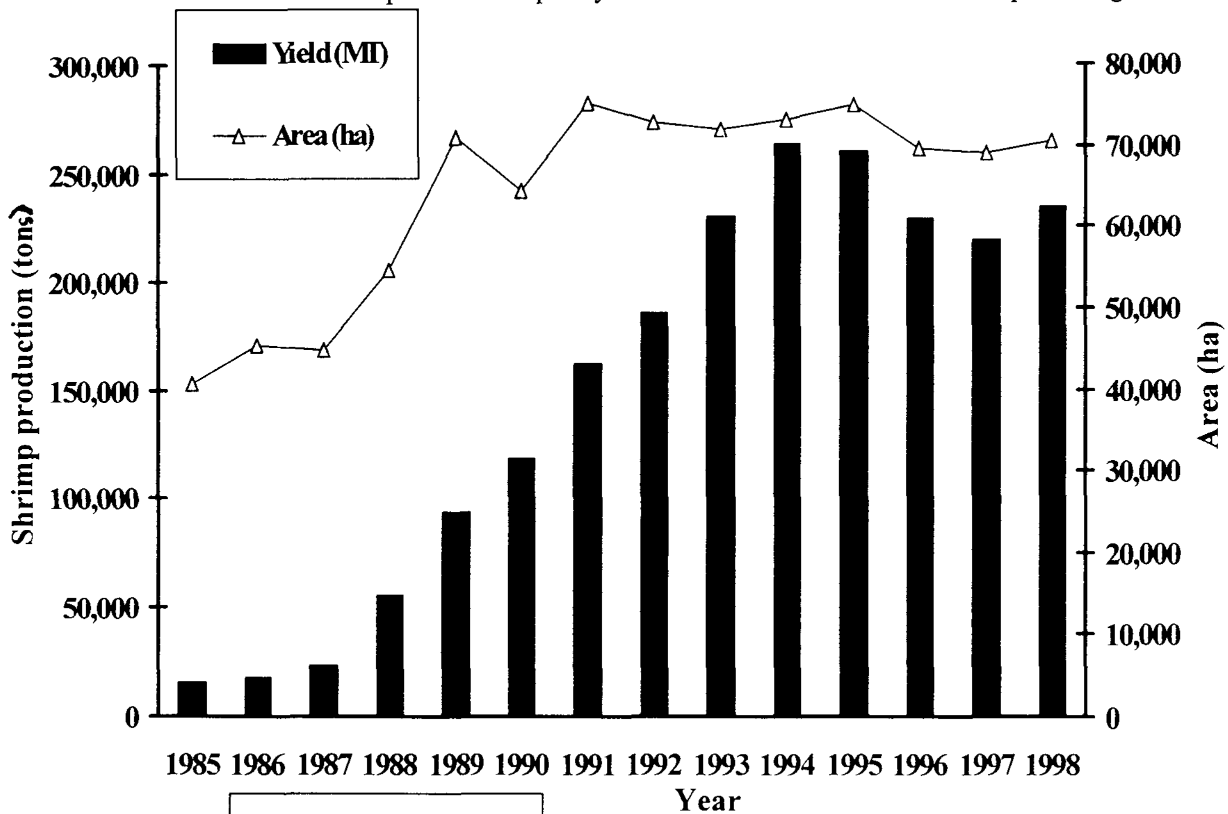
IV. Success Factors and Impacts of Shrimp Farming in Thailand

A. *The success factors*

The expansion of culture area and increase in production occurred very rapidly since 1985. Thailand has become the leading country in marine shrimp production from farming since 1991. Kongkeo (1994) and Tookwinas (1996) stated that the key factors for the success of marine shrimp farming in Thailand are attributed to the following factors:

1. <u>Suitable sites</u>

Thailand is in the tropics and has plenty of coastal areas suitable for shrimp farming.



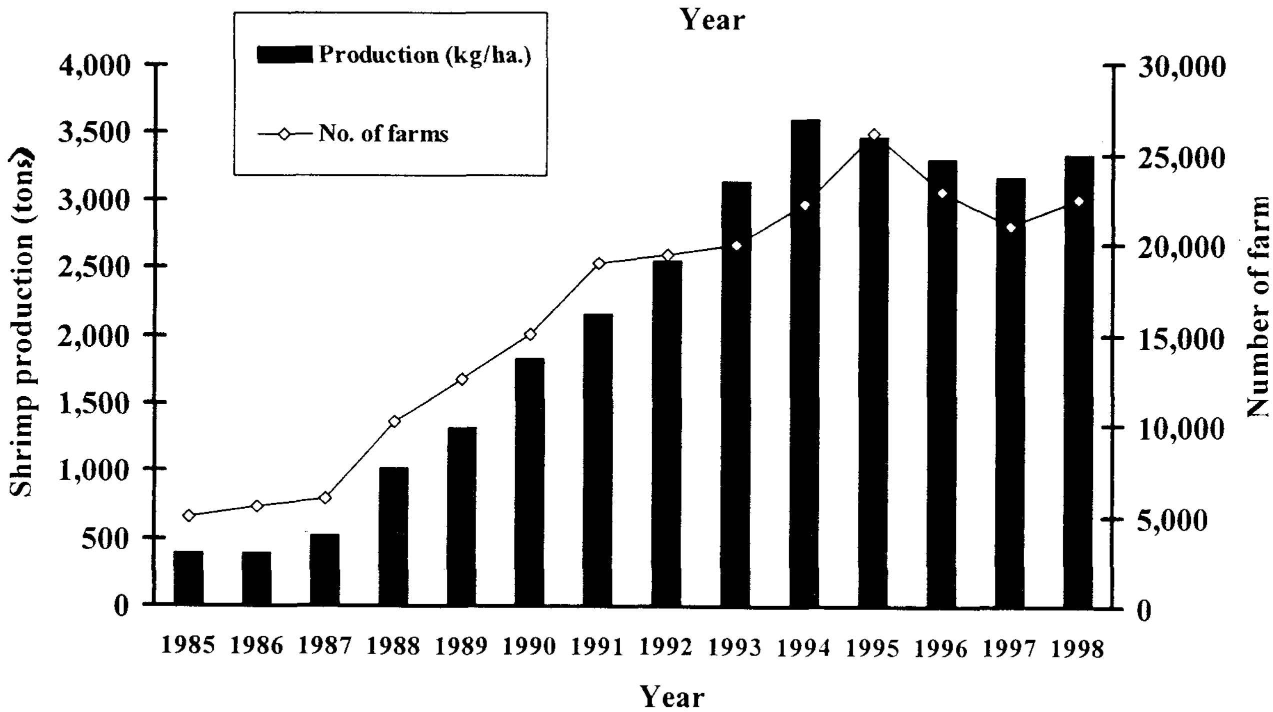


Fig 1. Shrimp production, culture area, annual yield and number of farms in 1985-1998.

Table 2. Export quantity of fresh and frozen farm shrimps by country 1989 - 1996
Quantity: tons

Country/ Year Total	**1989**		**1990**		**1991**		**1992**	
	74,294	**100%**	**84,724**	**100%**	**121,240**	**100%**	**130,516**	**100%**
JAPAN	40,258	54.19	43,486	51.33	56,194	46.35	51,166	39.20
U.S.A.	14,620	19.68	14,941	17.64	31,037	25.60	37,150	28.46
EU	6,184	8.32	11,837	13.97	15,351	12.66	16,790	12.86
ASEAN	7,585	10.21	7,307	8.62	8,139	6.71	10,176	7.80
TAIWAN	138	0.19	232	0.27	557	0.46	1,690	1.30
EFTA	0	0	597	0.71	687	0.57	1,793	1.37
OTHERS	5,509	7.41	6,324	7.46	9,275	7.65	11,751	9.00

Country/ Year Total	**1993**		**1994**		**1995**		**1996**	
	148,886	**100%**	**187,072**	**100%**	**175,091**	**100%**	**161,462**	**100%**
JAPAN	53,873	36.18	66,082	35.32	50,738	28.98	41,812	25.90
U.S.A.	46,034	30.92	53,332	28.51	44,385	23.35	35,575	22.03
EU	15,027	10.09	17,377	9.29	20,712	11.83	18,195	11.27
ASEAN	10,731	7.21	11,854	6.34	13,996	7.99	14,644	9.07
TAIWAN	8,338	5.60	11,649	6.23	11,743	6.71	10,034	6.21
EFTA	1,788	1.20	1,697	0.91	1,983	1.13	1,257	0.78
OTHERS	13,095	8.79	25,081	13.41	31,534	18.01	39,945	24.74

Source: Department of Custom (1988) cited by Fisheries Economic Division (1998)

2. Availability of wild broodstock

Tiger shrimp (*P. monodon*) is a local shrimp species in Southeast Asia and its wild broodstock is readily available in Thailand for the hatchery production of fry. The Department of Fisheries has implemented a conservation program for the restocking of shrimp fry in coastal waters at around 400-500 million fry every year. Some farmers in cooperation with the Department of Fisheries also restock portions of their shrimp production after harvesting in order to maintain or supplement the natural population of the tiger shrimp.

3. Long experience in aquaculture

The shrimp farmers in Thailand have a long experience in aquaculture and are also enthusiastic to learn and practice advanced technologies and new ideas for development or modification. The farmers are also eager to run experiments by themselves. The present success of Thailand in this industry is a testimony to the persistence and ingenuity of the Thai people in utilizing applied science to its utmost potential (CP Aquaculture, 1994).

4. Well developed infrastructure and support industries

Marine shrimp industry requires infrastructures and support services such as transportation, electricity and telephone communications that are most important for its fast development. Luckily, these are very well developed to support the industry in Thailand. There are also enough support and line business such as construction materials, heavy machines, feed mill, shrimp fry hatcheries, and food processing plants which help the development of the country's shrimp industry.

5. Small-scale industry

Marine shrimp farming in Thailand is still a small-scale industry where most of grow-out farm area is small at approximately 0.16-1.6 ha, and run by family members with intensive care and attention. This system is quite convenient for pond construction and operation, and the cost of investment is much lower. Thailand also uses techniques for backyard hatcheries, which can be managed with simple but efficient technology by farmers with little education, but producing more than 80% of the national shrimp fry production.

6. Control of environmental impact

Thailand has a coastal line of about 2600 km where the marine shrimp farming has expanded and scattered in every coastal province. Since the effluents from shrimp farms can be easily dispersed. the farmers adopt a low water exchange system which can reduce effluent release to the coastal areas. Previously, mangroves were converted to shrimp farms because of its convenience to get water supply.

Thus, vast mangrove areas were destroyed for the construction of aquaculture ponds. However, it has been accepted that the destruction of mangroves also destroys not only fish and crustacean nursery grounds but also natural flood and storm protection barriers (Sakthivel, 1985). The area now considered best suitable for shrimp farming are the rice fields in the coastal areas. These are the rice fields with very low production because of very high clay silt content of the soil, conditions suitable for pond construction and prevention of seepage. Government agencies such as the Department of Fisheries and Office of Environmental Policy and Planning have had many mitigation measure programs for aquaculture and other agriculture activities, as well.

7. Government support

The Thai government policy strongly supports the shrimp culture industry. The Government has provided investments in terms of infrastructure, research, training and extension, and other activities to support sustainable shrimp farming. This institutional support is a crucial factor in the development of the shrimp farming industry in Thailand.

8. Adaptability

The government and the private sector have been able to adopt management practices, policy, and institutional support responding to the changes in shrimp farming which have occurred over the past 10-15 years. For example, shrimp disease problem, marketing conditions, and other changes have been responded to quickly by government and the private sector.

B. *Impact of marine shrimp farming*

The growth of shrimp production from culture brings not only national income but at the same time, it also results in various impacts to the culture areas and the environment.

1. Impacts of mangrove removal

Mangroves are in the coastal areas close to the sea. In shrimp culture which made use of the extensive method, the shrimp seeds and sea water are pumped into the ponds during high tide. Therefore, the ponds are conveniently located in the mangroves or in areas near the sea. Although it is a known fact that mangrove areas are not really ideal for shrimp farm construction because the subsoil contains pyrite which can make the soil very acidic or low in pH when exposed to air. Secondly, mangrove soil is very soft and contains plenty of plant roots and stumps, not suitable for pond construction.

The satellite survey (Landsat TM5, 1:50,000) in 1993 showed that only 17.25% of the total area of the mangroves has been converted into marine shrimp farms (National Research Council of Thailand, 1989; Charuppat and Ongsomwang, 1995). Therefore, the main areas destroyed may have been used for other purposes. A Cabinet Resolution of 15 December 1989, resulted in the division of mangroves into three zones with the total area of 3724.48 km^2 (Budget Bureau, 1990; Kongsangchai, 1993).

Conservation zone is only for preservation purposes, Economic zone A is for timber and charcoal businesses, while Economic zone B which are unproductive areas that can be leased for any purpose from the government. In 1993, the remaining mangrove is only 45.29% or 168,682.5 ha. The area of shrimp farms in mangrove area is around 17.25% or 64,991.7 ha.

The shrimp farms in economic zone B (37,580.20 ha; 10.10%) have been leased to the farmers. Therefore, only shrimp farms in Conservation zone (4471.76 ha; 1.20%) and economic zone A (22,939.67 ha; 6.16%) totaling 27,441.44 ha or 7.36% may have been constructed from illegally destroyed mangroves. The mangrove areas may have also been used for land settlement (1.33% or 4,972.3 ha), and destroyed for other purposes (35.92% or 133,812.5 ha).

Table 3 showed that the decrease of the mangrove areas has no relation to the increase of shrimp farming areas. The data from satellite in 1996 which was done by Charuppat (1998) showed the same results, confirming that mangroves were not significantly destroyed for shrimp farms starting in 1993.

Table 3. Comparison between the decrease in mangrove areas and the increase in shrimp production areas

Unit: ha

Year	**Mangrove area**	**Decrease in Mangrove**	**Shrimp Production Area**	**Increase in Shrimp Production Area**
1961	356,700	-	-	-
1975	321,700	44,000	12,868	-
1979	387,308	25,392	24,675	11,807
1986	196,427	90,881	44,770	20,095
1989	180,560	15,867	64,606	19,836
1991	173,820	6,738	75,332	10,717
1993	168,682	5,138	71,880	-3,443
1996	167,582	1,100	69,464	-2,416

Source : Budget Bureau (1990), Kongsangchai (1993), Tookwinas (1996), and Charuppat (1998)

2. Effects on ground water and salinity intrusion

The abstraction of freshwater from underground aquifers for intensive shrimp farming in Thailand has resulted in saltwater intrusion and salinisation of freshwater aquifers (Liao, 1992 and Primavera, 1991). The problems and conflicts with local farmers and residents in Songkhla and Nakornsrithammarat provinces about salinity intrusion in freshwater consumption and agricultural water supplies occurred a few years ago. At present, shrimp farmers in many areas prefer to use full strength seawater directly from the open sea. Therefore, the farmers has stopped using the freshwater from aquifers for mixing with seawater for the ponds. The main effect was actually due to salinity drained out during water exchange and after harvesting the shrimps. However, the government has enforced a regulation not allowing farmers from pumping freshwater from agricultural areas.

3. Effects on coastal environment and resources

The effluents and sludge from marine shrimp farms have effects on the coastal environment. Macintosh and Phillips (1992) compared the quality of shrimp farm effluents to the wastes from other potential sources of pollution (Table 4) and their analysis showed that the pollution potential of shrimp farm effluents is considerably less than that of domestic or industrial wastewater. However, the waste from intensive shrimp farm has contributed many effects because of excess feeds, fertilizers, chemicals, and antibiotics (Table 5).

Table 4. Shrimp farm effluent during operation compared with other types of wastewater (Macintosh and Phillips, 1992)

Unit: mg/l

Parameter	Shrimp farm Effluent	Domestic waste Water (untreated)	Domestic waste Water (primary treatment)	Fish processing Waste water (untreated)
BOD	4.00 – 10.20	300	200	10,000 -18,000
Total nitrogen	0.03 – 1.24	75	60	700 - 4,530
Total phosphorus	0.011 - 2.02	20	15	120 – 289
Solids	30.00 – 225.00	-	500	6,880 -7,475

Table 5. Problems associated with effluents (Macintosh and Phillips, 1992)

Waste material	Primary effect	Secondary effect
1. Uneaten food, feces and dissolved excreta	Increased nutrient Loadings and reduced oxygen in ponds, water supplies, increased sedimentation	Environmental changes, reduced carrying capacity
2. Chemicals and drugs	Ecotoxicological impacts	Mortality and sublethal water quality changes
3. Antibiotics	Increased antibiotic resistance among micro-organism	Increased problem in treating, bacterial disease, residues in marketed shrimp

4. Chemicals and drugs

Chemicals and drugs are widely used in marine shrimp culture for the prevention or treatment of diseases or as disinfectants, pesticides or for soil or water treatment. Several compounds used pose potential treats to shrimp health and product quality (Macintosh and Phillips, 1992). For example, the widespread use of oxytetracyclin and oxolinic acid in Southeast Asian countries resulted in the development of resistant strains of *Vibrio* making the treatment of V*ibrio* infections extremely difficult (Nash, 1990). Improper use of antibiotics and some other chemicals leave residues in shrimp flesh, which may lead to the rejection of products in the export markets.

V. Technologies for Mangrove-Friendly Marine Shrimp Culture

A. *Water quality criteria for intensive marine shrimp culture*

Predalumpabuart and Chaiyakam (1994) and OECF (1991) have reviewed the water quality criteria for intensive marine shrimp culture. Results of their studies indicated that the criteria should include: water salinity ranging from 5 to 32 ppt; pH at about 6.5 – 8.5; transparency greater than 40 cm; BOD_5^{20} in the range of 0 – 3.0 mg/l; ammonia-nitrogen around 0 – 0.4 mg/l; total coliform bacteria less than 1,000 MPN/100 ml; total organochloride pesticide less than 0.05 microgram/L; sulfide less than 0.01 mg/L; cyanide less than 0.01 mg/L; and lead less than 0.05 mg/L

B. *Zero water discharge culture technique*

1. Pond preparation

The ponds to be used in the shrimp culture should be cleaned and maintained and the sludge or bottom mud sediment in the ponds should be cleaned after harvesting. Treatment is therefore necessary. The water in ponds is maintained at a depth of 5 – 30 cm. The water and sludge are pumped and sprayed over the pond bottom in order to have some air mixed with the water and the sludge. This is done twice in 3-5 days for the oxidation process in the sludge, and for the evaporation of the toxic gases such as ammonia and hydrogen sulfide. After three days, lime is sprayed over the pond bottom at the rate of 60-100 kg/rai or 375-625 kg/ha. The water and sludge are pumped and sprayed over the pond bottom again then the water is drained out.

The pond bottom will be left for air drying about one week then ploughed using a small tractor. This will facilitate oxidation in the bottom soil as well as evaporation of the toxic gases. Lime will be applied using the same rate as in the earlier process.

2. Sea water preparation

The sea water or the discharge water from shrimp farm is retained in reservoirs for about six weeks to allow suspended solids and other organic matters to settle down in the sedimentation pond. Then the sea water is pumped into the second pond which is stocked with sea grass, sea weeds and herbivorous fish. These organisms would neutralize the sea water quality making it suitable for marine shrimp culture.

3. Shrimp culture

The water salinity in culture ponds are adjusted to be the same as that in the hatchery. Thus, the aerators in culture ponds are operated for about one day before the shrimp larvae are stocked in order to increase the dissolved oxygen in the pond and the water temperature is also adjusted before stocking at a recommended rate density of around 30-40 PL/m^2, PL_{15} shrimp fry. The expected survival rate would be around 60-80%.

Commercial feed is given at the usual rate while the feed and consumption rates are regularly checked by cast nets. Then some small herbivores and omnivorous fish 0.5-3.0 cm in length are stocked in the culture ponds in order to get rid of some planktons, excess feeds and shrimp feces. One or two aerators per rai (6.25 rai = ha) are operated in order to increase dissolved oxygen and maintain the water circulation in the ponds. Lime is added to maintain the suitable pH range at 5-30 kg/rai. The sea water is not be changed, instead it is being refilled to compensate for the water lost due to evaporation.

4. Data collection

Data on shrimp growth, feeding rate, and survival rate should be checked every two weeks.

C. *Biotechnology for Shrimp Effluent Treatment*

1. Effluent treatment study

Treatment of shrimp pond effluents offers considerable potential for reducing the impacts on the water quality in the external environment (Macintosh and Philips, 1992). One major problem is the diluted but high volume of aquaculture effluents compared with traditional forms of wastewater (Muir, 1982). Thus, the treatment system is divided into physical, chemical and biological methods.

Physical methods include filtration or settlement treatment. In one study, a one ha settling pond was required to handle 900 m^3 of shrimp pond effluents per day (Rubeland Hager, 1979). The authors concluded that filtration was the best treatment process to remove suspended solids of concentration less than 10 mg/l. However, the cost of filtration is likely to be high and prohibitive.

Many experiments for shrimp farm effluent treatment have been conducted. Tookwinas (1995) conducted chemical treatment trials in the laboratory. The results showed that calcium oxide (CaO) at 0.3 mg/l or zeolite at 10 mg/l with aeration can reduce the effluent concentrations down to acceptable level in 24 hr. The efficiencies were about 89% and 94% for CaO and Zeolite, respectively.

An experiment on seaweed cultivation in the effluents from shrimp ponds was conducted at Chanthaburi and Songkhla provinces (Daroonchoo, 1991; and Chaiyakam and Tunvilai, 1992). Results indicated that ammonia-nitrogen and BOD were absorbed by seaweeds in 24 hr at 100% and 39% efficiency, respectively. Experiments using *Artemia* and green mussel were also conducted (Tunvilai and Tookwinas, 1991; and Chaiyakam and Tunvilai, 1992). The results showed that the green mussel could decrease ammonia-nitrogen and BOD in the effluent with an efficiency of 67% and 77% in 24 hr, respectively. Using such biological treatments, the closed system and recycle system of marine shrimp culture may be possible.

Herbivorous fish such as mullet, together with *Gracilaria* and mussel cultured in drainage ponds can be used in a biological treatment system. In this way, the sea water could be purified and recycled back to the culture pond (Tunsutapanich et al, 1994). Results of chemical and biological processes are shown in Table 6. More research on this subject is recommended to study the details for further development and improvement of the system.

Table 6. Potential treatment methods (Modified from Macintosh and Phillips, 1992)

Method	Benefits
1. Mussel and oyster	Removal of particulate organic matter and phytoplankton from water column
2. Brackish water fish (Mullet and tilapia)	Removal of particulate organic matter
3. Red algae	Removal of dissolved nutrients (N and P)
4. Sedimentation pond plus adding CaO and Zeolite	Removal of particulate organic matter
5. Mangroves	Wetland to absorb nutrient and increase the sedimentation rate by mangrove trees.

2. Design for biotechnology of shrimp farms effluent treatment

Tookwinas (1995) reviewed the possibilities and proposed the recycling of discharge water from marine shrimp farms and the biotechnology for shrimp farms effluent treatment. The discharge water or effluents would be treated using biological and physical processes before recycling. The conceptual design, drawn up from some technical information (Fig. 2), involves the following processes:

a. Water improvement process

After draining the water from intensive marine shrimp ponds, the water improvement process is as follows:

Step 1. Use mussel culture pond, since mussel can reduce toxic gases, organic matter as well as suspended solids in the discharge water or shrimp farm effluents. The stocking rate should be around 1400 pcs/rai (or 1600 m^2) and the residence time should be between 2 to 7 days.

Step 2: Use sedimentation ponds with physical treatment processes. The residence time may be 1 to 4 days. Aeration, as a physical process, should be applied.

Step 3: Use biological filtration pond or maturation pond to receive the water from the sedimentation pond. Sea weeds, sea grass and herbivorous fish such as mullet should be stocked to clear the water until its suitable quality then pumped to the culture ponds or released into coastal waters. The retention time should be 5-10 days.

b. Water recycle

After the biological filtration process, the water quality should be good enough for releasing into the coastal waters or for recycling back to shrimp culture ponds.

c. Treatment area

The area for the three ponds may be 60% of the culture pond area. However, it is important that the farmers should pay more attention to this aspect to ensure sustainability of marine shrimp culture.

Conceptual design for sustainability

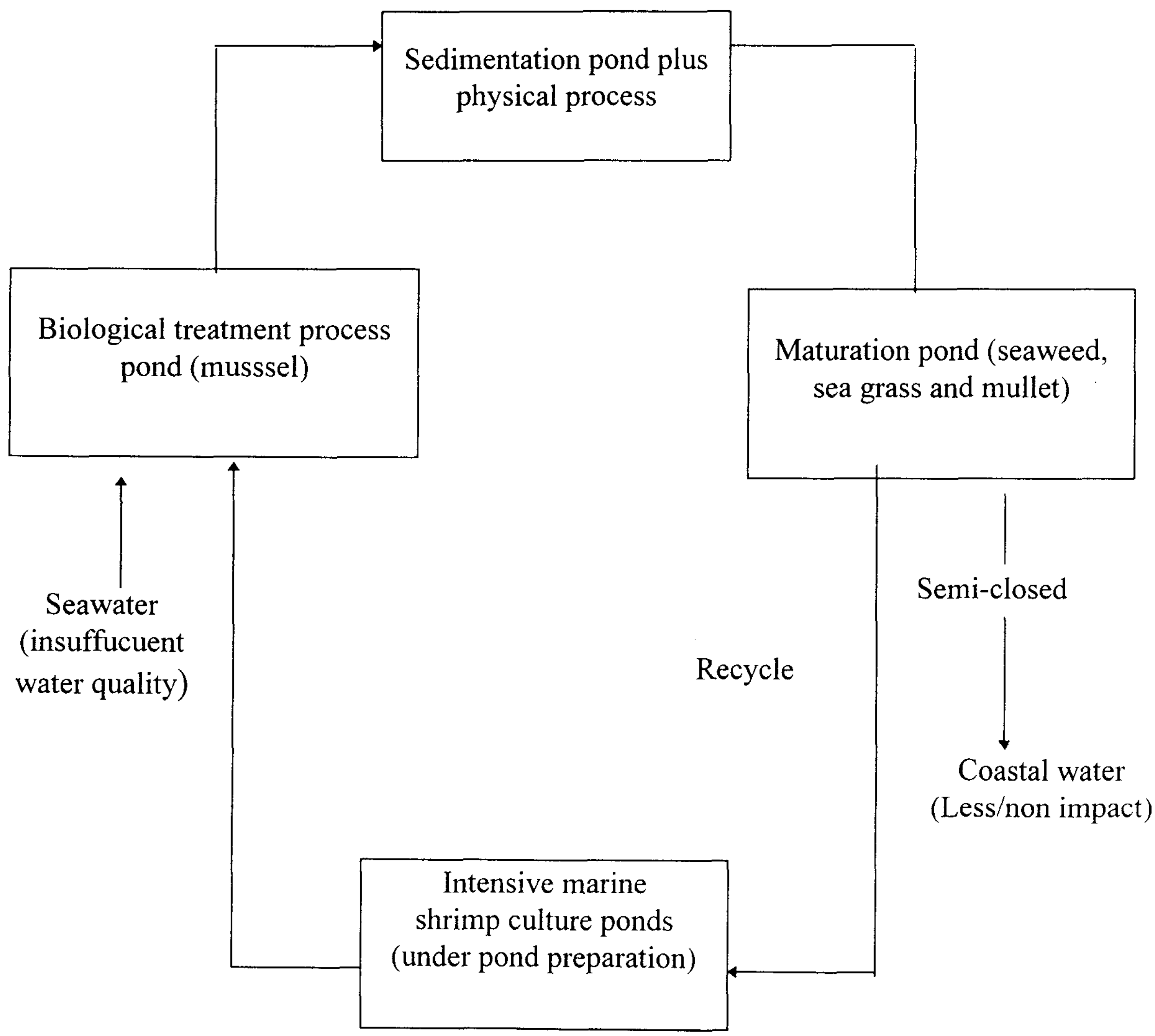


Fig 2. Conceptual design for biotechnology of marine shrimp farms effluent treatment

VI. Mangrove Reforestation Policy and Action Plan

A. Mangrove rehabilitation project

The National Mangrove Rehabilitation Project has been funded by the Royal Thai Government for the past years. Seedlings are raised in large nurseries run by government staff using seeds bought from villagers. Coastal communities are directly involved in raising the seedlings and are apparently involved in the extension of the program.

The local people could now initiate and run their own rehabilitation projects. The project has set a target of planting 50,000 rai (8,000 ha) per year. The program record is shown in Table 7.

Table 7. Progress of mangrove replanting record in February 1995

Unit : ha

Province	1992	1993	1994	Total
Rayong	12.8	15.36	64.00	92.18
Chanthaburi	25.60	28.16	-	53.76
Trat	25.60	33.28	38.40	97.28
Petchburi	23.04	30.72	25.60	79.36
Prachup Khiri Khan	2.56	7.68	15.36	25.60
Chumphon	25.60	-	46.08	71.36
Surat Thani	51.20	-	51.20	102.40
Nakhan Sri Thammarat	16.64	51.20	76.80	144.64
Pattani	-	5.12	-	5.12
Ranong	-	25.60	38.40	64.00
Krabi	17.54	29.44	38.40	85.38
Phangnga	68.2	11.52	12.80	34.56
Phuket	-	21.76	12.80	34.56
Trang	42.75	33.28	40.96	116.99
Satun	46.85	43.52	61.44	151.81
Total	358.40	336.60	560.64	1,255.70

Source : Royal Forestry Department (1995)

A number of mangrove rehabilitation projects have also been undertaken by NGOs and local communities (MIDAS, 1995). One project was in Klong Khone sub-district in Samut Songkhram province. The project had originally been the idea of the provincial government and in the first two years, planting was done by volunteer laborers from the local community, the province and NGOs from Bangkok. In these two years, areas of around 500 rai (80 ha) were planted in a comparatively short time.

In the first year, planting of exclusively *Rhizophora* was made but this was almost 100% failure due to barnacle spat settling on the seedlings which later broke under the weight of the developing barnacles, and some seedlings being eaten by crabs. In the second year, planting of *Rhizophora* and *Avicennia* at a 1:1 ratio was made.

During the third year (1994) around 1000 rai (160 ha) were planted with *Avicennia* from seedlings that were raised and planted by local people. Planting in 1995 availed of a neighboring sub-district which agreed to join in the planting program. Another mangrove rehabilitation project was at Khao Sam Roi Yod National Park. Mangrove seedlings are obtained from nurseries growing *Rhizophora* sp. and *Ceriops* sp from seed stocks collected locally. Community groups, particularly school groups visiting the Park are encouraged to plant the mangrove trees. Several hectares have been planted during the past two years.

B. *Reforestation program under the Royal project.*

Some mangrove reforestation projects have been done under the Royal Project. The mangrove replanting at Kung Krabean Bay has been actively done under The Kung Krabean Bay Royal Development Study Center since 1987. Around 264 ha of productive mangrove area has been strongly reserved and approximately 166.4 ha was replanted.

Another mangrove reforestation project was also done under the Royal Princess Sirinthorn Project since 1995 in Petchburi province about 160 km south of Bangkok, where an area of around 17 ha was reforested. Scientists have also carried out a research program under this Royal Reforestation Project.

C. *Research for replantation in abandoned shrimp farms*

Some research activities were conducted to rehabilitate abandoned shrimp farms which were formerly mangrove areas. Macintosh (1996) mentioned the result of an experiment in Ranong province, Southern Thailand under the joint research project of Stirling University, U.K.; Aarhus University, Denmark; and Royal Forestry Department of the Royal Thai Government, that mangroves can be planted successfully in shrimp waste sediments. The growth of young mangrove was four times faster than the growth in the natural habitat.

The same observation has also been made in Chanthaburi province, Eastern Thailand. It was found that the abandoned shrimp farms in Tha Mai District, Chanthaburi can be naturally planted with wild mangrove trees where the growth rate is also comparable to the growth rate in the natural habitat.

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THE ROLE OF MANGROVE ECOSYSTEMS AND COASTAL AQUACULTURE IN THE LIFE OF PEOPLE IN COASTAL MANGROVE AREAS

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I. Introduction

Mangroves, the important ecosystems with high productivity in the tropical coastal zone, are very sensitive to both human and natural impacts. Mangroves provide not only valuable forestry products such as timber, firewood, charcoal, tannin, food, medicines, but also serve as the breeding ground for many species of marine organisms, water birds, migrating birds, and other economically valuable terrestrial species like monkeys, wild boars, boas, etc. Mangroves have important role in protecting the coastlines and the riversides, regulating the climate, limiting erosion, expanding mainland areas, restricting saline intrusion, and in protecting dikes, fields and coastal inhabitants' residence from the damages of monsoons, typhoons, and sea level surge.

Reports have indicated that mangrove resources in Vietnam are seriously deteriorating. The American chemical warfare (1962 - 1971) destroyed a big area of mangroves in South Vietnam, where mangroves had the best growth and of the best species. After the war and under the pressure of economy and population growth, mangrove areas continued to decline in structure as well as in quality.

The indiscriminate exploitation and clearance of forests for land to convert into urban cities and towns, ports, to practice agriculture and salt making, and especially the destruction of forests including the protected ones for conversion into natural extensive shrimp ponds have currently been the great threats to the natural resources and the environment. Consequently, soil degeneration has increased, the climate has obviously been changing for the worse, saline water has intruded farther and farther inland, the natural stocks of shrimps and fishes have decreased, many marine species have been deprived of their habitat and certain fish species of their breeding grounds, and riverside and coastal erosion occurs daily owing to the loss of the forests, menacing the lives of the poor coastal dwellers.

The above-mentioned situation is happening because of inadequate and insufficient understanding among the coastal inhabitants and local authorities of the multi-sided and great benefits that the mangrove ecosystem brings for people. In order therefore to remedy the situation, the role and potential of this essential ecosystem should be assessed, the causes leading to the deterioration of mangrove areas and quality should be analyzed, and the damaging impacts of the loss of forests on the biodiversity resources, coastal environment and life, should be appraised. Based on the results, policies and strategies suitable to the Vietnamese situation should be drawn up in order to improve the knowledge and the lives of coastal dwellers, and at the same time protect and promote sustainability of the natural resources and the environment.

II. Mangrove Areas

Before the war, there was about 400,000 ha of mangroves in Vietnam (Maurand 1943), mainly in the South (250,000 ha). There were two areas with large mangrove forests: the Ca Mau peninsula (200,000 ha of which 150,000 ha was virgin forests and 5,000 ha of mixed ones) and Rung Sat (Bien Hoa and Ho Chi Minh City) with 40,000 ha of mangroves (Cuong, 1964).

Owing to the over exploitation of the forests for timber, firewood and charcoal, the mangrove extent has rapidly decreased. In 1950, there was only 290,000 ha left (Rollet, 1956), and in 1962, only 286,000 ha remained (Ross, 1975). From 1962 to 1971, the chemical warfare of the American Army destroyed 104,939 ha of mangrove areas, of which 52% was in Ca Mau Cape, 41% in Rung Sat and the remaining in some western provinces of the South. Since 1983 when only 252.000 ha of mangroves existed, the forest extent has continued to diminish due to deforestation. use of coastal land for agricultural production, and for extensive shrimp farming.

According to an incomplete investigation data, the present mangrove extent in Vietnam accounts for only one fourth of the pre-war extent, now consisting mainly of secondary forests. Only over 300 ha of virgin forests remained in Minh Hai and about 2000 ha of natural mangroves at Tien Yen District, Quang Ninh Province. At the end of 1998, there were only 65,799 ha of mangroves left in Minh Hai, the province which used to have the largest area of mangroves in Vietnam (Coung, 1994). Since then, the forests have been continuously diminishing because of migrants who destroyed them indiscriminately in order to convert to shrimp culture areas.

After the war, when the coastal people return to their native places and the mass migration from other provinces to the mangrove areas in the South, have led to the increased demand for building timber, firewood and charcoal. In addition, the increasing exploitation of the Forestry Agencies on the decreasing resources also exhausted the forests. Moreover, the people in the communes of Vien An Dong and Dat Mui, Ngoc Hien district produced charcoal on commercial scale for sale to the other provinces. This industry destroyed many valuable forests including those that were newly-planted after the war.

The coastal area of Quang Ninh province used to have thick natural forests in which *Bruguiera gymnorhiza* were 7-8 m high, *Kandelia candel* 4-6 m high and *Rhizophora stylosa* 5-7 m high. At the river mouths, there were *Sonneratia caseolaris* 8-12 m high such as in Uong Bi (Quang Ninh). Thuy Nguyen, Kien Thuy, Tien Lang (Hai Phong), Nghi Loc (Nge An), Nghi Xuan, Can Loc (Ha Tinh), Quang Trach (Quang Binh). But owing to the absence of proper management. these forests were destroyed and in some places no traces of mangroves were left.

III. Role and Potential of Mangroves in the Economy and in Nature

In discussing the benefits from forests, usually only the direct products such as timber or other forestry products are counted. Little attention is made on indirect benefits such as climate regulation. erosion prevention, flood restriction, etc., which are of great importance because mangrove forests grow at tidal and riverside areas where winds and waves are usually strong. In this paper, the direct products and indirect benefits from mangrove forests are discussed.

A. *Direct products*

1. Forestry products

The composition of mangrove forests is much less varied than that of inland tropical forests because only certain species of trees can adapt to the saline, muddy and tide flooding conditions. Chapman (1975) produced a list of the world's mangrove flora comprising 68 species. In Vietnam, researchers on mangroves have listed 51 species (Hong and San, 1984), of which 49 species are very popular.

These species have various uses and the percentage of species which are useful over the total number of species is very high. They have for long met the daily needs of the local inhabitants such as timber for construction, leaves for roof-thatching, food, fuel, livestock feeds, etc.

Among the 51 mangrove species listed in Vietnam, only some species are of little value, the rest can be grouped in the categories of their utilization (Hong & San, 1984). These are the species giving timber, firewood, charcoal; species giving tannin; species providing materials for green fertilizer used in, improving or maintaining soil productivity; species providing herbal medicines; species providing honey or bee raising facility; and species providing sap for producing soft drinks, sugar, alcohol

There are also species which are used in minor industries, such as those that are utilized to produce lie for cork making, hard hat frame making, and those that provide fibers. Other uses include providing materials for producing paper and pressed planks, new emerging industries that need attention in the near future.

Of the species providing timber, only 5-6 popular species could give high productivity such as *Rhizophora, Bruguiera, Lumnitzera,* etc. Even with these species the uses vary in different localities depending on the ecological conditions and the size of the trees.

In Ngoc Hien (Minh Hai), *Rhizophora apiculata* are 25-30 m in height and 39-40 cm or more in diameter providing a valuable source of timber. The reserve in the natural *Rhizophora* forests at Ngoc Hien at ages 30 is 210 m^3/ha, but it could reach 450-600 m^3/ha in some areas (Forest Planing and Investigation Institute, 1985).

According to some preliminary works, the average growth rate of *Rhizophora* spp. in Ca Mau is 0.6-0.7 cm/year in diameter and 0.6-0.8 m/year in height with a volume of 0.2 m^3/year. *Avicennia* in natural forests are about 20-30 years old with an annual growth of 4 gm^3/ha/year. On the other hand, *Bruguiera parviflora* grows more slowly: 45-year-old trees are still 21 m high with an average diameter of 25 cm. The average growth rate is 0.48 cm/year in diameter and 0.64 m/year in height (FIPI, 1985). In general, in the natural forest lands with high tree density, the annual growth rate can reach 15-20 m^3/ha/year.

If the forests are properly managed, mangroves will provide a significant amount of timber for use in various ways, such as, poles, planks, and common tools for use in the localities. They are also used in many countries as railway sleepers, as supporting poles in furnaces, in making paper, etc.

Charcoal from *Rhizophora* and *Bruguiera* is very popular because it produces little smoke with high heat energy. One kg of *Rhizophora* charcoal can provide 6.675 Kcal and it is 6.375 Kcal with *Bruguiera* charcoal. At present, *Rhizophora* charcoal is used in the metallurgical industry. Charcoal from *Lumnitzera racemosa* was used to run steam ships during the Second World War (Hong et al. 1988). Trees in mangrove forests are also important sources of firewood, many of which give good quality firewood with little smoke and high energy. In the past, the coastal dwellers in Quang Ninh, Hai Phong and Ha Nam Ninh used firewood from mangroves. In Hai Phong in 1960, 18,000 mt of firewood was exploited from the mangrove forests on Dinh Vu Island and its neighboring areas. Afforestation in the coastal muddy salty land therefore, provided a considerable source of firewood.

Since 1978, the Ho Chi Minh City Forestry Department has planted nearly 20,000 ha of *Rhizophora* on the areas sprayed with chemicals during the war. This project has not only improved the local environment but also supplied a large amount of firewood for the City's dwellers. From each hectare of forests at the age of 8-10 years old, 6-7 steres of firewood on the average, can be exploited through thinning.

Another important product from mangroves is tannin. Compared to other vegetative species, the amount of tannin in the bark of many mangrove species is high. The percentage of tannin varies between 4.6-35.5 % from the different species and the quality of the tannin from mangroves is good. Tannin is used in the industries for curing leather, dying cloths and fishing nets, making glues, and other uses in the pharmaceutical and printing industries. Although a good number of species provide tannin, only 56 species give high yields and are usually exploited. Moreover, different kinds of barks are used in different areas. In Quang Ninh, Hai Phong, the bark of *Bruguiera gymnorhiza, Kandelia candel,* and *Rhizophora stylosa* is mainly used while in the South, *Rhizophora apiculata* and *Ceriops tagal* are often exploited. The older the tree is, the thicker is the bark. The bark of *Rhizophora apiculata,* 25 cm in diameter is 1 cm thick. The thick-barked *Ceriops* can provide 7,740.47 kg of bark/ha and 3,956.91 kg of branch bark/ha (calculated in dry weight, Hong and Tri, 1986).

In addition to the main species which provide timber, firewood, and tannin, *Nypa fruiticans* is worth mentioning. *Nypa fruiticans* grow naturally in estuarine areas and along brackishwater rivers, sometimes 60 km from the sea (as at Tien River, Hau River). It is not difficult to plant *Nypa fruiticans* and its abundance is not harmful to agriculture.

For many generations, coastal and estuarine dwellers have been using *Nypa fruiticans* leaves to thatch the roof and make walls for their houses, and also to make other home implements like brooms, water scoops, baskets, hats, etc. Young leaves are used to wrap a kind of delicious coconut cake, the leaf stems used as buoys of fishing nets, while the outside cover of the stems is a good electricity-insulator. The fibers in the stems of nipa leaves are woven into strong ropes which can tolerate salty water. The people at Binh Dai District (Ben Tre) weave mature leaf ribs together and use as the bottom of sluicegates in shrimp ponds instead of wood which can last for 5-6 years.

The young meat of nipa fruit which is sweet and fatty, is either eaten fresh or used to cook sweet soup or to make soft drinks or ice cream. The mature shell is used to make buttons and fine art articles. Some countries in Southeast Asia use the young buds, leaves, stems, and roots of *Nypa fruiticans* as medicines for boils, toothache, headache (Burkill, 1935). Recently, the South Sub-Institute of Forestry Research was successful in making planks from *Nypa fruiticans* leaf ribs.

The percentage of sugar in nipa sap is high, ranging from 13 to 17%. Results of the study by P.N. Hong and H.T. San (1993) showed that one hectare of *Nypa fruiticans* in Thanh Phu Ben Tre produced a considerable amount of sap which can be made into 8-10 mt of sugar or 720-730 liters of wine. The process of making sugar from *Nypa fruiticans* is simpler and has more advantages than the sugar from sugarcane. The soil for planting sugarcane must be ploughed thoroughly, in many cases it is also necessary to make sugarcane beds. Sugarcane has to be re-planted every year, while machines are needed for pressing sugarcane and treating its residues.

Nypa fruiticans are planted only once and can be harvested continuously after the fifth year. The tools used for collecting sap are simple comprising mainly bamboo tube to contain the sap which will then be boiled into sugar or into other products like soft drinks, wine and alcohol preparations. *Nypa fruiticans* are also very effective in retaining accreted soil, protecting the banks of rivers and canals, and preventing erosion due to the tide's influence. *Nypa fruiticans*, when planted inside the embankments of brackishwater shrimp ponds, will help retain soil, shade the pond water and provide shelter for shrimps when it is hot and sunny.

2. Terrestrial animals

Although the mangrove environment is not as favorable for terrestrial animals as the inland forests due to lack of freshwater and the muddy soil, there are still a number of rare animal species in mangroves because of the availability of food. The mangrove forest at Ca Mau, was once a habitat for tigers, leopards, crocodiles, and monkeys. Snakes and varans are also abundant in mangroves because of their favorite food which includes bird eggs and young birds, *Presbytis cristata* in Thailand or *Macaca* sp. in Vietnam. The *Macaca fascicularis* live in large herds in mangroves, searching for food in swamps at ebb tide and living on the trees or in high dunes at flow tide. In Can Gio Forest Park, which has a good protection, there are now hundreds of *Macaca fascicularis* which are producing at a fast pace.

Mangroves are the habitat, nesting place or food source of more than 200 bird species including some rare ones like *Mycteria cinerea*, *Pseudibis davisoni*, *Leptoptilos*, and *Guis antigone sharpi*. These species used to be popular in Southeast Asia but now only few remain in the Mekong Delta area, Cambodia, and South Thailand (Quy, 1984).

Several migrating bird species are also found in mangrove forests. In the breeding season from April to February, the birds gather and build their nests in huge flocks in certain mangrove forests or "bird sanctuaries". There are 10 bird and bat sanctuaries in Minh Hai (Thuy, 1994), six of the bat sanctuaries are privately owned. The Tan Khanh Sanctuary (Cai Nuoc District) with an area of approximately 130 ha is considered the biggest natural bird sanctuary in Southeast Asia (Quy, 1984).

The terrestrial animals living in mangrove forests excrete a large amount of feces everyday. This is a source of nutrition for the forest trees and also food for various creatures, small invertebrate animals, shrimps, and fishes in canals and rivulets. With forest destruction, and the over-hunting and trapping of mangrove animals, the natural resources have greatly declined. Some species are in danger of extinction due to the loss of their habitat while for some species, very few individuals remain in protected forests. However, the situation has improved recently in Minh Hai where many birds and bat sanctuaries owned by households have been formed and more animals have come to these sanctuaries to settle.

B. *Agricultural products*

The agricultural products provided by mangroves are not rice or food plants but livestock feed and honey. Although mangrove leaves are tart, they are rich in protein and are good feed for livestock especially the *Avicennia* leaves.

If rationally exploited and well processed, this can be an abundant and nutritious source of dry feed for livestock as well as fishes raised in cages or in rafts. Mangrove leaves have high salt contents and iodine because mangroves grow in the muddy, salty environment flooded with sea tide giving big advantage over the leaves of other inland tree species.

Of the many agricultural products provided by mangroves, honey is considered of great economic value. Raising bees in mangrove forests is not complicated and does not harm the environment. On the contrary, the productivity of mangroves is increased because of the process of pollination. In mangrove forests, since there are many species which bear flowers with honey such as *Avicennia, Excoeccaria, Ceriops, Bruguiera, Rhizophora, Kandelia candel, Aegiceras*, bees can be raised in small or medium scale levels.

There are various simple techniques of raising bees in mangrove forests. The most popular way is to search for natural beehives but this method does not give good yield because it is dependent on luck. For better control of the yields, studies are done to build wooden bee hives with fresh water container for the bees' daily use. With simple techniques and small investment, raising bees in mangrove forests can bring about a valuable product for the economy of any country.

The most difficult problem in raising bees in mangroves is the high content of salt. Some species, usually those with a lot of flowers with honey like *Avicennia* and *Aegiceras*, can excrete their surplus salt to the leaf surface through their salt glands. The salt is then dried into small grains on the leaf surface which bees, while searching for food, can bring with them to their hives. Bees can only tolerate a low content of salt in their blood and will die when the salt content in their body reaches 0.125%. However, this is not a very serious problem because some species of bees do not bring salt to their hives. Furthermore, the bee species living in mangrove forests for many generations have already adapted to this environment, especially those that build their hives on poles installed in mangrove forests by local inhabitants.

The leaves of some mangrove species are also used to make green fertilizers for agriculture production, especially *Avicennia* leaves which have high contents of salt and are very good green fertilizer for certain kinds of plant species. The coastal inhabitants of Quang Ninh use *Avicennia* leaves through fermentation, into other kinds of green fertilizer which when applied, the cultivated plants are less attacked by pests or fungi.

IV. Role of Mangroves in Marine Resources

In mangroves, the fallen leaves and other plant parts which are decomposed by various micro-organisms, form "humus" which serves as food for many aquatic animals. On the other hand, the intricate root systems of the plants retain alluvia and create an appropriate living environment for many zoo benthos.

Mangroves play an important role in the nutritional cycles and serve as source of organic matters to increase the yield from the coastal areas. Mangroves also play an important role in the reproduction, growth and as a permanent shelter for many valuable sea products such as fish, shrimps, crabs, molluscs, etc.

A number of reports indicated that high fishery yield is mainly obtained from rivers, coastal areas, and estuaries with mangroves. This is because of the high concentration of nutrients brought by rivers from upstream areas and by tides from the sea. Reports also showed that there is a close relationship between the yields of mangroves and the quantity of sea products caught in a locality. In Western Australia, 67% of the total amount of commercially valuable sea products are collected from mangrove areas. Hamilton and Snedaker (1984) estimated that 90% of sea organisms for some periods of their whole life, live in estuaries with mangroves. For many marine creatures, this relationship is indispensable.

The first food, abundant and diverse in sea products, is plant organic matters, also called "humus". It comes from the decayed plant remains such as leaves, branches, buds, and roots from mangrove plants. According to Snedaker (1978), the dry mass of fallen leaves from mangrove plants in the South of Florida (U.S.A.) is 10,000-14,000 kg/ha/year of which 79.71% are leaves. Ca Mau *Rhizophora* forests on the other hand, can provide the ecosystem with 8,400-12,000 kg of leaves/ha/year (dry mass) (Hong, Tri, 1986).

All year round, leaves fall in rivers and channels or on the forest grounds and are carried away by tides. The decaying process takes place throughout the year. When the leaves are still on the trees, some fungi live on them as parasites (on the surface or under the epidermis). When fallen into the tidal water, after 24 hours, they begin to undergo a decaying process facilitated by the micro-organisms; first by *Phytophora* (in the *Phycomycetes* family), then by *Fusarium* and *Penicillium* in the family of *Fungi imperfecti*. After 2 or 3 weeks, they are replaced by other micro-organisms such as *Zelerion* and *Lulozthia*. Porous tissues are decomposed first, followed by cellulose and lignin last. In the decomposition process, the protein content in the leaves increased by 2-3 times (Kaushik and Hynes, 1971). Analyzing and comparing the amino acids (both with and without protein) of the leaf surface and the leaf composition, these are considerably larger in decomposed leaves than in fresh ones.

On high lands, fallen leaves, when not carried away immediately by tide, are decomposed mostly by some earth creatures on the forest grounds. The products of this decomposition process are mainly easily-dissolved organic matters concentrating at the surface soil layers. After some time, the amount of fallen leaves augments and so does the organic matters. These are carried with rain to canals, rivulets and estuaries to enrich the food source for the creatures in the estuaries and in the seas.

Mangroves provide food both directly (humus, fallen leaves and fruits) and indirectly (through humus eating animals as preys) for big fishes and some other species of predators. Therefore, the composition of the fauna in the mangrove areas, although diversified is very abundant. Preliminary surveys in Minh Hai mangroves showed 64 fish species in 35 families (Yen, 1986), 25 shrimp species (Thoung, 1990), 22 reptile species (Sang and Cuc, 1978), 67 bird species, and 21 animal species (Duc, 1989).

Young shrimps, crabs, and fish in the mangroves areas are also always in abundance. A comparison of the composition of fishes and shrimps in the mangrove areas, the sandy coastal areas and the areas with sea grass, showed a far higher quantity of larvae in the first type of land in all seasons of the year. From that, one can say that mangroves are the main breeding ground for the larvae of shrimps, crabs and some other species of fish and oysters. Mangroves provide the seed source for aquaculture because the larvae and post-larvae of many species such as banana shrimp, crabs, oysters, and fish inhabit the mangrove areas.

The tidal flats with mangroves are also the habitat of many species of water birds and migrant birds. The main food of these birds are certain small marine creatures (fish, shrimps, small crabs, shells). The birds excrete a considerable amount of feces, which facilitates the trees' growth and increases the amount of organic matters as feed for aquatic creatures and benthos, attracting many species to the area to search for food, thus forming a diversified ecosystem which is rich in species.

V. Role of Mangroves in the Climate, Accretion Expansion, and Erosion Limitation

A. *Climate*

Mangroves can help regulate the local climate where they grow. Laco (1975) who studied climate and forest micro-climate commented that mangrove communities contribute to the cooling of the climate and in decreasing the temperature and heat amplitude to the minimum. There have been many typical examples of mangrove losses that lead to changes in the micro-climate of a region. After the vegetation has been cleared, evaporation increases, resulting in the increase of water and soil salinity. In some places, after mangroves are destroyed, the regional wind velocity could suddenly soar, causing desertion due to moving sand which fill up canals and fields. The increased wind velocity also causes big waves breaking dikes, dams, and eroding the coastline. Thus, the loss of mangroves adversely affects the rainfall of an area.

A huge area of mangrove forests in the Bay of Fort de France in the Martinque archipelago (France), for example, were cleared due to industrial wastes. Soon afterwards the rainfall in that locality changed, the wind velocity in the coastal area increased, pollution and noise together with epidemics spread (Blasco, 1975).

In the last tens of years, a considerable area of mangroves in Minh Hai has been destroyed to be converted into extensive shrimp ponds. Consequently, the beautiful sight has disappeared and tens of thousands of hectares of land has become fallow. Many canals and rivulets which used to provide food and shelter for fish and shrimp larvae have now been filled with sand, while hot, harsh climate and pollution spread over a large area.

A very typical example of the devastating effect of the American warfare herbicides on the mangroves was experienced in South Vietnam. Tens of hectares of mangroves were cleared up, the soil was exposed to sunlight, the salinity in the surface soil layer at Can Gio, Ho Chi Minh City reached to 35-40%o in some places. The loss of the vegetation has adversely influenced the whole ecosystem, including the local natural conditions and climate. After the forests have now been restored, the view and climate have changed for the better and the forests have now been considered "the lungs of the City."

B *Accretion expansion and erosion limitation*

The development of mangroves and expansion of accretion are two processes which always go hand in hand except in some special cases. Mangroves are generally found on all the accretions with suitable climate, with availability of seeds and in areas that are protected. Mangrove stretches can be found on soft mud, sandy clay, sand and even on coral reefs (Snedaker, 1978, 1982). On newly-accreted land, pioneer mangroves belonging to the *Avicennia, Sonneratia ovata* genera are found in the coastal areas with high or relatively high salinity. *Sonneratia cascolaris* often grows at the estuarine areas with lower salinity

Mangrove roots especially the vegetative communities that grow thickly help sediments to accumulate more rapidly. The roots prevent the waves' damaging activities effectively and promote sediment accumulation. Thus, the presence of mangroves increases the speed of sediment accumulation, expands the area of accreted lands, and at the same time limits the coastal erosion processes. The afforestation and preservation are aimed not only at exploiting the resources but also at protecting the coastline, expanding accretions and regulating the climate. In natural conditions, mangroves follow closely new accretion and regulate the climate.

In only 30 years (1964-1994), two small islets named Con Trong and Con Ngoai have been formed at Ong Trang Mouth (Ca Mau Cape). Con Trong has many typical species of mangroves, and Con Ngoai has been fully covered with the pioneer *Avicennia alba*. In the estuarine areas of the Red River, many islets with mangroves have also been formed like Con Den, Con Vanh (Thai Binh), Con Thoi, Con Ngan (Nam Ha). Many valuable marine species and birds have come and live in those islets.

VI. Reasons for the Deterioration of Mangroves

A. *Conversion into shrimp ponds*

Due to the alleged huge benefit from shrimp export while the marine catch yield has been decreasing, shrimp farming has been encouraged by the government and many local authorities. Therefore, both the indigenous people and state bodies have felled down lush mangrove forests (at Thai Binh, Nam Ha, Ninh Binh) to be converted into extensive shrimp ponds. In some provinces such as in Minh Hai, the forest clearance for shrimp farming has been carried out not only by the indigenous inhabitants but also by people migrating either legally or illegally from other areas. Since 1991, thousands of people from Ca Mau town have constructed embankments on the new accretion southwest of Ca Mau tip for shrimp ponds and also houses for long-term residence.

According to the statistics of Searprodex Company (1987), brackishwater shrimp ponds which was 50,000 ha in 1981, increased to 120,000 ha in 1987. Minh Hai, the province with the largest area of mangroves in Vietnam, is also the place where most forests were destroyed to give way to shrimp aquaculture. The extent for shrimp farming from 1980 to 1981 was only 4000 ha. This has increased 230 times in 1992 to 80,000 ha (Minh, 1993). Each year Ngoc Hien district loses an average of 5000 ha of forests to shrimp aquaculture.

From 1982 to 1986, the Thai Thuy district (Thai Binh) destroyed 668 ha of planted and protected *Kandelia candel* forests for conversion to shrimp ponds. Most of the protected forests in Tien Hai district (Thai Binh) and many dike-protecting *Sonneratia caseolaris* and *Aegiceras* forests in Hai Phong, Ninh Binh were also cleared to give way to shrimp aquaculture.

B. *Conversion to agricultural areas*

The rapid population growth and its consequence, such as the need for food, led many people from the localities to cut mangroves and build dikes to encroach the sea. A great deal of money and effort was spent, but in most cases the effort was a failure because of insufficient freshwater supply. The yield was very low and in some worse cases no harvest could be made.

For instance, 6039 ha of tidal flats, mostly those with mangroves, in Hai Phong, Quang Yen was used for rice cultivation for 38 years (1954-1992). Owing to the lack of freshwater, the soil became acid sulfate and 1154 ha was left fallow. In Minh Khai, Minh Thanh, Dong Mai (Yen Hung Quang Ninh), after 30 years of forest destruction to give way to agricultural production, the land is now completely wasted (Cu, 1993). In some other places, although a part of the land may still be arable, the productivity is very low.

Salt production has also been practiced for a long time in the coastal areas with sandy soil and brackish salty water. Due to the rapid growth of population and the lack of available jobs, people in some localities such as in Thuy, Nguyen, Kien Thuy (Hai Phong), Vinh Chau (Soc Trang) cleared the mangrove forests, including the protected ones, in order to make salt pans. Of the 9067 ha of salt ponds spreading on the 59 km of the coast in Minh Hai province, a considerable area was once coastal *Avicennia* protected forests.

C. *Mining activities*

Some open mines such as those in Ha Tu, Cam Pha, Mong Duong in Quang Ninh province are near the coast and salty rivers which support the mangroves. During the exploitation, workers discharge waste into the rivers or the sea and into the mudflats affecting the growth of the mangroves. The construction of some coal ports in this province such as in Uong Bi, Cua Ong, has also led to the destruction of many mangrove forests.

D. *Urbanization*

In recent years, the conversion of mangrove areas into towns, industrial zones, and ports also contributed to the narrowing of the mangrove forest areas. For example in Nam Can town in Minh Hai province, after ten years of the mangrove conservation, the town had increased its population by 10 times. Furthermore, houses and enterprise buildings gradually replaced the areas which once supported dense forests of *Rhizophora* or *Avicennia*. In Quang Ninh, the urbanization of Ha Long City also affected all the mangrove forests at Coc 3, Coc 5, and Coc 8.

E. *Infrastructure development*

In line with the economic development of the coastal areas, some localities have constructed dams and roads such as the dam at Cam river, the road joining Dinh Vu and Phu Long islands in Hai Phong, and the road to Hoang Tan island in Yen Hung, Quang Ninh. Although road transportation has been facilitated, this caused adverse effects on the environment.

VII. Impacts of Deforestation on Shrimp Pond Construction

A. *Deterioration of the biological resources*

The deterioration of mangroves has been most serious in Minh Hai, the province with the largest and most luxuriant mangrove forests in Vietnam. During the two resistant wars, many mangrove forests served as protection for the people and soldiers against the enemies' bombs and attacks. Sweats, tears and even blood were shed to protect and restore these valuable forests which are now being destroyed for some short-term benefits, leaving very serious consequences. At present, only 1/4 of the forest land is covered with mangroves, mostly secondary and newly-planted ones.

A worse situation has resulted from the deforestation and the shrimp culture method using a large area which caused degradation of the pond environment. Most of the shrimp ponds have very few sluicegates for water tide exchange so that the pond environment is polluted, adversely affecting the shrimps in the ponds.

A study of P.N. Hong, L.D. An and collaborators (1992) revealed a considerable decrease in plankton as feed for shrimps after only two years from the construction of the shrimp ponds, at the west accretion of Ca Mau Cape. On the contrary, some blue algae such as *Oscillatoria* species are developing vigorously. When these algae die, the soil at the pond surface is oxidized, forming H_2S and NH_4 which are poisonous to living creatures in the pond.

On the tidal flats are the typical tidal micro-organism species adaptable to the substrate exposed to the sun at ebb tide and flooded at flow tide, particularly the crabs species of two families, namely *Grapsidae* and *Ocypodidae*. Unicellular silica algae are important food source for shrimps, fish and their larvae, and these are found in rivers and canals. Other species of algae, such as blue-green algae (which are adapted to stagnant waters) and green algae, are present in smaller quantities in the ponds. The species of blue-green algae *Oscillatoria subbrevis*, *O. princeps*, *O. lemusa*, *O. chaiyeta*, *O. salina*, *O. geitleriana* and *O. planetonica* which are commonly present in culture ponds in South Vietnam (Canh et al., 1993), caused the foul smell in the water.

In ponds with a great quantity of organic matter, an alga mat may be formed at the bottom, harming the activities of shrimps and consuming oxygen during the night. When the algae die, they are anaerobically decomposed releasing H_2S and causing serious pollution in the pond. The research results of the Research Institute of Aquaculture No. 2 (1992) showed that in the extensive culture ponds of the Ben Tre province, the pond environment decays during the first year of use changing the community structure of the organisms. Water temperature in shrimp culture ponds is high (sometimes reaching 36-37°C) mainly due to lack of forest cover. The alluvium sediment silts up the canal (0.3-0.5 cm) and water turbidity is high (5-15 cm), restricting the growth development of the aquatic organisms and algae (Luu, 1993).

The shrimp ponds which occupy an extensive area have reduced or replaced the habitats of many benthos and plankton species originally abounding the muddy tidal flats. Furthermore, this has also destroyed the nurseries of shrimps and crab larvae, affecting the livelihood of poor people catching crabs and picking shells on the tidal flats. A survey showed that there are 22 species of benthos on the mud flat whereas there are only two species remaining in the ponds, which serve as important source of food. In some cases, there were ponds where shrimps could not even survive (Hong and An, 1992) for lack of natural food in the ponds.

Destruction of the natural and planted mangroves along the coast of Thai Binh, Quang Ninh, Hai Phong has decreased the quantity and quality of marine life which often live the whole or part of their life cycle in mangrove forests. If mangroves are not rehabilitated, these creatures would not be able to find food and have to leave for the other more conducive areas.

B. *Waste of shrimp resources*

The practice of "keeping shrimps in the pond" in too short period of 15-20 days, resulted in harvest of small-sized shrimps (500-1,000 ind/kg), of which only shrimps of the size of 20-50 ind/kg are of high value. In the southwest accretions of Ngoc Hien (Minh Hai Province), hundreds of mt of young shrimps at juvenile sizes were harvested at each tide cycle. The productivity in other ponds behind the embankments has also largely decreased because most of the shrimp source are caught at the accretions.

Some shrimp culturists know that early harvest will adversely affect the crop, but since the pond environment has been degraded, the shrimps would either not grow or die gradually if culture is continued for a longer period. Therefore, farmers would rather harvest a little than harvest nothing at all.

C. *Decline in the seed source of shrimps and crabs*

Indiscriminate forest destruction has greatly reduced the seed source of shrimps and crabs. These species lay eggs at sea, their larvae and post-larvae move to the river mouths with mangroves and live until they become mature and go to sea again to lay eggs. When mangrove forests are no longer there, they also lose their habitat and have to leave for other places. Many economically valuable marine products such as *Mugil cephalus, Lates calcarifer, Muraenesox talabon, Pseudapocryptes serperaster, Parapocryptes macrolepis*, oyster, shells, terrestrial animals such as reptiles and birds are also deprived of their habitat, breeding ground and living environment.

A vivid example on the role of mangroves in this aspect is in Can Gio District. After the American herbicide war, the forests were destroyed, all fauna resources also declined. But after the mangroves were rehabilitated, the yield of marine products in the area has increased year after year. According to the statistics data of Ho Chi Minh City Aquatic Product Service 1990, in 1977, when there were no forests, the catch yield was 10 mt of fish and no shrimps. In 1989, when mangroves were young, the yield was 3172 mt of fish and 150 mt of shrimps. In 1989, the forests closed canopy and provided a lot of humus and the quantity of fish caught was 15,870 mt, while shrimps was 2430 mt. Although this could also be due to other factors such as improved catching tools and equipment, and increased number of laborers involved. On the other hand, from 1993, the number of long tailed monkeys have increased rapidly to approximately 300 individuals at Khe Dinh, Khe Doi. Other animal and bird species have also increased in quantity.

VIII. Impacts of the Construction of Shrimp Ponds

A. *Salt intrusion*

In the plains of Bac Bo, saline intrusion extends rapidly in the dry season when river flows are reduced from December until May, a minimum flow of which occurs in March. In the Thai Binh river system, saline intrusion is worse than in the Red River system, mainly due to the smaller water flow in the Thai Binh river during dry season, and also because the Hai Binh river is located on the lower land and the tidal amplitude is higher. A maximum of 1‰ salinity may intrude more than 20 km in the Kinh Thay river, Lach Tray river and about 10 km in the Red River (Thanh et al, 1990).

During the last few years, the construction of a series of large shrimp ponds along the coast, estuaries and riverbanks has considerably decreased the area of tidal water distribution, particularly during high tides. When high tides coincide with the north-eastern monsoon, saline water may intrude farther inland and produce saline pollution not just in the land outside the dike, but also in the plain inside the dike.

Under dry, low humidity weather patterns, saline pollution may emerge at the surface and affect plant life. Saline pollution disrupts the ecological balance in estuarine areas causing some brackishwater organisms (among them species of crab, *Uca*, *Sesarma* and some species of molluscs) to invade farther inland. Freshwater organisms either die because they cannot adapt to the salinity or they migrate farther inland. Some riverside freshwater plant species such as *Paspalum scrobiculatum, Hemarthria compressa* and *Digitaria violasceus*, which are important food sources for cultured animals die or become sterile as a result of the expansion of saline-adapted weed species, such as *Cynodon dactylon, Sporobolus virginicus, Paspalum vaginatum* and *Cyperrus stoloniferus* (Hong, 1995 A).

Saline intrusion during the monsoon period also causes erosion along the riverside, destroying the habitats of some land organisms, such as the freshwater crabs and earthworms. In some locations, the dike boundaries are extended for rice farming purposes but, due to the soil acidity and salinity, the yield remains low. In some parts of the land area transformed into ponds to culture brackishwater shrimp and crabs inside the dike boundary, as in Uong Bi Town and Yen Hung District (Quang Ninh), Kien Thuy and Tien Lang Districts (Hai Phong), the yields usually decrease due to restricted water exchange. Some organisms, especially nitrogen-fixing micro-organisms also die causing the restriction or obstruction of the mineralisation process of organic fertilizers used for rice cultivation.

The salinisation of agricultural land due to shrimp culture creates antagonism between rice and shrimp farmers. This happened not only in some parts of Vietnam but also in many other countries. Macintosh and Phillips (1992) recorded that 16 - 22% of agricultural land in Thailand has been affected by saline pollution as a result of the construction of shrimp ponds.

B. *Enhancement of mud accumulation and erosion*

Apart from the extension of the dike boundary to increase land area for rice cultivation purposes, the embanking of dikes to enlarge some shrimp culture ponds has filled up some smaller rivers flowing into the sea or into larger rivers. This has resulted in the alluvium and sediment concentration in the great estuaries of the Red River system or accumulating inside the dike. In the smaller estuaries, erosion occurs due to lack of accumulated alluvium. One representative case is a part of the seashore from Gia Hai to Van Ly (Nam Ha Province), which is 20 km long and since it has no tidal mud marshlands, serious erosion has occurred.

For nearly a century ago, one branch of the Red River used to flow across this area, but what is left now is a small branch called the So River with weak water flow (Thanh et al., 1990). Many other branches of Bach Dang river in Uong Bi, Yen Hung (Quang Ninh) have also been reclaimed for land to rear shrimps and cultivate rice. Consequently, the topography has changed for the worse and the abundant source of biodiversity resources at tidal flats, including many marine species of high economic value, has been destroyed.

In some areas, namely Thai Thuy, Tien Hai, Xuan Thuy, Kim Son, south Hoang Hoa, south Lach Ghep Estuary and especially the southwest of Ca Mau Cape, shrimp ponds are built on loose accretions which are in the process of forming tidal flats with mangrove forests. Under the impacts of monsoons, particularly at spring tide and during typhoons many ponds break or erode because the substrate is soft mud.

The composition is usually powder sand or fine sand, poor in nutrition and lacking in glue substances. This led to wastage of a great deal of money and labor. On the other hand, the above-mentioned activity has harmed the environment and natural resources, devastating the habitats of many benthos species, and preventing the shrimp/crab seeds from entering rivers and canals. Furthermore, due to the building of the embankments preventing the accumulation of mudflats, a number of pioneer sea-encroaching species such as *Sonneratia caseolaris*, *Acanthus ilicifolius*, *Avicennia alba,* and *Sonneratia alba* cannot grow (Hong 1995).

The construction of the chain embankments along the southwest side of Ca Mau Cape from the tip to Bay Hap river mouth, has hindered the transport of alluvia from the east of the peninsula to the west through the river system. The accreting soil is mainly fine sand (0.002-0.01 mm) in the form of wet mud which can be very easily carried away by waves, especially during the southwest monsoons when the amount of alluvia is small and the current and waves are strong. This situation will remain and the consequences will become imponderable when Ca Mau no longer has forests and the pioneer species stabilizing the accretion of land like *Avicennia alba,* has no more place to develop seaward.

C. *Water pollution*

Due to the holding of shrimps in the ponds for a longer period and weak water exchange, however, the pond medium may become strongly polluted by the formation of H_2S and NH_4 originating from the decomposition of the saline flooded plant debris. This is a common phenomenon in extensive pond culture in North Vietnam as well as in the South where there is presence of oscillating algae. These algae often develop into green, mucus stratum and die, rendering the pond water obnoxious with low dissolved oxygen and rapidly deteriorating the pond water quality. During the harvest of shrimps and fish, the effluent flow carries toxic metabolites along rivers and canals, and pollutes the surrounding environment. In some cases after heavy rainfall, the saline concentration abruptly decreases which leads to massive death of shrimp in the pond, as anaerobic decomposition will form into toxicants. During pond drainage, these toxicants will be released to the marshland environment and affect other organisms, including seed sources of many high value fishes (Hong 1995).

The inadequately planned construction of shrimp ponds has led to lower ponds receiving waste water from the higher ones. On the contrary, the tide passing the lower ponds before flowing into the ponds on higher land at spring tide, facilitates the spread of the dirt into the ponds. Poisonous matters like Fe^{2+}, Fe^{3+}, NO_3, NH_4, blue algae, organic wastes and disease-carrying bacteria from the ponds are brought by the tide to canals and rivulets, severely affecting the coastal and riverside flora and fauna.

D. *Spread of diseases and epidemics*

In some culture ponds, due to poor water quality, diseases and pests caused by bacteria or fungi begin to appear. Due to lack of preventative measures and pathological and nutritional methods for shrimp culture, the prevalence of the diseases occurs. This greatly affects the culture yields and in many cases, the disease spread throughout the whole area, where effective measures to counteract them are not adequate.

In some locations, especially in the coastal areas of south Vietnam, farmers adopt methods of killing fish in the culture ponds using a killing agent which is mainly the plant *Derris sp.* or waste of tea seeds. The liquid killing agent is poured into the pond to kill the fishes, while the rotting fish serves as food for the shrimps. The pond water would therefore, be seriously polluted affecting adjacent ponds and surrounding rivers and canals destroying many organisms in the area. Moreover, the obnoxious smell affects the human health.

The forest clearance for shrimp farming has also created a breeding place for the anopheles mosquitoes. After the forest are destroyed, the water becomes stagnant and a species of *Cyanophyta*, a food for the anophele larvae, receives enough light to develop and thus facilitates the quick growth of the anopheles mosquitoes. In the last few years, malaria has spread to some coastal areas with mangroves such as Can Gio-Ho Chi Minh City, Binh Dai-Ben Tre and Ngoc Hien-Minh Hai, threatening the lives of local people, workers in manufacturing and industries, and many members of research teams (Hong, 1994).

In 1994, the shrimp culture band wagon in the South provinces spread over an area of 84,858 ha, resulting in a loss of approximately 294 billion Dong (Information on Fisheries, No. 2-19095). There are many reasons for such loses, but an important reason is deforestation which degenerates the environment, and the wide spread of the shrimp culture using low technology. This has left a terribly bad impact on the economy of coastal Minh Hai.

Many shrimp farmers went bankrupt, the working people encountered many problems while a number of freezing factories stopped operating for lack of materials, and workers became unemployed. In order to meet their immediate needs, the people continue to destroy the already exhausted or newly-planted mangroves, leading to even more serious deterioration of the resources.

IX. Impacts of the Conversion of Mangrove Areas

A. *Agricultural land*

1. Soil degeneration

The destruction of mangrove forests for agricultural production when there is a shortage of freshwater to wash away the acid and salt cause degeneration of the soil. Gradually, oxidation, salt endosmosis and acidification turn the soil into complete fallow.

In the coast where soil has no vegetative cover, the content of sulfur is high, oxidization and sulfatation take place from the surface to the gray sediment underneath. Therefore, the soil becomes salty and acidic and poisonous ions Al^{3+}, Fe^{3+}. Fe^{2+}. SO_4 are released. The coastal salinity goes up (Table 1) while the pH becomes low. resulting in the death of the animals in the water. Meanwhile. in the environment which is regularly flooded by tide, in spite of the oxidization and sulfatation, the average pH and the rate of poisonous ions are low because there is no free Al^{3+}.

It has been confirmed that the construction of dike to reclaim the sea for agricultural production in areas lacking water such as in Quang Ninh, Hai Phong and some other localities, is a very serious mistake. It is a waste of labor and money while the environment is ravaged, turning vast areas of land fallow; destroying the habitats and breeding ground of many tidal animals and creatures living in the shallow sea; and depriving coastal poor people of their livelihood which is dependent on the animals living on tidal flats within mangrove forests (Hong, 1994).

The construction of salt-preventing dikes has also hindered the flow of freshwater from the mainland, destroying the adjacent areas with mangroves. Furthermore, the use of chemical manure and pesticides also leave bad effects on the creatures in the ecosystem (Aksornkoae, 1993).

Table 1: Changes in soil chemical features of oxidized sediments in the surface layer (0-20 cm) of coastal tidal flats reclaimed for agricultural production

(N.D. Cu, 1993)

Location	Free Ions (ppm)			Salinity (‰)				Environmental factors		
	Al^{3+}	Fe^{3+}	Fe^{2+}	Cl	SO_4	Cl/SO_4	pH	$\%Fe^{3+}$	$\%Fe^{2+}$	Fe^{3+}/Fe^{2+}
Minh Khai	1,524	289	189	0.920	1.824	0.51	2.0	1.12	0.50	2.24
Minh Thanh	1,428	262	202	0.890	1.762	0.50	2.4	1.38	0.60	2.30
Dong Mai	1,287	256	211	0.792	1.420	0.56	2.6	1.16	0.52	2.23
Ha An	875	304	248	0.820	1.418	0.58	2.8	0.94	0.48	1.96
Song Khoai	776	323	237	0.893	1.382	0.65	2.8	1.08	0.58	1.86
Gia Minh	632	176	156	0.682	0.652	1.05	3.2	1.42	0.83	1.72
Tan Vu	520	147	122	0.641	0.587	1.09	4.0	0.86	0.65	1.32

2. Rise in the extent of fallow lands

The destruction of forests for shrimp pond construction or agricultural production has increased the extent of follow land. Data from the Minh Hai Forestry Service showed a loss of 86,037 ha of forests until September 1993, of which more than 20,000 ha is now fallow land where only the ditches can be used for shrimp culture.

Due to the large-sized ponds with too few sluicegates, the water tide exchange between the ponds and the outside environment is irregular and hence the environment has degenerated. In some coastal areas, especially in Quang Ninh Province, a 5000 ha of mangrove forests was bounded by dikes to bar saline water, and the area was used for agricultural production. Due to the lack of freshwater in these areas, the soil became degraded and unsuitable for rice cultivation.

A large part of this land was abandoned and afterwards part of the land was used for shrimp and fish culture ponds, as in Ha Dong - Ha Thu (Tien Yen district), Ha An, Gia Ninh. In some other provinces, such as in Hai Phong, Thai Binh, Nam Ha, Ninh Binh and Thanh Hoa, many mangrove areas have been destroyed for the construction of extensive shrimp culture ponds. In these areas were *Somneratia caseolaris* natural forests in the riverside marshlands for protection against storms and floods, and *Kandelia candel* forests planted some decades ago to protect the coastal dikes. During construction, the pond bottom was dried, which resulted in soil oxidation and the transformation of decayed materials. The pyrite stratum (FeS_2) in the soil layers (having saline plant debris, lack of water and also being exposed to solar radiation) become oxidized. The ratio of Fe_2O_3/FeO in the substrate increased rapidly, especially in the surface layer. A comparison of the content of solvable Fe_2O_3 and FeO in the marshland soils with saline water plants to that of the culture pond after deforestation and soil decay, showed that the Fe_2O_3 content in pond is 7-10 times higher and the Fe_2O_3/FeO ratio 4-5 times higher (Cu and Hoa, 1990). In addition, there is an increase in the SO_4^{2-} in the surface layer.

In the bottom layer, a great deal of precipitated Fe^{2-} and Mn^{2-} could accumulate resulting in the transformation of the neutral, nutrient-rich, mangrove forest soil into the acid-sulfate soil, unsuitable for breeding aquatic animals (crab, fish, shrimp) and other organisms. The seaweed *Gracilaria sp.* transplanted in Ha Dong pond died after one month mainly due to the adhesion of iron hydroxide to the algae, restricting photosynthesis and nutrient exchange, and destroying the algae cells. The oxidation process also hardened the pond bottom making it unsuitable for zoobenthic and shrimp life. In some ponds, where the soil and water quality is good enough and the dike surface and sides are not covered by weeds and vegetation, oxidation transforms the soil into acid-sulfate soils. Rainfall causes erosion of the dikes and sweeps acid soil from the adjacent hills and dike sides into the ponds. In ponds where water exchange is poor, the pH of the water decreases, where many organisms in the pond could not adapt, leading to shock and death of the organisms. The acidity of water in the pond also affects the development of organisms, including protozoa which serves as food for cultured species. The lower pH levels also destroys the carbonate equilibrium, releasing heavy metals, which are toxic to aquatic organisms and immobilizing the phosphate ions necessary for algal growth (Hamilton and Snedaker, 1984).

Owing to the loss of the forest canopy covering the land, under the impacts of strong sunlight and high temperature, the soil rich in organic matters and sulfate is oxidized into sulfate acidic and salty soil. Furthermore, the peat layers abounding in carbon are also oxidized, forming a large amount of CO_2 dispersed into the air and heating the atmosphere.

B. *Salt pans*

The conversion of mangrove areas into salt pans has also proved uneconomical. Only on coarse sandy soil will water evaporation take place easily and where the salt yield is high. Mangrove land is very fine mechanic soil with 50-70% clay grains 0.062 mm in size, hence the capacities of endomensis and evaporation are weak. Besides, the content of sulfa in the sediments is high, usually 1.5-2.0% in the surface layer and 2.5-3.5% in the underneath greenish gray layer, hindering the formation of salt. The sulfates Fe, Al, Mn released from the sediments together with salinity come to the surface of the pans and make the salt very salty (N.D. Cu, 1993).

This explains why many salt producers in Yen Hung-Quang Ninh, Can Gio- Ho Chi Minh City have failed, leaving the land fallow. The salt pans at some areas have now been converted to agricultural land or aquaculture land, but was almost equally ineffective.

C. *Development of infrastructures*

1. Construction of towns, ports and factories

The construction of towns, ports and factories have devastating effects on the rich natural resources of the mangrove ecosystems and also bad effects on the environment because of the solid domestic and industrial wastes discarded into the water. Ships and motor boats which discharge oil and other substances, pollute the mangrove environment as well as the adjacent areas and killing many animals or forcing them to move farther away. Further more, this also results in the erosion of river banks due to the plying of large motor boats (like in Ca Mau) or due to change of the water flow. A typical example is the change of the flow near the river bank after the construction of Cua Lo port, which caused strong erosion at Cua Hoi. More than half of Xuan Hoi commune and a part of Xuan Truong commune where there used to be green *Sonneratia* and *Aegiceras* forests had been washed away.

2. Construction of dams and reservoirs on rivers

The construction of dams and reservoirs on rivers also destroyed the natural breeding grounds and migration routes of some species of freshwater animals as well as marine water fishes at the river mouths. The nutrients which used to be transported through the river mouths, coastal areas and on the freshwater bodies into the mangrove areas, have been redirected somewhere thus, strongly affecting the physical activities of the flora and fauna especially during the breeding season. The change of the river flow together with the monsoon's effect has brought salt water mainland, resulting in intrusion and changes of the accumulation-accretion process. The physio-chemical environment in the estuarine and coastal area is disturbed, leading to the changes in the habitats, distribution, and life of the marine species (V.T. Tang, 1994). The construction of the dam at Cam river and of the road to Dinh Vu island (Hai Phong) obstructed the Cam river mouth where water is now redirected to the Nam Trieu mouth. This change has resulted in the erosion of the tidal flat with mangrove forests in Dinh Vu, replacing the floury muddy sediments at the edge of the island by sandy sediments and moving a whole large sand dune from road No 14 near Lach Tray river mouth to Doc mountain (N.D. Cu, 1993).

3. Development and expansion of the transport system in mangrove areas

When large systems of transportation and roads were built through mangrove areas, the consequence is the forests could not receive (enough) tidal water. After a short period of time, the mangrove forests near the mainland at some communes of Can Gio district, Ho Chi Minh City have gradually degenerated and the trees grow very slowly. Some wild species such as *Phoenix padulosa* and *Acrostichum* replaced the mangrove species like *Avicennia*. In some other places such as in Long Phu, Vinh Chau, Soc Trang, Can Gio, Ho Chi Minh City, *Avicennia lanata* regenerated in the form of stunted bushes.

The expansion of waterways also changes the sedimentary environment in tidal flats as can be seen clearly with the opening of a new river way joining Thai Binh river and Van Uc river. This caused the salt intrusion of Thai Binh river and Van Uc river, and in the gradual narrowing of the Thai Binh river and the water flowing into Van Uc river, and then to the sea. This is also the reason for the salt intrusion of Thai Binh river deep into the mainland as far as Do Dang, Do Han (Hai Phong) in the dry season with salinity 2-4‰ (N.D. Cu, 1993).

X. Sustainable Use of Mangrove Ecosystem

While waiting for the State to issue mangrove management policies and strategies, managing bodies at the central and local levels in coastal areas should coordinate closely with each other for the sustainable utilization and development of mangrove resources and development. The following measures are therefore recommended:

1. It is urgent and practical to make an overall production plan of the areas with mangroves; and to conduct investigations and surveys of the exact current status of mangroves, shrimp breeding land, agricultural land, eroded land, accretion land in Minh Hai Province (and if possible, in some other coastal provinces with mangroves) through satellite photos. aerial photos and field trips done by professional staff. Afterwards, planning of the irrigation system, clean water supply for the forest ponds and sewage system should be given sufficient concern. Adequate investment from the State and the provinces would also be essential. Funds borrowed from the World Bank and other projects on the locality should be made full use of. Another requirement would be a capable and active management system which can build up the projects within a short period of time.

2. Temporary stoppage of the exploitation of timber, charcoal and firewood in mangrove areas. Encourage the implementation of mangrove reforestation and re-plantation programs.

3. Assessment with regards to the economic, resources and environment impacts of some models in the silvo-fishery enterprises of 184, Tam Giang 3 (Minh Hai Province) should be carried out in order to evaluate achievements to be replicated in other areas and problems to be solved. Some shrimp culturists should be organized to apply appropriate models in other places with the financial and technical support from the projects.

4. Researches should be done on the relationship between mangroves and marine products through the amount of decomposed vegetative detritus and nutrition cycle in the shrimp farming areas with different proportion of the extent of forest shrimp ponds in order to work out the economic and environment impacts. Based on the results, a specific appropriate proportion of the extent of forests shrimp ponds will be calculated for each locality in the province.

5. Regarding the management of soil, mangrove, and pond resources, the local authorities of Minh Hai and the districts with mangroves should work out specific and proper measures in order to implement the following action plans:

a) Survey and classification of shrimp culturists for documentation purposes.

b) The natives who have lived in the area for a long time and legal migrant households whose stay has been allowed by the local authorities should be persuaded to reduce their extensive shrimp pond area, apply the improved extensive culture method with the technical assistance of the project. State banks should grant them loans to repair their ponds, to build sluicegates, buy feed and young shrimps. The Forestry sector should provide them with tree seeds for reforestation of the land for forest based on long-term land and forest allocation with written commitment that they are really the owners of the production areas. The households with shrimp ponds and land for afforestation should be organized into a production group.

c) Illegal migrants who destroyed the forests to build shrimp ponds without any permission, should be classified. The poor people who would like to settle should be allocated with land and forests. This will enable them to implement proper production method applying the silvo-fishery combination in accordance with the common planning and instruction of the local authorities. They can either work on a family scale or in groups supported technically by the forestry and fishery sectors and financed by banks through loans. The central authorities should discuss with the provincial localities regarding deforestation by illegal migrants who make their fortune out of destroying the natural resources. They may be required to return to their home places.

d) The forest lands and accretions which have been invaded illegally or allocated to the wrong people must be returned to the government. Planning will be done afterwards and the lands will then be re-allocated to the households which can meet the criteria for long-term management and utilization. The State and National Assembly should also pay attention to, give instructions for, and increase investments in the socio-eco-resources-environment problem currently existing in coastal areas.

e) The provinces from which migrants have illegally flowed to mangrove areas should cooperate and support local administration in setting up an overall plan of the mangrove ecosystem as well as in stabilizing the situation, as soon as possible.

6. Before a new project is implemented and landforest allocation according to an overall plan is carried out, training courses for staff of the relevant sector such as forestry, fishery, banking, finance, police, army as well as the local population and culturists should be conducted on the role of mangroves to the marine products and on the damaging consequences of deforestation with funds from the World Bank's loans, or from projects and from the localities.

Since good trainers are essential for effective training, the Ministry of Fishery and Ministry of Agriculture and Rural Development should cooperate with the Ministry of Education and Training to provide trainers for students at the secondary/special purpose colleges, then send them to the coastal Districts to participate in the training. The provincial administrations and their districts should arrange meals and accommodation for the trainees as well as organize the training courses. The course shall include the techniques of improved extensive shrimp culture. If the State and the provinces do not pay proper attention to this important activity, other activities will be difficult to realize or complete and finally the forest will continue to be destroyed, and resources continually devastated.

7. Part of the funds for experimental purposes of the projects should be spent on exploring the culture of other species such as oysters, crabs, *Lates calcarifer*, on the tidal flats fronting the mangroves, and in cages and rafts along the rivers. The techniques will be introduced to the local people later thus creating more jobs for the unemployed, increasing the local dwellers' income, and reducing human impacts on the mangroves which are now in serious deterioration.

8. Educational activities for the local population, on the protection of the natural resources and mangrove environment combined with family planning education should be enhanced. The specific activities include dissemination of information through the national and local mass media, and publication and distribution of mangrove books for the coastal teachers, schoolchildren and dwellers in order to avoid and limit the increasing damage caused by natural disasters. The Mangrove Ecosystem Research Center, Vietnam National University, Hanoi has been actively involved in these activities and is now ready to supply the necessary mangrove books and organize the training courses where and when required.

9. The mangrove rehabilitation in Vietnam cannot be done overnight. There should be effective measures for replanning the production and land distribution based on specific natural economic and social conditions. These measures should be flexible but safe, helping to the betterment of the living standard of the indigenous people. At the same time, the ecological equilibrium needs to be restored on this potentially rich but fragile land.

Lack of measures and means of education and lack of information dissemination to the communities and agencies with great role of mangroves forest in the coastal area as mentioned above, have been considered part of the major constraints. Consequently, since the knowledge of the local leaders as well as the inhabitants on this issue is very limited, they could only think of immediate benefits rather than long-term advantages.

In conclusion, in order to rehabilitate the mangrove forest and marine product resources, to use them rationally and to protect this degenerating environment, there should be concerns from the State, the provinces and districts, various sectors and the people as well as a close coordination among these groups. This is in order that an overall plan can be drawn up and implemented. While experience is learned during the process, the effectiveness will be increased gradually.

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CONCEPTUAL FRAMEWORK FOR SUSTAINABLE AQUACULTURE AND COASTAL RESOURCES MANAGEMENT: APPROACH TO THE ADOPTION OF MANGROVE-FRIENDLY AQUACULTURE

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I. Introduction

Poverty characterizes most fishing communities in the Southeast Asian region. In the Philippines, the socio-economic survey of the National Statistics Office showed that 684,500 or 95.3% of the total 718,267 fishing families belong to the low-income group (Herrin and Racelis, 1992). The poverty of fisherfolk is directly caused by the widespread degradation of marine and coastal resources (Lacanilao, 1989), their low educational attainment, lack of skills for alternative livelihood and non-empowerment in local governance (Agbayani, 1995).

Producing food, generating employment and providing basic social services for the burgeoning population, and earning foreign exchange to fuel economic development, are among the top priorities of the Asian region. The region's vast and rich coastal and inland waters have been a major source of adequate and cheap protein food and livelihood for the people.

In the past, the seas teemed with fish. However, over the years, overfishing, destructive fishing practices, indiscriminate cutting of mangroves, and industrial and human wastes have gradually depleted the rich aquatic resources.

Mangrove forests, aside from seagrass beds and coral reefs, form part of the coastal ecosystems that support coastal resources. Consisting of intertidal flora and fauna, mangrove forests thrive in the tropic and subtropical regions of the world. More than a quarter of this important resource is found in Southeast Asia (Spalding *et al*., 1997) and have contributed significantly to the socio-economic well-being of the coastal communities (Field, 1995).

Mangrove ecosystems provide the following ecological and economic benefits including the provision of nursery grounds for fish, crustaceans and molluscs that are recruited into the fishery resources; production of leaf litter and detrital matter which are broken down into bacteria, fungi, and other microorganisms which in turn provide valuable source of food for marine animals in estuaries and coastal waters; and protection of lagoons and estuaries from storm and erosion.

The mangrove ecosystems also facilitate the reduction of some organic pollution in nearshore waters by trapping or absorption; provide recreational grounds for bird watching and observation of other wildlife; and provide access to a high diversity of mangrove plants and animals, and their adaptations (Saenger *et al*., 1983; Hamilton and Sneider, 1984).

Population growth and immense aquaculture development in the region have severely damaged the mangrove area. In Vietnam alone, mangrove forest cover was about 400,000 ha in 1943 but was reduced to 250,000 ha due to cutting primarily for charcoal. In addition, the chemical war in 1962-1971 destroyed about 105,000 ha. Specifically, from 1983 to the present, mangrove forests have been converted into agriculture lands and shrimp ponds.

The areas for shrimp ponds however, are too large with few sluice gates for tide water exchange resulting in the degradation of pond environment. Many people have abandoned their ponds and moved to other areas to destroy other mangrove forests for new shrimp ponds (Hong *et al.*, 1995).

Mangrove cover in the Philippines, on the other hand, had been reduced from 400,000 ha in the 1960s to barely over 100,000 ha in 1994. This has been caused by their conversion to fishponds and recreational facilities as well as due to the indiscriminate cutting of firewood and materials for house construction (Primavera, 1993; Primavera, 1995).

Studies have shown positive correlation between nearshore fish and shrimp yields and mangrove areas in the Philippines (Camacho and Bagariano, 1986) and in Indonesia (Martosubroto and Naamin, 1977). The decline in mangrove areas and production from nearshore fisheries contrasts with the increase in brackishwater pond area and aquaculture production.

The destruction of mangroves and other coastal environments caused by shrimp farming has also led to the deterioration of local livelihoods (Barraclough & Finger-Stich, 1996) due to conversion and privatization of mangroves and other lands, salination of soil and water, impoverishment of local populations, and food insecurity. While aquaculture is considered as a key alternative to meet problems on food security, its development, however, in the Southeast Asian region has always been market driven.

The export demand for shrimp and other high-value species encouraged governments and investors in the region to convert mangrove forests to shrimp ponds. In the Philippines, for example, large scale aquaculture was facilitated by the government with the issuance of P.D. 704 in 1975 with a fisheries decree accelerating fishpond development, and BFAR A.O. 125 in 1979 converting fishpond permits from 10-year lease agreements to 25 years.

Added to this ecological disturbance was the adoption of intensive culture systems to maximize profit, on the part of investors, and provide Southeast Asian economies with the much needed foreign exchange. Thus, the adoption of unsustainable aquaculture technologies and the devastation of mangrove forest became a social problem.

The economic benefits realized in terms of private profits for big-time shrimp investors, taxes paid the government by shrimp growers, foreign exchange inflow earnings, and employment of skilled technicians were all negated by the adverse impacts on mangroves and other coastal resources. All these are however, to the detriment of the impoverished fishing communities.

Moreover, the uncontrolled destruction and exploitation of mangrove resources can be attributed to the lack of property rights regimes and institutional arrangements in managing coastal resources. Mangrove forests are technically government-owned common property where access and use is open to all.

The advent of aqua-silviculture provides options for ensuring food security through the practice of mangrove-friendly aquaculture techniques. Aqua-silviculture involves more traditional, non-destructive aquaculture techniques combined with sustainable forestry techniques, including limited harvest of mangroves (Primavera, 1993).

However, local situations should first be considered before technology interventions are introduced. This will ensure the sustainability of both the resource and the technology.

II. Conceptual Framework

The basic elements considered in the project formulation on sustainable aquaculture and coastal resources management are mainly the people or the socio-economic attributes of the community; the biophysical characteristics of the coastal and land-based resources; the traditional and other existing institutional rules and regulations in the management of resources; and the status of fishing and aquaculture technology in the community (Fig. 1). Market attributes will have to be looked into by project implementors to support the marketing efforts of fish and non-fish products and services from the community.

The integration of the basic elements of the project through an interdisciplinary approach is important in order to understand fully the social dynamics in adopting technologies in order to get economic benefits from the coastal resources. The integration process will lead to two action situations: technology transfer and adoption on one side; and property rights regimes and institutional arrangements on the other side (Fig. 2). The technology transfer and adoption mechanisms will require both research undertaking and development interventions.

Property rights and institutional arrangements is the coastal resource component of the project which will define the rules and rights in the management of common properties such as mangrove forests and other coastal resources. The property rights in mangrove areas is a grant of authority from the state to the users in form of tenurial rights and stewardship agreements.

The effects of the two action situations (technology and resource management) will lead to several patterns of interaction or behavior among the resource and technology users. The behavior could be a "free rider"; reciprocity; and collective action.

The most ideal pattern of interaction is the collective action of the community of resource users. In this behavior, the resource users are interested in attaining a common goal and benefit for all.

Thus, the two behavior may be individualistic or opportunistic. Moreover, the long-term outcomes of the projects will be measured in terms of efficiency, sustainability, and equity.

III. Research and Development Agenda

Using the conceptual framework, a research agenda can be prepared consistent to the interrelationship between and among the basic elements of the projects and the long-term outcomes.

A. *Socio-economics*

Socio-economic studies will provide base line information on the socio-demographic attributes of the community. Socio-economic impact analysis will be done to evaluate the technical and economic efficiencies of the mangrove- friendly technologies. Resource valuation studies on mangrove and other coastal resources (corals and seagrasses) will be among the components of the analysis.

B. *Bio-physical and environmental*

Biophysical and environmental studies will assess the mangrove and other coastal resources before, during and after the management and development interventions.

C. *Technology transfer*

Technology transfer and adoption will include actual field demonstration and verification of mangrove-friendly aquaculture systems. Training and extension services will ensure correct adoption of the technologies and eventual commercialization.

D. *Policy*

Policy studies will document and analyze the process, formulation, and implementation policies and institutional arrangements, specially issues pertaining to property rights.

IV. Approach

The concept of property rights as a management strategy in stopping further destruction of mangroves and rehabilitating destroyed mangrove forest, requires the collective effort of different users and stakeholders. The property rights in mangroves is a grant of authority from the state to users in the form of tenurial rights and stewardship agreements. These rights are guided by rules on what acts are permitted and forbidden in exercising the authority provided by the right.

Well-specified property rights provide incentives for either individuals or groups to invest in resources and maintain them over time in order to obtain benefits. Property rights are characterized by exclusivity or the right to determine who can use or access the resource; transferability or the right to sell, lease or bequeath the rights; and enforcement or the right to apprehend and penalize violators of the rights (Randall, 1987).

Community-based coastal resource management or CBCRM and co-management strategies have been successfully implemented in the Philippines (Pomeroy and Carlos, 1997; Agbayani and Babol, 1997; Primavera and Agbayani, 1996). The people-centered approach of CBCRM focuses on capacitating the fishing community through training, education and skills development in resource management, enterprise development, training on para-legal issues, gender sensitivity, and lobbying among others.

The people-empowering activities will prepare the community to be effective and active co-managers of coastal resources. Community-initiated institutional arrangements on marine sanctuaries and reserves have also been implemented in various fishing communities in the Philippines. The concept of territorial use-rights in fisheries (TURFs) which grants the organized community property rights over coastal resources has been encouraged and legitimized by the government through existing laws, such as the Philippine Local Government Code of 1991 and the Philippine Fisheries Code of 1998.

In mangrove forests, Administrative Order No. 15 (1990) of the Department of Environment and Natural Resources (DENR) sets aside public forest as "communal mangrove forest" for the exclusive use of residents of the municipality. From such forests, said residents may cut, collect, remove mangrove forest products, such as firewood and mangrove timber for charcoal production for home consumption in accordance with forest laws and regulations.

Community-based strategies are effective in addressing localized problems through localized solutions especially those pertaining to the exploitation of common property resources. External agents, e.g., NGOs, academic and research institutions, government agencies, have predominantly initiated CBCRM activities. The relationship of these external agents to the community, however, should be temporary until the community has developed a sense of preparedness and self-reliance.

Beyond the community-based initiatives, however, will be the bigger issue of legitimizing locally-accepted institutional arrangements by concerned government agencies. This act of delegating authority to the community to use and manage coastal resources is a co-management arrangement between the government and the local community. The process of co-management involves community participation in decision-making, power sharing, and conflict management.

The focus of co-management is the issue of property rights or rights to access and limit other users from the resource. Co-management addresses the issue on ownership of resource and mechanism to allocate use rights through rules and regulations.

However, to date, literature on mangrove utilization in the country has limited, if any, documentation on informal or customary use-rights particularly on the adaptive and evolutionary significance of the systems of appropriation - of their construction, logic, and historical transformation. There is therefore, a need to look into the social circumstances of the sectors because as their circumstances change, so does the organizational structure of the community.

Failure to recognize this aspect would eventually result in resource-use conflict (Cordell, 1992). Considering the multiple-use characteristic of this resource, other effects would be unsustainable practices and inequitable distribution of benefits (Ruddle, 1994).

There is also a need to examine and evaluate property rights and collective action on mangrove ecosystems to provide reliable scientific information for policy formulation. Considering the vast mangrove resources that have been destroyed, and are presently being converted to different uses, there is a need to rationalize development strategies that will ensure efficiency, equity and sustainability.

Poverty and food security are the burning issues confronting developing countries today. There is a need to balance environmental conservation and food security in the management of mangrove resources.

Mangrove-friendly aquaculture technologies are being tested, verified, and transferred for adoption by fishing communities in the Philippines, Vietnam, Indonesia and other Southeast Asian countries. The Workshop on Mangrove-Friendly Aquaculture was convened by the SEAFDEC Aquaculture Department with special fund allocation from the Government of Japan, in Iloilo City, Philippines in January 1999.

The Workshop identified factors that would contribute to the development of a definition of mangrove-friendly aquaculture. Among these factors were benign; harmonious existence between fisheries and mangrove resources; beneficial to the community and economically viable; enhances biodiversity with minimal impact on the environment; and integrates mangrove rehabilitation and protection with food producing activities such as aquaculture.

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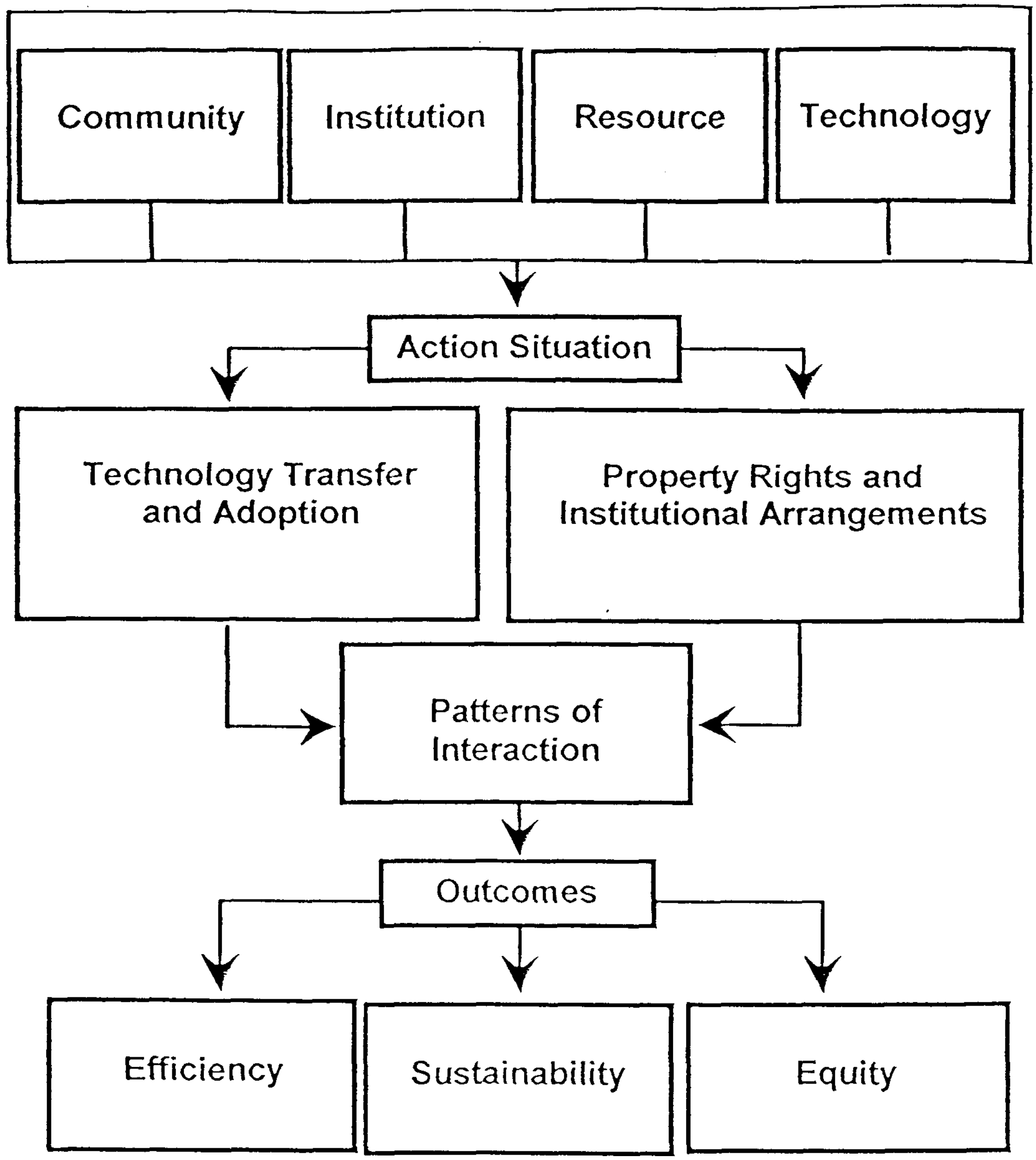

Fig. 1. Framework for sustainable aquaculture and resource management

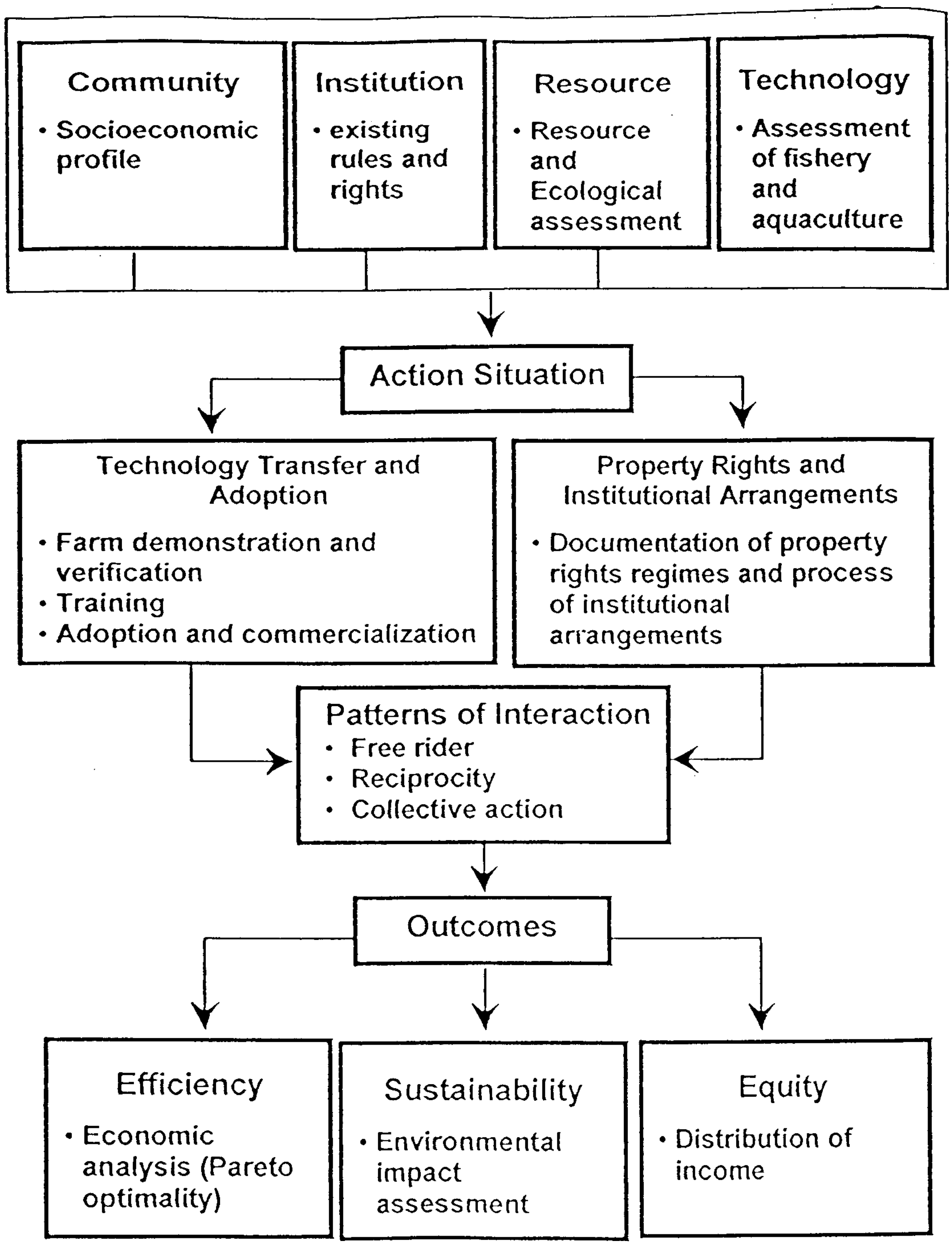

Fig. 2. Research and development agenda for sustainable aquaculture and resource management

AQUA-MANGROVE INTEGRATED FARMING: SHRIMP AND MUD CRAB CULTURE IN COASTAL AND INLAND TIDAL FLATS WITH EXISTING REFORESTED OR NATURAL GROWTH OF MANGROVES

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I. Introduction

Throughout the tropics, mangroves are being destroyed at an increasing rate for the development of aquaculture ponds. In the Philippines, for instance, mangroves were about 400,000 to 500,000 ha in 1918 but were reduced to 100,564 ha in 1987. On the average, about 3,500 ha of mangroves are lost every year in the country to accommodate the aquaculture industry (Baconguis et al., 1990). Loss of mangroves means loss of habitat, fishery, income, and livelihood for many coastal inhabitants. The annual catches of major fishing grounds in the Philippines were positively correlated with the areas of existing mangroves (Bagarinao, 1998). Restoration programs of the government such as mangrove reforestation and afforestation were attempted but could not catch up with the unending destruction. An alternative source of income which is directly supportive of resource management was therefore proposed to mitigate ecosystem degradation with the fisher communities in mind.

Fishing villages in the Philippines are generally located in the fringes of arable land along coastal plains and are dependent on fishing as a source of income. The common denominator of these villages is the presence of large areas of tidal flats with existing mangroves. To utilize the aquaculture potential of these mangroves, aqua-mangrove integrated farming development projects were introduced to provide alternative livelihood for the fishers in the village. This integrated approach to conservation and utilization of mangrove resource allows for maintaining a relatively high level of integrity in the mangrove area while capitalizing on the economic benefits of brackishwater aquaculture. The projects took off from the concept of co-management, that is, taking into account the partnership between the local community, the local government unit, and the SEAFDEC Aquaculture Department (SEAFDEC/AQD) in the management of the project.

II. Site Specification

Selection of suitable area is important in siting a rearing system designed for aqua-mangrove integrated culture of fish or crustaceans. Once the selection fails, remedial measures will be too expensive to undertake. The following are the recommended site specifications:

A. *Soil*

Physically, most mangroves are found on tidal flats with alluvial soils and situated adjacent to rivers or creeks near coastal shores and estuaries at almost sea level elevation. If you pick up a handful of soil from the mangrove area and examine it closely, you will find that it is made up of mineral and organic particles of varying sizes. The mineral particles are clay, silt and sand while the organic particles are organic matter of various stages of decomposition.

Depending on the relative proportion of the sand, silt and clay, soils are of varying texture such as silty clay, clay loam, and sandy clay. A sandy clay soil is more porous than a clay loam or silty clay, and a clay loam or silty clay will hold more nutrients and retain more water than a sandy clay. Soils with high clay and silt or loam contents are most desirable as materials for diking and can retain desirable water depth for the ponds.

B. *Environmental conditions*

Mud crabs and shrimps (e.g., *P. monodon)* are generally tolerant to a wide range of temperature and salinity. They can withstand water temperature from 12 to 35°C but their activity and feeding fall rapidly below 20°C. They are able to survive in a salinity range of 2-43 ppt.

Crabs have a well developed ability to exploit oxygen from the air. Under severe conditions of hypoxia, crabs leave the water and breathe air. But when crabs molt, they are unable to leave the water that is depleted with oxygen and consequently die. Like shrimps, they should also be provided with their daily oxygen needs for growth and survival.

The optimum water conditions required of crabs and shrimps are:

Water temperature (°C)	23-32
Water salinity (ppt)	15-30
D.O. Concentration (ppm, min)	not < 4
pH	7.0-8.5
Water depth (cm)	≥ 80

C. *Other factors*

These factors include available source of stocking materials; free from pollution; and sufficient supply of cheap trash fish or brown mussel meat. Storage facilities should also be available for fresh unprocessed feed and the site should be secured from poachers.

III. Design and Construction of Aqua-Mangrove Pond/Pen

A. *Design of aqua-mangrove pond*

Aqua-mangrove integrated farming or aqua-silviculture is an ancient coastal resource management concept which has been put into practice in many Asian countries. The design of the system is similar to a pond where there is a big perimeter dike and a sluice gate to fully control the water but mangroves in this system are left untouched. This particular design was recently adopted by SEAFDEC/AQD.

Existing aqua-silviculture pond design in the Philippines included the project exemplified by Mr. & Mrs. Melchor Sur of Puerto Galera, Mindoro, Philippines, and the SEAFDEC/AQD project in Bugtong Bato, Ibajay, Aklan, Philippines. The Surs built canals around a soil flatform with existing natural growth of mangroves using the 70:30 mangrove covered soil flatform to open pond area. The same ratio of flatform to canal is implemented by SEAFDEC/AQD only that central canals are dug in addition to the peripheral canals.

B. *Design of pens*

SEAFDEC/AQD has also developed a pen designed for aqua-mangrove integrated culture that preserves the vital role of mangroves as nursery grounds for finfish and crustaceans. The design allows flooding of the culture area at high tide, while structures are installed to prevent siltation of pen canals and maintain the required water depth of the cultured species. Such pen design is demonstrated in SEAFDEC/AQD's project in New Buswang, Kalibo, Aklan and in Bugtong Bato, Ibajay, Aklan, Philippines.

The Kalibo project is situated in coastal tidal flats at the mouth of Aklan river about 200 m from the sea and with existing reforested mangroves. The ratio of mangrove covered soil flatform to canals (peripheral and central) is 70:30. The set up is flooded at high tide when tide level is $\geq$ 0.8 m. On the other hand, the project in Ibajay is situated in inland tidal mud flats with existing natural growth of mangroves. The site is about 2 km from the mouth of a creek. The mangrove covered soil flatform to canal (peripheral and central) ratio is 70:30. The set up is inundated when tide level reached 1.5 m. Water can still be replenished in pens by opening the pen gate at tide level of 1.3-1.4 m. Below this level however, water change is no longer feasible.

C. *Construction of ponds*

Construction of aqua-silviculture pond follows the specific strategies and work program when all the general design features and other technical factors have already been considered such as size, shape, and orientation of the pond and the size and height of the perimeter dike. In general, the pond is built using mainly manual labor because mangroves are not accessible for the movement of heavy equipment.

Normally, the first structure to be constructed is the perimeter dike which measures 4 m at its base in order to control the level of water inside the site. Without any control, water in the job site will rise and fall with the tide which makes programming extremely difficult if not impossible. Simultaneous with the construction of the perimeter dike, work on the main gate may be started once its exact location has been fixed. The main gate is generally located at the lowest portion closest to the source of water but strategically located so as to distribute water effectively into the pond. The gate may be made of wood or reinforced concrete and provided with two pairs of middle grooves, one pair each towards the end of each gate. The two pairs of middle grooves are 30 cm apart for occasional needs to soil seal the gate. The pair of grooves on both ends are used for the installation of screens. As the work in the perimeter dike progresses, construction of peripheral and central canals representing about 30% of the pond area may be undertaken. Canals 50-100 cm wide and 50 cm deep are dug carefully so as not to destroy the mangroves inside. Soil excavated from canals may be used for diking. The dike is constructed layer by layer of neatly placed mud blocks (like mounting hollow blocks in the construction of a building) allowing each three layers to shrink and settle before piling another layer.

If the pond is intended for rearing mud crab, additional structure such as net enclosure, will have to be installed along the inner side of the pond dike to prevent crab stocks from escaping. A green net, 12 mm mesh size and 2 mm twine diameter are used with bamboo as structural framework. The lower end of the net is buried about 60 cm below the pond bottom surface to prevent the escape of the crabs through burrows. The inner side of the upper end of the enclosure is lined with 30 cm wide thick plastic sheet (gauge #18 or 20) to prevent crabs from escaping over the enclosure.

D. *Pen construction*

Pen for the culture of aquatic species in tidal flats with existing mangroves should have a minimum area of 200 m^2 or a maximum of 1200 m^2 to enable all households in a fishing village to avail of mangroves adjacent to or near the village. A green nylon net 12 mm mesh size is used and 2 mm diameter twine with bamboo as structural framework. The height of the enclosure should be 30-40 cm above the highest tide. The lower end of enclosure is buried 40 cm below the pen bottom for shrimp culture or 60 cm for mud crab culture. Fine-meshed nylon screen is fitted on the inner side of the enclosure and its lower end buried about 30 cm below the pen bottom for shrimp culture. For mud crabs, fine-meshed screen is not needed, instead a 30 cm wide thick plastic sheet is fitted on the inner side of the enclosure to about 30 cm from the top end.

About 30% of the total area of pen is allocated for 50-100 cm wide and 50 cm deep peripheral and central canals which may be dug between mangroves being careful not to damage or cut the mangroves. The canals are intended to retain 50 cm water during lowest tide. A 50-60 cm wide and 50 cm high dike is installed surrounding the enclosure to retain additional water level of 50 cm during lowest tide, thus meeting the optimum water depth requirement of crabs and shrimps. The set up is intended to be inundated during highest tide. A 50-60 cm wide and 50 cm high wooden gate (made of wood and marine plywood) is installed for draining the water every 7 days (for 3 continuous days) during night time only, to allow exposure of mangrove roots. Continuous submergence of mangrove roots will lead to the death of the mangroves. Fine-meshed nylon screen with bamboo framework is also installed surrounding the dike to minimize if not totally prevent siltation of the canals. A wider meshed B-net set in a half round is placed fronting the gate.

IV. Mud Crab Culture

Mud crab is an aquaculture commodity which is well liked for its taste, texture and nutritional value. It has high potential for commercial aquaculture production in the Indo-Pacific region, and a promising alternative to the weakening shrimp aquaculture especially in the Philippines. With high market demand and lucrative domestic and export price of live mud crabs coupled with available technology and adequate capitalization, opportunities for a profitable mud crab farming are very encouraging.

Studies at SEAFDEC/AQD have addressed constraints in the management of mud crab aquaculture in mangroves. Management and operations described in this lecture are the results of research studies, either funded by SEAFDEC/AQD alone or by SEAFDEC/AQD in collaboration with the Australian Centre for International Agricultural Research (ACIAR) under Project No. 9217. We take note and accept the fact that more efforts need to be done in relation to the development of the mud crab culture technology.

A. *Species of commercial value*

1. *Scylla serrata* (Forsskal)

Locally called "giant crab", this species is morphologically characterized as greenish in color with white polygonal markings on the swimming and walking legs, chelipeds, carapace, and with orange claws. It has deep serrated and pointed frontal spines with prominent spines at the dorso-posterior side of the merus.

2. *Scylla tranquebarica* (Fabricius)

This species, locally called "manginlawod" or "lawodnon" has almost the same features as the *S. serrata* species except that the polygonal markings are only prominent at the chelipeds and swimming legs gradually fading towards the anterior walking legs. It has shallow serrated and blunt frontal spines, while the spines at the dorso-posterior side of the merus are not as prominent as the *S. serrata* species. These differences however, can not be identified while the crabs are at the juvenile stage. When their sizes reach sub-adult weighing > 90 g, *S. serrata* can be differentiated easily from *S. tranquebarica*. Sex however, can be identified even at the juvenile stage.

3. *Scylla olivacea* (Herbst)

Locally called "pulang alimango" or "native", this species has deep green to grayish green color of the carapace, rusty brown chelipeds, swimming and walking legs. Unlike the other species mentioned, *S. olivacea* has no polygonal pattern. The frontal spines are shorter, rounded with shallow interspaces while the spine at the outer side of the merus is absent.

B. *Transport, stocking and acclimation*

Mud crabs (juveniles or lean marketable size) are normally contained in wicket basket or "bakag" or pandan bags during transport from the dealers to pond/pen site for stocking. The survival of crabs depends on how it is packed and cared for during transport. Although mud crab can tolerate a wide range of temperature and salinity, they also need to be acclimated before stocking to prevent death due to thermal and salinity shock.

1. Procedure for transporting mud crab juveniles for grow-out culture

   a. Provide transport containers with fronds of mangroves;
   b. Remove chelipeds ("sipit", "kagat") of crabs weighing < 30 g. Do not remove when weight is > 30 g. Chelipeds of the latter will regenerate but no longer of equal size;
   c. Place 500 crab juveniles, chelipeds removed, in a big transport container; and
   d. Pour seawater frequently into the container while in transport to keep crabs moist.

2. <u>Procedure for transporting lean marketable size mud crabs for fattening</u>

a. Provide transport containers with fronds of mangroves;
b. Buy lean marketable size crabs ("Pulang alimango": 100-150 g females, 200-250 g males; giant crab: 300-350 g females, 350-400 g males) by contracting on-site collectors or buy them from local markets;
c. Tie crab chelipeds firmly to prevent antagonistic behavior among crabs while in transport;
d. Place 150-200 lean crabs in big transport containers ("bakag" or "bayong"); and
e. Pour seawater frequently into the container while in transport or while waiting for additional crabs to be bought.

3. <u>Procedure for stocking and acclimating mud crab juveniles for grow-out culture</u>

a. Stock crab juveniles early in the morning (0600-0800 H) or late in the afternoon (1630-1800 H);
b. Stock 1.5-2.0/m^2 7-11 g or 16-20 g crab juveniles;
c. Stock males separately from females (monosex culture);
d. Sort according to size and sex, and count according to desired stocking density for each pond/pen;
e. Acclimate crab juveniles before releasing them in pond or pen, to pond water temperature and salinity by placing them in plastic basins. Moisten them first, then gradually pour pond/pen water into the basin until crabs are soaked; and
f. Release crab juveniles in pond/pen by floating the basin with crabs for 5-10 min, then tilting the basin to allow the crabs to crawl out or be released.

4. <u>Procedure for stocking and acclimating lean marketable size mud crabs for fattening</u>

a. Stock crabs early in the morning or late in the afternoon;
b. Stock 2 lean marketable size crabs/m^2. Stock together male and female of the same species;
c. Remove the movable parts of the mud crab claw and apply Povidone-Iodine (Betadine) to the injured part to prevent infection;
d. Place crabs in basins, acclimate to pond water temperature and salinity by moistening, then gradually pour pond/pen water into the basin until crabs are soaked; and
e. Acclimate crabs further in pond/pen by floating the basin with crabs for 5-10 min before they are released. Remove cheliped ties when crabs are released into the pond/pen.

C. *Quality monitoring and management*

Water quality is the most important factor affecting the production of cultured aquatic species. Good water environment is necessary for growth and survival. Hence, water quality parameters have to be monitored as a tool for management since these parameters directly or indirectly affect the behavior of cultured species, and thus, measures can be done immediately to prevent the occurrence of conditions harmful to the animals. Water quality parameters like water temperature, salinity, DO concentration, pH, water color, and transparency should be monitored daily. taking note of the crab conditions like feed consumption, signs of disease, swimming behavior, mass climbing in net enclosures, etc.

Water depth (install depth gauge) and net enclosures should be inspected daily for possible leakage and holes in nets. Water in pond should be changed for 3-4 continuous days every spring tides to about 30% of the pond water volume on the first month, 40% - 2nd month, 50% - 3rd month, and 60% on the 4th month onward of the culture period. Pen should be drained every 7 days for 3-4 continuous days at night time lowest tide to expose roots of mangroves while retaining water in the canals.

D. *Feeds and feeding*

Feed comprises 40-60% of the total cost of production. The use of cheap but effective feeds and the right amount will prevent feed wastage and pollution in ponds/pens and subsequently save on cost. Crabs are fed with fresh or frozen trash fish. If brown mussel meat is available and cheap, a mixed diet of 75% brown mussel meat and 25% trash fish may be used instead. Mud crabs given fresh brown mussel-based diet attain better growth performance.

Mud crabs in the grow-out culture are fed at the rate of 10% of the crab biomass per day when carapace length (CL) is < 6 cm and 5% when CL is 6 cm. On the other hand, mud crabs in the fattening culture are fed at the rate of 10% of the crab biomass per day. The same amount of daily ration is given through out the culture period.

The crab biomass is calculated as B = (ES)(INCS)(ABW), where B is the total weight (biomass) of the surviving crabs in pond/pen, ES is the estimated crab survival based on a linear decrease in survival from 100% at stocking to 70% one month before harvest, INCS is the initial number of crabs stocked, and ABW is the average weight of the estimated surviving crabs in pond/pen.

On the other hand, the total daily feed ration is calculated as DR = (B)(FR), where FR is the feeding rate and where 40% of the daily ration is given at 0700 H and 60% at 1700 H. Feed is broadcast evenly in the pond/pen. About 20-25 crab sub-samples are taken from each pond/pen monthly for weight and CL measurements. Daily feed ration is adjusted monthly based on the observations from the stock sampling.

V. Culture Technology

In the Philippines, mud crabs used to be incidental harvest with milkfish, five decades ago. Later with scientific research, and with the improvement in pond/pen design and construction, new technologies were developed out of which mud crab culture techniques and systems have evolved utilizing available resources and approaches to further increase production.

A. *Culture methods*

There are two existing forms of mud crab culture in the Philippines, grow-out culture and fattening culture. The grow-out culture period extends to more than 30 days and uses crab juveniles for stocking while fattening culture period extends to a maximum of 30 days and uses lean marketable size crabs for stocking.

B. *Culture systems*

Recently, three culture systems have evolved, namely: extensive, modified extensive, and semi-intensive. The systems are categorized according to sources of food and the inputs applied.

Under the extensive system, crabs are solely dependent on the natural food existing in the ponds. Thus, the only food available to crabs are benthos, zooplanktons, and other slow-moving aquatic animals present in ponds. Stocking density ranges from 0.1 to 0.2 individuals/m^2. Using this system, many fish farmers from Panay Island, Philippines claimed a survival of 60-70%. This system has not yet been tried in aqua-mangrove integrated culture of crabs in the Philippines but this system will surely work, considering that mangrove ecosystem supports a rich fauna in the form of plankton, benthos and nekton. Zooplankton is an important biotic component of the mangrove aquatic system. A hoard of aquatic fauna both in fauna and epifauna are the happy residents of mangroves. Nektonic groups include a great diversity of fish and prawn species which could be divided into residents and migrants.

In the modified extensive culture system, the crabs initially feed on natural food existing in pond/pen. After the food is depleted, supplemental feed is given to augment the already depleted natural food.

Semi-intensive system is considered a medium stocking density culture. The crabs are stocked at 2.0-3.0/m^2, and artificial diet is the main source of food. This is a recent development in the culture technology of mud crab in the Philippines after cannibalism, a major constraint in the culture of mud crab, has been addressed. Chen (1990) reported a much higher density (3-5/m^2) than what is being practiced now in the Philippines.

For all the culture systems mentioned, water exchange is still dependent on the tidal level in aqua-silviculture ponds. In pens, water exchange should be done twice in 24 hours as the site is inundated during high tide.

1. <u>Mud crab monoculture in aqua-mangrove pond</u>

a. Pond preparation

Ponds are prepared before stocking or releasing the mud crabs, and conditioned for the culture of *Gracilaria* or other macrophytes that can serve as shelter for the mud crabs.

b. Pond conditioning

Water is drained from the pond by closing the pond gate and sealing it with soil. Pond bottom is dried for 5-7 days or until the soil cracks. Hydrated lime is applied at the rate of 1 t/ha. Immediately after liming, ammonium sulfate is applied at the rate of 2 g for every 10 g of hydrated lime in 1.0 m^2 of undrained area (usually near the drain gate) with 5 cm water depth to eradicate unwanted species.

c. Culture of macrophytes

Organic fertilizer is applied at the rate of 2 t/ha, top dressing with inorganic fertilizer at the rate of 75 kg/ha using urea (45-0-0) and ammonium phosphate (16-20-0) at a ratio of 1:2. The pond is filled with water from the incoming high tide to about 10 cm deep, closing the pond gate and sealing it with soil. *Gracilaria* is planted using the rice planting method where a plant should weigh about 10 g of vegetative parts. Each plant should be spaced about 10-20 cm.

The pond should be gradually filled with additional 5-10 cm water level daily until water level of about 60 cm is attained. When luxurious growth of *Gracilaria* is noted, pond water level is increased to 100 cm, then stocking of mud crab could be made. *Gracilaria,* however, grows well only during the dry season. Hence, if mud crab culture is done during the rainy season, planting *Gracilaria* may no longer be carried out.

The color of the pond bottom should always be monitored. A thin green film appearing at the bottom of the pond suggests *lablab* growth. As soon as a prominent green color appears, pond should be gradually filled with additional 5-10 cm water level daily until a depth of 80-100 cm is reached. When the water level increases, *lablab* mats also thicken. But when water level reaches 60 cm and light no longer penetrates the pond bottom, *lablab* growth is suppressed and "lumut" starts to grow. "Lumut" occupying about 40-60% of pond area could serve well as shelter for crabs. Any other macrophytes like "kusay-kusay" (*R. mauritima*), and "digman" *(N. graminea)* could also serve as shelter. When such factors are noted, the pond should be ready for stocking.

2. <u>Selective/progressive harvesting</u>

Progressive harvesting is the removal of harvestable size and fat mud crabs from ponds several times over the culture period. Reports indicated that progressive harvesting enhances survival and improves growth. The removal of bigger and fat crabs minimizes competition for food and space, and reduces incidence of cannibalism since a more homogenous size range of crabs is maintained. This also allows smaller crabs to grow fatter thus shortening the culture duration.

a. Marketable size and fat crabs (150 g or more for females and 250 g or more for males of "pulang alimango", 350 g or more for female and 400 g or more for male giant crab) are selected and removed simultaneously with stock sampling from the end of the second month of culture by current method. Marketable size fat crab usually go against the current and congregate near the gate as water enters the pond/pen, and can be caught using a scoop net. A lift net method may also be used to catch crabs immediately after the water in the ponds has leveled off.

b. Crabs may also be totally harvested at the end of 120-150 days culture, using current and lift net method. Ponds are drained totally to manually collect the remaining crabs, making sure that crabs are not damaged during harvest. Loss of appendages in crabs will reduce their market value.

c. Harvested crabs should be kept moist by placing mangrove fronds in the harvest container and frequently pouring pond water into it. Crabs should not be exposed to heat and should not be hang as this reduces the turgidity of the crab muscles.

3. Financial feasibility projections

a. For a 1.0 ha pond crab monoculture in tidal flats with existing mangroves on a per cropping basis.

(i) Technical assumptions

Species intended for culture: "pulang alimango" or giant crab

Stocking requirement per run (pc)	5,000
Duration of culture (mo)	4-5
Cropping per year	2
Survival per cropping (%)	85
ABW/cropping:	
"Pulang alimango"	250
Giant crab	400
Amount of feed needed/cropping (kg)	
"Pulang alimango"	2,678
Giant crab	14,000
Cost of feed (₱/kg)	10
Production output/cropping (kg)	
"Pulang alimango"	638
Giant crab	5,100
Estimated price/kg (mean of male and female ₱ price)	310

(ii) Financial assumptions

Miscellaneous costs are estimated at 2% of variable costs.
Caretakers salary at ₱1000/month
Interest rates on investment is 8% per year
Sales tax is 1% of revenues
Pond rent is in accordance with FLA rate

(iii) Investment (₱)

	Giant "alimango"	"Pulang alimango"
Development costs	₱ 27,445	₱ 27,445
Construction of enclosure		
(Pond development costs were assumed that pond already existed)		
Operating capital (₱)		
Variable costs		
Crab juveniles	142,500	75,000
Feeds	140,000	26,780
Seaweeds	5,000	5,000
Hydrated lime	1,250	1,250
Chicken manure	2,200	2,200
Inorganic fertilizer	463	463
Caretaker salary	5,000	5,000
Miscellaneous cost	5,928	2,214
Total variable cost	₱ 302,341	₱ 117,907
Fixed costs		
Pond rental (FLA)	500	500
Interest on capital investment	2,196	2,196
Total fixed cost	₱ 2,696	₱ 2,696
TOTAL OPERATING CAPITAL	₱ 305,037	₱ 120,603
TOTAL INVESTMENT	₱ 362,482	₱ 148,048

(iv) Cost-return analysis (₱)

Sales (crabs)	₱ 1,581,000	₱ 988,280
Less: Operating capital	305,037	120,603
Net income before tax	1,275,963	867,677
Less: Sales tax	15,810	9,883
NET INCOME AFTER TAX	₱ 1,260,153	₱ 857,794

4. Mud crab polyculture with milkfish in aqua-mangrove pond

Mud crabs dwell at the bottom of the pond while milkfish occupies the water column. Apart from this, they complement each other in their food needs. Mud crabs are carnivores while milkfish are herbivores. Stocking together complementary species in one pond was found to enhance the overall production of the pond per unit area.

a. Pond preparation

In addition to conditioning, pond used for the polyculture of mud crab with milkfish are prepared for the production of *lablab* as natural food base for milkfish. The pond preparation procedure starts with draining the pond water and drying the pond bottom for 5-7 days. This is followed by the application of hydrated lime at the rate of 1 t/ha and immediately top dressing with ammonium sulfate.

Organic fertilizer (chicken manure) is applied at 2 t/ha and top dressed with 75 kg/ha inorganic fertilizer using urea (45-0-0) and ammonium phosphate (16-20-0) at a ratio of 1:2. The pond is filled with water from the incoming high tide to about 10 cm deep. Water is maintained at this level for a few days while taking note of the color of the pond bottom. Patches of thin green film appearing at the bottom of the pond suggest *lablab* growth. When a prominent green color appears, the pond should be gradually filled with additional 5-10 cm water level daily until a depth of 50 cm is reached. When *lablab* mats thicken, water level is increased to 60 cm. As soon as "lumut" growth develops in pond some *lablab* will still survive. "Lablum" growth will then prevail in pond providing food for milkfish and shelter for the crabs. Then the pond is ready for stocking crab juveniles and milkfish.

b. Stocking density and water change

Crab juveniles and milkfish fingerlings should be stocked early in the morning or late in the afternoon at the rate of $1.5/m^2$ 7-11 g or 16-20 g crab juveniles and milkfish fingerlings at $0.25/m^2$. Male crabs should be stocked separately from female crabs. If milkfish fingerlings are not available, milkfish fry are stocked first in nursery pond 30 days ahead of the mud crab stocking.

Water is changed every spring tide for 3-4 consecutive days to about 30, 40, 50, and 60% of the pond water volume on the 1st, 2nd, 3rd, and 4th month onward of the culture period, respectively. Inorganic fertilizer is applied at the rate of 1/2 the basal rate (urea - 12 kg/ha, ammophos - 25 kg/ha) during pond preparation on the last day of the 3-day water change for the maintenance of natural fish food growth in the ponds.

c. Selective/progressive harvesting for mud crabs

The procedure for this operation is the same as that on total harvesting in the grow-out monoculture of mud crabs in aqua-mangrove ponds.

d) Financial feasibility projections on a per ha/crop basis

(i) Technical assumption

Species to be cultured: "Pulang alimango" or Giant "alimango" and milkfish

Stocking density requirement:	
Crab ($1.5/m^2$)	15,000
Milkfish ($0.25/m^2$)	2,500
Duration of culture (mo)	4-5
Cropping/year	2
Survival (%):	
Crab	80
Milkfish	90
ABW (g):	
Crab:	
"Pulang alimango"	200
Giant "alimango"	400
Milkfish	250
Total amount of feed needed (kg):	
"Pulang alimango"	7,875
Giant "alimango"	12,600
Milkfish	None
Estimated price per kg feed for crabs (₱)	10
Production output (kg):	
"Pulang alimango"	2,400
Giant "alimango"	4,800
Milkfish	563
Estimated price per kg produced (₱):	
Crab	310
Milkfish	60

(ii) Financial assumptions

Miscellaneous cost are estimated at 2% of variable cost.
Caretaker salary at ₱ 1000/month.
Interest rate on capital investment is 8% per year.
Sales tax is 1% of revenues.

(iii) Investment (₱)

	Giant "alimango"	"Pulang alimango"
Development Cost	₱ 27,445	₱ 27,445
Operating capital:		
Variable costs		
Crab juveniles	142,500	45,000
Milkfish fingerlings	5,000	5,000
Feed for crabs	126,000	78,000
Pond preparation materials	4,985	4,985
Caretaker salary	5,000	5,000
Miscellaneous costs	5,670	2,375
Total variable cost	₱ 288,655	₱ 141,110
Fixed costs		
Pond rental (FLA)	500	500
Interest on capital investment	2,196	2,196
Total fixed cost	₱ 2,696	₱ 2,696
TOTAL OPERATING CAPITAL	₱ 291,351	₱ 143,806
TOTAL INVESTMENT	₱ 318,796	₱ 171,251

(iv) Cost-return analysis (₱)

Sales:		
Crabs	₱ 1,488,000	₱ 744,000
Milkfish	13,780	13,780
Total sales	1,501,780	757,780
Less: Operating capital	291,351	143,806
Net income before tax	1,210,429	613,974
Less: Sales tax	14,880	7,440
NET INCOME AFTER TAX	₱ 1,195,549	₱ 606,534

5. Monoculture of mud crab in pens set in tidal flats with existing mangroves

a. Pen preparation

Hydrated lime is applied at 1 t/ha during lowest tide, then *Gracilaria* is planted during the dry season culture or other macrophytes that can grow well in the site during the rainy season. Aside from roots of the mangroves, macrophytes serve as additional shelter for crabs. When there is luxurious growth of macrophytes, the pen is ready for stocking.

b. Stocking density and water change

Crab juveniles should be sorted according to size and sex, and counted according to the stocking density desired, i.e., 2.0/m^2 with 7-11 g or 16-20 g crab juveniles. Males should be stocked separately from females (monosex culture). Crabs are acclimated to pen water salinity and temperature before releasing them into the pens. The pen design would allow a change of water twice per day since the area is usually inundated during high tide. At night time during low tide, water in the pens should be drained for 3 consecutive days after every 7 days to allow exposure of mangrove roots but the canals should always be filled with water.

c. Selective/progressive harvesting

Marketable size and fat crabs, 150 g or more for female and 250 g or more for male "Pulang alimango", 350 g or more for female and 400 g or more for male giant "alimango", are harvested simultaneously with the stock sampling from the 2nd month of culture using lift net or current method. Crabs may also be selected and removed manually by hand picking them during the weekly draining that falls towards the end of every month.

d. Total harvesting

Harvesting may be by lift net method which would involve total draining of the pens at lowest tide and collecting the remaining crabs manually.

e. Financial feasibility projections on a per 200 m^2 pen/cropping basis

(i) Technical assumption

Species to be cultured: "Pulang alimango" and Giant "alimango"

Stocking requirement (2/m^2)	400
Duration of culture (mo)	4-5
Cropping per year	2
Survival (%)	85
ABW (g):	
"Pulang alimango"	250
Giant "alimango"	400
Total amount of feed needed (kg):	
"Pulang alimango"	255
Giant "alimango"	375
Production output (kg):	
"Pulang alimango"	85
Giant "alimango"	136
Estimated price per kg (₱)	310

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable costs.
Caretaker salary (family labor) at ₱ 100/mo (basis: 2 ha mud crab farm for every 1 caretaker paid at ₱ 5,000/mo)
Interest rates on capital investment is 6% per year.
Sales tax is 1% of revenues.

(iii) Investment (₱)

	Giant "alimango"	**"Pulang alimango"**
Development costs	₱ 5,275	₱ 5,275
Operating capital:		
Variable costs		
Crab juveniles	3,800	1,200
Feed	3,750	2,550
Pen preparation materials	355	355
Caretaker salary	500	500
Miscellaneous costs	168	98
Total variable cost	₱ 8,553	₱ 4,677
Fixed costs		
Interest on capital investment	211	211
Total fixed cost	₱ 211	₱ 211
TOTAL OPERATING CAPITAL	₱ 8,764	₱ 4,888
TOTAL INVESTMENT	₱ 14,039	₱ 10,163

(iv) Cost-return Analysis (₱)

Sales	42,160	26,350
Less: Operating capital	8,764	4,888
Net income before tax	33,396	21,462
Less: Sales tax	422	264
NET INCOME AFTER TAX	₱ 32,974	₱ 21,198

6. Crab fattening monoculture in aqua-mangrove pond

a. Pond preparation

The pond is prepared following the same procedures described in the grow-out monoculture of mud crab in ponds.

b. Selective/Progressive harvesting and restocking

One of the common features in mud crab fattening culture is selective/ progressive harvesting and restocking. At the end of the 20th day after stocking, fat crabs are selected and removed by harvesting fat female "pulang alimango" weighing 150 g or more, and male 250 g or more; fat female giant "alimango" weighing 350 g or more, and male 400 g or more. Not all crabs fatten at the same time in one culture duration, however observations indicate that about 50% of crabs fatten in 15-20 days.

Crabs harvested are replaced not later than a day after the removal of the fat crabs taking care to acclimate them, cutting movable parts of the claw, and disinfecting before releasing to the pond/pen. Crabs are harvested and replaced every 10 days. Each harvest should be about 30% of the stock assuming always a 100% survival at the end of the 130 days of culture if the culture period is 150 days or 20 days before the total harvest. A total of 14 selective harvesting and 12 restocking days can be attained in 5 months. However, harvested crabs should not be replaced on the 13th selective harvesting day.

Harvesting is by the current and lift net methods. Mud crabs that go against the current and congregate around or near pond gate are 98% fat, and therefore should be caught with a scoop net.

c. Total harvesting

Crabs are totally harvested at the end of the 120 or 150 days of culture by draining the pond and manually picking up the remaining crabs.

d. Financial feasibility projections on a per 200 m^2 aqua-mangrove pond/cropping basis

(i) Technical assumptions

Species: "Pulang alimango" and Giant "alimango"	
Stocking requirement (2/m^2)	2,098
Duration of culture	5
[(with progressive harvesting and restocking), (mo)]	
• 1st harvest and restocking is 20 days	
• after stocking; subsequent harvest and restocking is every 10 days	
Cropping per year	2
Survival (%)	
ABW at harvest (g):	
"Pulang alimango"	20
Giant "alimango"	400

Amount of feed needed (kg)	
"Pulang alimango"	1,070
Giant "alimango"	2,120
Cost of feed (₱/kg)	10
Production output (kg):	
"Pulang alimango"	357
Giant "alimango"	713
Estimated price/kg produced (₱)	310

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable cost
Caretaker salary (family labor) at ₱ 100/mo.
Interest rates on capital investment is 8% per year
Sales tax is 1% of revenues

(iii) Investment (₱)

	"Giant alimango"	**"Pulang alimango"**
Development costs	₱ 5,275	₱ 5,275
Operating capital:		
Variable costs		
Lean crab	41,960	20,980
Feed	21,200	10,700
Pond preparation materials	438	438
Caretaker salary	500	500
Miscellaneous costs	1,282	652
Total variable cost	₱ 63,380	₱ 33,270
Fixed costs		
Interest on capital investment	211	211
Total fixed cost	₱ 211	₱ 211
TOTAL OPERATING CAPITAL	₱ 65,591	₱ 33,481
TOTAL INVESTMENT	₱ 70,866	₱ 38,756

(iv) Cost-return Analysis (₱)

Sales	₱ 221,030	₱ 110,670
Less: Operating capital	65,591	33,481
Net income before tax	155,439	77,189
Less: Sales tax	2,210	1,107
NET INCOME AFTER TAX	₱ 153,229	₱ 76,082

7. Mud crab fattening monoculture in pens in tidal flats with existing mangroves

a. Pen preparation

The procedure described in monoculture of mud crab in pen is followed for this operation.

b. Selective harvesting and restocking, and total harvesting

The procedures described in mud crab fattening monoculture in aqua-mangrove pond, are followed.

c. Financial feasibility projections on a per 200 m^2/cropping

(i) Technical assumptions

Species: "Pulang alimango" and Giant "alimango"	
Stocking requirement	
Initial	400
Total (include restocking)	2,098
Duration of culture (mo)	5
Cropping per year	2
Survival (%)	85
ABW at harvest (g):	
"Pulang alimango"	200
Giant "alimango"	400
Amount of feed needed (kg)	
"Pulang alimango"	1,070
Giant "alimango"	2,120
Cost of feed (₱/kg)	10
Production output (kg):	
"Pulang alimango"	357
Giant "alimango"	713
Estimated price/kg produced	310

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable cost.
Caretaker salary (family labor) at ₱ 100/mo.
Interest rate on capital investment is 8% per year
Sales tax is 1% of revenues.

(iii) Investment (₱)\

	Giant "alimango"	"Pulang alimango"
Development cost	₱ 5,275	₱ 5,275
Operating capital:		
Variable costs		
Crab juveniles	41,960	20,980
Feed	21,200	10,700
Pen preparation materials	335	335
Caretaker salary	500	500
Miscellaneous costs	1,280	650
Total variable cost	₱ 65,275	₱ 33,165
Fixed costs		
Interests on capital investment	211	211
Total fixed cost	₱ 211	₱ 211
TOTAL OPERATING CAPITAL	₱ 65,486	₱ 33,376
TOTAL INVESTMENT	₱ 70,761	₱ 38,651

(iv) Cost-return Analysis (₱)

Sales	₱ 221,030	₱ 110.671
Less: Operating capital	65,486	33,376
Net income before tax	155,544	77,294
Less: Sales tax	2,210	1,107
NET INCOME AFTER TAX	₱ 153,334	₱ 76,187

VI. Shrimp Culture

In the Philippines, shrimp culture had been a very promising industry during the first few years, although the culture has not been that successful attaining only an average production of 500-800 kg/ha per crop even in areas where shrimp culture appeared to be highly suitable. With the technological advancement in pond engineering and culture methods, and the availability of feeds and hatchery produced fry, this production report has recently increased tremendously to a range of 3-12 t/ha/crop. Thus, production has increased a hundred fold. Since there was demand for shrimp in the world market, many pond operators switched from milkfish to shrimp production. Other shrimp ponds were built anew from mangroves or from lands previously planted to rice, sugarcane, and coconut. In many cases, intensive culture system was used.

The loss of mangroves associated with the rapid increase in the intensive pond production of cultured shrimp accompanied by rapid drop in fisheries yield and the occurrence of disease problems in ponds became a recent trend. This resulted in shrimp farms ceasing operations due to the prevalence of luminous bacteria resulting in almost total mortalities of shrimps through out the country. In itself, shrimp culture is a very good business. However, shrimp farmers should be convinced to incorporate environment-friendly methods in their operations. The industry should consider that shrimp farming is part and parcel of a bigger ecosystem.

In order to save the industry, two alternatives supportive of resource management for developing shrimp culture in the country, were introduced. Shrimp culture in ponds where natural stands of mangroves inside it are left untouched and shrimp culture in mangroves enclosed with a suitable netting or screening material, a process known as pen culture.

In view of the rich structural features of the mangrove ecosystem, certain clear advantages in shrimp-mangrove culture is envisage. Among these are: the mangroves can purify nutrients and inorganic matter from the waste water (Tam and Wong, 1995) and have the capacity to absorb pollutants in the water (Landers and Knuts, 1992) suggesting that shrimp culture in mangroves may prove an alternative rearing system that is technically appropriate and sustainable.

Being freely confluent with a large dynamic water system connected with the sea, it is assumed that oxygen deficiency, often experienced in ponds, would not occur in pens. Moreover, pen culture would not require expensive and complicated pond and sluice gate construction with highly technical expertise. It would not also require expensive mechanical assistance for filling, replenishing, exchanging and draining of water which are essential in shrimp ponds. Low investment and simple construction are other factors favoring pen culture of shrimps.

VII. Shrimp Culture System

The increasing demand for shrimp in the international market and the breakthrough in the mass production of shrimp fry under controlled conditions triggered the interest of both the government and private sectors, and thus marked the take-off point in the development of shrimp industry in the Philippines. Today, four different approaches or systems are practiced in the culture of shrimps, namely, extensive, modified extensive, semi-intensive, and intensive. The systems are categorized according to source of food, stocking density, and inputs more especially on the support facilities used. In these systems, an overall relationship of stocking rate with food is considered i.e., a balance of population with food. The estimated stocking rate is, therefore, respectively based on the amount of food in the pond whether it be on natural food available alone or with the addition of supplemental feed or solely on artificial feed.

A. *Extensive culture system*

Extensive culture is a low stocking density system where fry are stocked at 0.3-1.0/m^2 with natural food organisms available in the pond as the only source of food for the shrimps. Water exchange is undertaken during spring tides.

B. *Modified extensive culture system*

Locally called medium low stocking density system, the fry are stocked at over $1.0/m^2$ to $5/m^2$ with supplemental feeding on the 16th day after stocking. Water exchange is tidal (during spring tides). A standby water pump is provided for emergency use on the 4th month of culture when oxygen depletion is usually experienced especially with a stocking density of $5/m^2$.

C. *Semi-intensive culture system*

This is a medium high stocking density culture system. The fry are stocked at over $5.0/m^2$ to $15/m^2$. The shrimps subsist on natural food endemic in ponds for 7-10 days and feeding commences thereafter. At $5\text{-}7.5/m^2$, water exchange is tidal but a standby water pump is provided; beyond it water pump is a must and paddle wheel aerators are provided at 1 paddle wheel for every 50,000 shrimps/ha stocking density.

D. *Intensive culture system*

Stocking density is over 15 to a maximum of $50/m^2$. This is the latest technology generated as a result of advances in aquaculture engineering which enable fish farmers to control and maintain the limiting water quality factors and in shrimp nutrition which cater to the complete nutritional requirement for growth of the shrimps.

This system virtually increases the yield/ha/crop, however, it is not recommended because of the high risk, high capital inputs, and effects on the environment. Under conditions of mangrove-friendly aquaculture, the first three culture systems are recommended. It should be taken into consideration that based on experience recorded, disease problems are likely to appear under the intensive culture conditions.

VIII. Mangrove Pond Preparation

Pond preparation involved pond soil manipulations such as draining or flushing of ponds and subsequent reworking of the pond soil. The typical pond soil manipulations include draining of the pond, drying, liming, and fertilization, for the purpose of enhancing biological productivity in the pond.

A. *Pond drying*

Pond drying eliminates predators and competitors. It also oxidizes obnoxious gases harmful to the stock in the pond.

B. *Eradication of unwanted species*

There are some portions of the pond which could not be drained, hence, unwanted species could not be completely eliminated. An application of 10 g of ammonium sulfate and hydrated lime at a ratio of 1:5 on a per m^2 of water 5 cm deep effectively eradicates these unwanted species.

C. *Liming*

The application of lime after drying the pond, is an indispensable operation. This is intended to raise the low pH of the water to a slightly alkaline value which is more favorable to shrimp health and to the growth of natural food in the ponds. Lime is applied at the rate of 1 t/ha depending on the acidity of the pond soil.

D. *Fertilizing*

The application of fertilizer is essential in pond preparation to stimulate and develop the growth of natural food in ponds. There are two kinds of fertilizer used, namely, organic and inorganic fertilizers. Organic fertilizers are those of plant and animal origin, but the most commonly used is chicken manure, applied at the rate of 2 t/ha. Inorganic fertilizers are of mineral origin or manufactured chemical fertilizers containing plant nutrients such as nitrogen and phosphorus. Inorganic fertilizers consist of urea (45-0-0) and ammonium phosphate (16-20-0) at of 1:2 ratio, and applied at 75 kg/ha.

Organic fertilizer application is done immediately after liming, after which inorganic fertilizer may be applied. The pond is flooded through the incoming tide to about 10 cm deep. *Gracilaria* is planted using rice planting method, then the pond is gradually flooded 5-10 cm additional water depth each day until a desired depth of 100 cm, measured from the canal, is reached. When luxuriant growth of *Gracilaria* is observed, the pond is ready for stocking.

IX. Pen Preparation

Hydrated lime is applied during lowest tide at the rate of 30 kg/200 m^2. Ammonium sulfate is immediately used to top dress the undrained portion of the canal in order to eradicate unwanted species. *Gracilaria* is planted during lowest tide of the following day using rice planting method. Pen is ready for stocking after a luxuriant growth of *Gracilaria* is observed.

X. Fry Selection, Transport, Stocking and Acclimation

A. *Fry selection*

The selection of healthy fry will assure good growth and survival. Thus, MBV free or MBV negative fry should be selected since the growth of MBV infected fry is slow if not stunted. Buying fry from different batches for stocking in one pond or pen, should be avoided.

The antennules of the fry should be closed or drawn to each other, taking note that the antennules of a shrimp is separated as a V type at its front side. The antennules of a healthy fry (PL_{20}) are drawn close to each other; sometimes separating for a while then closing instantly. If the antennules are separated all the time but do not close, the fry is not healthy and should not be used for stocking.

Moreover, the abdominal segments should be long just like the long internode of a sugar cane, an indication of a healthy and fast growing fry. The uropod should be wide-open like a fan while swimming and muscles in the abdominal segment should be fully developed. Ocular inspection would show that healthy fry gather quickly towards a white board which is placed in tanks.

B. *Fry transport*

Plastic bags 50 cm wide, 83 cm long and 0.0075 cm thick are used in transporting shrimp fry. Around 5,000-10,000 fry are put in a plastic bag (two plastic bags, one placed over the other) with 1/3 full of water and with similar salinity as that of the tank water and source of the fry. The top of the inner plastic bag where the fry are contained is opened, bunched together and pressed down to remove air. Oxygen is pumped through a hose until the bag is inflated, then tightly closing the bag with a rubber band. The outer plastic is also closed with a rubber band

The filled plastic bag is placed in a "bayong" or woven bag made of pandan leaves if transported by land or if transported by air, the bags are placed inside Styrofoam boxes. Ice is placed outside the fry bags, in between the fry bag and the styrofoam container, to lower the temperature to 20°C. The fry are then ready for transport and be transferred to a previously prepared pond or pen.

C. *Fry acclimation and stocking*

Prior to the release of the shrimp fry, they should first be acclimated to the pond/pen water environment. The temperature and salinity of the transport water should be about the same as that of the pond/pen. In any case, the difference in salinity should not be more than 5 ppt.

Fry are acclimated and stocked during the cooler period of the day, that is, early in the morning (0600-0800 H) or late in the evening (1630-1800 H), by floating the oxygenated plastic bags with fry in the pond/pen water for 5-10 minutes or until such time that the temperature in the bag is similar to that of the pond/pen water. The bag is opened and pond/pen water poured into it gradually until the salinity in pond/pen water and water in the bag are about the same. The lid of the bag is lowered into the pond/pen water to allow gradual entrance of the pond/pen water into the bag. Healthy fry will usually swim out of the bag actively against the current and into the pond water.

XI. Water Quality Monitoring and Management

Water quality is the most important factor affecting successful shrimp grow-out culture. The required quality of water earlier mentioned is the function of the specific culture organisms and has many components that are completely interwoven. By monitoring water parameters daily, developing undesirable conditions will be known and corrective measures may be immediately done. Hence, the data should be used as a tool for the management of desirable water conditions in ponds.

Water temperature, salinity, DO concentration, pH, water color, water transparency, and water depth, should be monitored daily, while taking note of shrimp conditions like feed consumption, swimming behavior, and signs of disease. For instance, if shrimps swim to the water surface and float, and will not sink even if human shadow appears or moves, this indicate DO deficiency in the pond.

Water depth should be inspected daily through the installed depth gauge for possible leakage. Pond water should be changed regularly for 3-4 continuous days every spring tides to about 30% of the pond water volume on the first month, 40% - second month, 50% - 3rd month, and 60% on the 4th month onward of the culture period.

XII. Feeds and Feeding Management

Feeds consist about 50-60% of the total cost of production of shrimps. Using cheap but effective feed and the right amount will prevent feed wastage and therefore will minimize pollution and save on cost.

Artificial feeds in pelleted form are now available in the market, coming in three different kinds, namely: starter, grower, and finisher. The use of these feeds and feeding schedule are being recommended by the feed miller, which should be followed as these are based on successful field trials. Use a brand of commercial feed best reported by other shrimp growers in the site. A SEAFDEC/AQD study found out that brands of commercial feed are site specific, thus a brand best in one site may not perform well in other sites.

A. *Feed requirement for one cropping*

The feed requirement for one cropping is computed as TFR = (FS)(ES)(FCR), where TFR is the total feed requirement in kg, FS is the total number of fry stocked, ES is the estimated survival at harvest, ABW is the estimated average body weight of shrimp survivors in pond/pen at harvest, and FCR is the estimated feed conversion ratio of 1.75:1 at harvest

With TFR known, the computation for the different kinds of feed is as follows:

Starter = 0.0125 (TFR)
Grower = 0.2375 (TFR)
Finisher = 0.75 (TFR)

B. *Feeding rate*

Shrimps should be fed at a sliding rate of 10% of the shrimp biomass per day on the first month, 8% - second month, 6% - third month, 4% - 4th month onward of the culture period. The daily ration is computed as DR = (FS)(ES)(ABW)(FR), where DR is the daily ration, ES is the estimated survival in a linear decreasing order with 100% for the first 15 days to 75% 15 days before harvest, and FR is the feeding rate.

C. *Feeding scheme*

1. For modified extensive culture system

Days of Culture	Feeding Time (% of daily ration)				
	0600	1000H	1400H	1700H	2200H
1-15	Feeding on natural food organisms				
16-30	50			50	
31-45	30			50	20
46-60	30			50	20
61-75	30	10		40	20
76-90	30	.10		40	20
91-105	25	10	10	35	20
106-120	25	10	10	35	20

2. For semi-intensive culture system

Days of Culture	Feeding Time (% of daily ration)				
	0600	1000H	1400H	1700H	2200H
1-7	Feeding on natural food organisms				
8-15	50			50	
16-30	50			50	
31-45	30			50	20
46-60	30			50	20
61-75	30	10		40	20
76-90	30	10		40	20
91-105	25	10	10	35	20
106-120	25	10	10	35	20

3. Feed consumption monitoring

Although a daily feed ration is prescribed, feeding on demand is also recommended. It is therefore important that feed consumption is regularly monitored by providing feeding trays, 4 trays/ha in pond and 1 tray for the 200 m^2 pen. Catwalk should be installed, one on each side of the pond and one for the pen. Sufficient length of rope is used to connect each of these trays and to the catwalk.

During feeding, 1% of the amount of feed intended for the feeding schedule should be placed equally in the 4 feeding trays. After 2 hours but not later than 4 hours after feeding, the trays are inspected. If the feeds are consumed or almost consumed, feed equivalent to 5% of the total amount of feed intended for the next feeding schedule should be added. Otherwise, feed should be reduced by 5% of the next scheduled ration.

4. Harvesting

Water should not be changed 5 days before harvest to prevent molting. Harvesting soft-shelled shrimps should be avoided. Usually, the buyer is informed ahead of time on the choice of the scheduled harvest, then his representative will be asked to take sub-samples from the pond as basis for the pricing of the harvest.

Harvest should be by total draining of the ponds and by providing "lumpot" (bag net) at the drain gate, taking note that the shrimp goes with the current. Shrimps are collected from bag net periodically and placed directly into chilling tanks. These are washed and transferred in boxes provided by the buyer for weighing. Once weighed, the buyer transfers shrimps to another box to be filled with cracked ice. The remaining shrimps in pond/pen are picked up and washed thoroughly before placing them in chilling tanks.

5. Post-harvest handling

Shrimps should not be taken out from chilling tanks before the arrival of a buyer. Once exposed and their heads redden, the shrimps may be rejected by the buyer. The buying price is based on the sub-samples taken a day before the scheduled harvest. From the samples, soft shelled and undersized shrimps could be usually determined by computing the % soft shelled and undersized shrimps from the total weight of the harvest. What remains is considered good shrimps.

For example in a sub-sampling, results showed an ABW of 32 g but 1% was found to be soft-shelled and 3% is below 18 g. Therefore from a total harvest weighing 2 tons, the expected volume of soft shelled is computed as 1% of 2000 = 20 kg, while the expected volume of undersized shrimps is computed as 3% of 2000 = 60 kg, giving a total of 80 kg. The total harvest less 80 kg (expected rejects) would therefore be 1,920 kg of expected good shrimps.

At ₱450.00/kg based at 30 g ±₱5.00, the price per kg of the shrimp harvest is ₱460.00, thus, the total revenue is: ₱460 x 1920 = ₱883,200. Adding the revenue of the rejects and soft-shelled: ₱180 x 80 = 14,400. Therefore the TOTAL REVENUE = P897,600

6. Financial feasibility projections

a. On a 1.0 ha pond shrimp monoculture per cropping basis using extensive culture

(i) Technical assumption

Stocking density (/m^2)	0.3
Duration of culture (mo)	5
Survival (%)	75
ABW (g)	30
Amount of feed (kg)	none
Estimated price/kg (₱)	450

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable cost.
Caretaker salary at ₱ 1,000/month
Interest rates on investment is 8% per year
Pond rent is in accordance with FLA rate.

(iii) Investment (₱)

Development costs:	
Construction of dikes, canals and leveling	2,000
Operating capital:	
Variable costs	
Shrimp fry	750
Feeds	None
Pond preparation materials	11,985
Caretaker salary	5,000
Miscellaneous costs	355
Total variable cost	18,090
Fixed costs	
Pond rent (FLA)	500
Interest on capital investment	2,880
Total fixed cost	3,380
TOTAL OPERATING CAPITAL	21,470
TOTAL INVESTMENT	93,470

(iv) Cost-return analysis (₱)

Sales	30,375
Less: Operating capital	21,470
Net income before tax	8,905
Less: Sales tax	304
NET INCOME AFTER TAX	8,601

b. For a 1.0 ha pond shrimp monoculture on a per cropping basis using the modified extensive method

(i) Technical assumption

Stocking density (/m^2)	5
Duration of culture (mo)	5
Survival (%)	75
ABW (g)	30
Amount of feed (kg):	
Starter	25
Grower	467
Finisher	1,476
Cost of feed (₱):	
Starter	45
Grower	36
Finisher	35
Production output (kg)	1,125
Estimated price/kg produced	450

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable cost
Caretaker salary at ₱ 1000/month
Interest rates on investment is 8% per year
Sales tax is 1% of revenues

(iii) Investment (₱)

Development cost	72,000
Operating capital:	
Variable costs	
Shrimp fry	12,500
Feeds	69,597
Pond preparation materials	11,985
Caretaker	5,000
Miscellaneous costs	1,982
Total variable cost	101,064
Fixed costs	
Pond rental (FLA)	500
Interest on capital investment	5,760
Total fixed cost	6,260
TOTAL OPERATING CAPITAL	107,324
TOTAL INVESTMENT	179,324

(iv) Cost-return analysis (₱)

Sales	506,250
Less: Operating capital	107,324
Net income before tax	398,926
Less: Sales tax	5,062
NET INCOME AFTER TAX	393,864

c. For a 1.0 ha pond shrimp monoculture on a per cropping basis (Semi-intensive)

(i) Technical assumption

Stocking density (/m^2)	15
Duration of culture (mo)	5
Survival (%)	75
ABW (g)	30
Amount of feed Kg):	
Starter	74
Starter	74
Grower	1,403
Finisher	4,430
Cost of feed (₱/kg):	
Starter	45
Grower	36
Finisher	35
Production output (kg)	3,375
Estimated price/kg produced	450

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable cost.
Caretaker salary at ₱ 1000/month
Interest rates on investment is 8% per year
Sales tax is 1% of revenues

(iii) Investment (₱)

Development cost	72,000
Operating capital:	
Variable costs	
Shrimp fry	37,500
Seeds	208,888
Pond preparation materials	11,985
Caretaker salary	5,000
Miscellaneous costs	5,267
Total variable cost	268,640
Fixed costs	
Pond rental (FLA)	500
Interest on capital investment	5,760
Total fixed cost	6,260
TOTAL OPERATING CAPITAL	274,900
TOTAL INVESTMENT	346,900

(iv) Cost-return analysis (₱)

Sales	1,518,750
Less: Operating capital	274,900
Net income before tax	1,243,850
Less: Sales tax	15,188
NET INCOME AFTER TAX	1,228,662

d. For a 200 m^2 pen shrimp monoculture on a per cropping basis (Semi-intensive)

(i) Technical assumption

Stocking density (/m^2)	15
Duration of culture (mo)	5
Survival (%)	75
ABW (g)	30
Amount of feed (kg):	
Starter	2
Grower	28
Finisher	89

Cost/kg feed:	
Starter	45
Grower	36
Finisher	35
Production output (kg)	68
Estimated price/kg produced	450

(ii) Financial assumption

Miscellaneous costs are estimated at 2% of variable costs
Caretaker salary at ₱ 100/month
Interest rates on investment is 8% per year
Sales tax is 1% of revenues

(iii) Investment (₱)

Development cost	5,275
Operating capital:	
Variable costs	
Shrimp fry	750
Feeds (kg)	4,213
Pond preparation materials	346
Caretaker salary	500
Miscellaneous costs	116
Total variable cost	5,925
Fixed costs	
Interest rates on capital investment	211
Total fixed cost	211
TOTAL OPERATING CAPITAL	6,136
TOTAL INVESTMENT	11.411

(iv) Cost-return analysis (₱)

Sales	30,600
Less: Operating capital	6,136
Net income before tax	24,464
Less: Sales tax	306
NET INCOME AFTER TAX	24,158

WISE USE OF IMPORTANT MOLLUSC SPECIES IN MANGROVE AREAS: MALAYSIA

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I. Introduction

Mangroves are productive intertidal ecosystems with ecologically diverse habitats, forming a unique combination of terrestrial and aquatic environments. The sand-silt-clay sediment composition of the mangrove ecosystems, support numerous species of aquatic flora and fauna. The trees in the mangrove areas contribute bulk of the organic matter which is utilized by various organisms in the ecosystem, including the molluscs (Shigeo, 1997). Malaysia is blessed with some 646,000 ha of mangrove swamps with the largest area found in the states of Sabah, Sarawak and Perak, respectively.

For centuries, several edible mollusc species are being collected for food by coastal communities from these mangrove ecosystems. The most common molluscs collected are cockles, various species of oysters, clams and cerithids. This paper attempts to discuss the most practical culture technologies that have been developed for some of the more important mollusc species that are cultured in Malaysia. In order of priority, these are *Anadara granosa* (blood cockle), *Crassostrea iredalei* (brackishwater slipper oyster), *Crassostrea belcheri* (mangrove oyster), and *Cerithidia obtusa* (horn shells).

Hatchery propagation techniques have been developed for the cockles and oysters. However, it was proven that hatchery propagation is economically viable for the oysters only because of the need for large quantities of spat for the cockle industry in Malaysia, which is operating on a very large scale.

Reports of diseases are the major factor affecting the consumption and the market trend of shellfish. Thus, in order to create public awareness on the safety of shellfish consumption, concerted efforts were made to introduce commercial depuration units for both the cockle and oysters. The system developed was effective in removing fecal coliform bacteria from the molluscs.

II. Mangrove Mollusc Species of Commercial Importance

A. *Anadara granosa*

Malaysia is the world's largest producer of cockles with annual landings of 71,795.59 mt (Annual Fisheries Statistics, 1996). Some 4548 ha have been used for this purpose with about 311 cockle farmers in the country. The culture of this species is confined to the west coast states of Peninsular Malaysia where there are extensive mudflats bordered by mangroves as compared to the exposed sandy beaches of the east coast and east Malaysia.

Cockles have contributed more than 80% of the total aquaculture production in Malaysia for the past two decades. In 1980, peak landings of 120,000 mt of cockles from both the wild and commercial culture beds had been recorded. The landings had since then fluctuated from year to year (71,795 mt in 1996) and from place to place.

B. *Crassostrea* spp

Coastal inhabitants of Malaysia traditionally consume oysters harvested from wild stocks. Oyster farming is a recent innovation, beginning with trials as far back as in the 1960s. In order to promote growth of the mollusc industry in Malaysia, the Department of Fisheries, targeted oysters for aquaculture development during its 7th Five Year Plan. Financial and technical assistance was requested from the Bay of Bengal Programme (BOBP) in 1987 and a BOBP subproject "Oyster Culture in Malaysia" was established.

A variety of suitable oyster species such as *Crassostrea belcheri, Crassostrea iredalei, Ostrea folium* and *Saccostrea* spp. were identified and of these oyster species, those confined to the mangrove regions are from the genus *Crassostrea.* They are large and measure up to about 10 cm (marketable size), thriving best in estuarine locations with a salinity range of 15-28 ppt. *Crassostrea belcheri* is common in the estuarine along the west coast of Peninsular Malaysia (states of Kedah, Perak, and Johor) with a higher salinity regime and has also been reported to occur along the mangrove coast of Sabah. *C. iredalei* on the other hand, is confined to brackishwater lagoons with lower salinity levels in the east coast states of Terangganu, Kelantan and Pahang.

Of the two species, *C. iredalei*, is most desired by consumers because of its creamy white meat color as compared to *C. belcheri* which has a brownish tinge. These oysters are sold in the form of shucked meat or shell-on depending on the needs of the buyers (restaurants and hotels). Oyster landings (42.3 mt in 1996) in Malaysia, ranged third after cockles and mussels in terms of production.

C. *Cerithidia obtusa*

This is a very common gastropod found in almost any mangrove area, estuarine or brackishwater conditions or mudflats and are considered vegetarians as they feed on mangrove detritus. Although the culture is not commercialized as yet, small-scale culture by fisherfolk have been reported in some parts of Peninsular Malaysia and Sarawak.

III. Spat Collection Techniques

A. *Anadara granosa*

Cockle culture depends largely on the natural supply of cockle spat from the intertidal mudflats, largely limited to the west coast of Peninsular Malaysia. However, spatfall have been reported to occur in the east coast but are considered not important as they are sporadic covering only a small area, natural spatfall areas shifting from year to year.

It is believed that these shifts are brought about probably by the effects of water current and human activities. The fluctuation in spat availability is also partly due to vagaries of nature and probably due to the releasing out of some unproductive natural beds for cockle culture.

1. Spatfall season

The breeding cycle of cockles appears to be closely related to salinity. Seasonal rains bring about considerable changes in the salinity which directly or indirectly affect the breeding of the cockles. Data indicate that breeding takes place more or less throughout the year, but two main peaks in spatfall could be distinguished. The first peak is between January to March while the second is from May/June to September and minor spatfalls throughout the year (Ng, 1984). However, this is dependent on the spawning successes of both the naturally occurring and cultured cockles.

Spat supply is unpredictable and fluctuates from year to year and from place to place. Availability of spat in an area during one particular season does not confirm spatfall in the subsequent years. Sometimes there is a possibility of spatfall occurring in the culture beds itself.

2. Spat collection methods

Spat collection is done when the spat size ranges 6-10 mm in length. Spat collection is allowable only if a license is obtained from the Department of Fisheries after notification of spatfall by relevant authorities. Spat collection is usually allowed from 6 AM to 6 PM as specified in the Fisheries Act (1985). Cockle spats are hand collected with a fine wire-meshed scoop (hand made) by sieving the mud flats and rinsing them in seawater prior to emptying the spats into plastic sacks weighing about 60 kg or tins of 18 liter capacity. No merchandised collection is allowed.

The best quality spat are those caught in the first few weeks of the collection season. In Malaysia, the legal size considered as spat for collection are those measuring more than 6.4 mm which should be landed at sites specified by the Fisheries Authorities, for monitoring purposes. The size is specified in order to minimize mortality of the spat while being transferred for culture.

B. *Crassostrea* spp

Natural spat collection is enhanced by placing suitable substrates (cultches) in the water column at the appropriate time and place, for the oyster larvae to set on. Defining the appropriate timing is an important factor in determining successful seed collection. Placing the cultch too early will result in its surface being smothered by silt, reducing its attractiveness for larval settlement, or being settled on by barnacles, tubed polychaetes, sponges or other fouling organisms. Placing the cultch too late means having to wait for the next spatfall season.

1. Cultch types

Several kinds of cultches have been identified that are suitable for spat collection depending entirely on whether the culture is for oyster to be sold shell-on or for the oyster meat. Although there are a broad variety of cultch types that can be used, those which are cheap, readily available and does not pollute the water system are recommended (Mohd. Yatim, 1993; Ahmad, et al., 1994).

If the demand is for single oysters, the cultch types used are netlon or coconut shells. However, if the need is for oyster meat, the cultch types may be made of motorcycle tires or oyster shells.

Netlon is an extruded HDPE mesh which, although relatively expensive, is extremely durable lasting many years in seawater. Netlon of 1.0 cm mesh size cut into panels measuring 62 cm x 67 cm are formed into cylinders by joining and lacing opposite edges along the 67 cm side. These cylinders are then dipped in a mixture of cement-sand-lime mixture (ratio 5:2:1) and after two days drying, this cultch could be put in the water.

The hard, inner shell of the coconut is also easily gathered in the country, coconut being widely cultivated for home use and as cash crop. In sandy areas like Merchang and K. Setiu in Terengganu, the shells are scattered on the bottom or hung where the shells are strung at 2.0 cm apart on a string adjusted to the water depth.

Discarded motorcycle tires are readily available for free and attractive to oyster larvae. The tires are turned inside out and suspended individually from raft/racks or made into reefs. The reef tires are placed at the bottom and tied to a rope marked with floats for easy retrieval. Observations have shown that oyster spat tend to settle more on the inner side of the tire.

Discarded oyster shells are abundant at the culture sites, having been discarded after shucking the meat. The shells are punched and strung on HDPE line.

2. Spat collection systems

The cultches are hung from various systems that are installed depending on the characteristics of the spat collection sites.

a. Rafts

A standard raft measures 6.7 m x 6.7 m and cost about RM 3,000-4,000. The frame is made of hard timber (*Balanocarpus heimii*) and is supported by about 15 floats (plastic drums of 60 liter capacity). However, a cheaper version was tested in which only the frame was made of hard timber while mangrove poles were used for hanging the culture trays, thus reducing the cost to about RM 2,000. Rafts are suitable for sheltered sites with water depth of at least 3.0 m during low tide.

b. Long lines

Stretching some 50 m in length, longlines are the most economical culture systems, costing about RM 1,000. The structure is simple; parallel polyethylene ropes are lashed to 40 liter plastic drums which serve as floats. The longlines are anchored at either end, with allowance for the depth difference between low and high tides. Longlines are well suited for slightly exposed areas, the advantage being that better water circulation around the oysters promotes faster growth.

c. Racks

Racks are used in shallow lagoons which have sandy floors. Their heights are adjusted according to the water depth in the area during high/low tides. The dimensions of the racks are similar to that of the rafts. Racks are stationary and supported by nibong poles (local palm whose trunk is highly resistant to seawater and marine borers) driven into the bottom.

d. Modified long lines with marker buoys

This is a slightly modified version of the longline. Small floats are used here to indicate the longline to which the tire reefs are tied. The longline in this case is for the easy retrieval of tires on which the oysters are attached.

C. *Cerithidia obtusa*

Spatfall of this shell is still dependent from the wild where spat is collected (handpicked) from the mangrove area and transferred to the culture area which can be nearby or otherwise. The gastropod is cultured in a more confined area so that they do not wander off to unwanted areas. The gastropod are found grazing on the ground surface during low tide and tend to attach themselves onto the mangrove trees during high tide.

IV. Culture Techniques

A. *Anadara granosa*

1. <u>Sustainability of Area</u>

Areas that are considered suitable for cockle culture are tidal flats of fine soft mud, protected from strong wave action, and situated outside the mouth of estuaries. Some of the characteristics considered in choosing a site for cockle culture include areas that are well sheltered from strong wind and current to prevent the spat from being buried under the mud; mudflats with sandy-loam soil texture; salinity range of 28-30 ppt; stable culture bottom with a gradual or no slope; and areas without pests or pollution

The culture beds are usually located far from natural grounds and in most cases very far off. Most of the cockle culture operations are well organized and is being practiced by the Majuikan or through Fishermen's Cooperatives (Persatuan Nelayan). The farmers would have to apply for a temporary occupational license (TOL) charged on a yearly basis to operate cockle culture activities. Currently, some 4500 ha of mudflats are used for the culture of cockles. The spats can be transported under semi-dry conditions (mixed with mud) over a period of 48 h with very low mortality rate (about 5%). The quality of the spats depends on the impurities comprising detritus and other clams.

2. Preparation of culture bed

Most of the culture plots are bounded by natural landmarks, but where these are lacking, the boundaries are marked by other means such as mangrove poles or watch huts. Prior to sowing of the spats, the culture bed should be cleared of empty shells and predators if the area is small. But in some areas, farmers reckon that clearing of culture plots which may exceed 60 ha is too tedious and expensive. They also feel that given time, the shells could easily sink into the mud. Thus, as soon as a batch of cockles are harvested from the plot, new spats are sown immediately into the area.

3. Stocking density

Stocking density of spats per acre depends on the size of the spats. For spats of about 5000/kg, 150 to 200 tins of spats/acre appear to be the best stocking density. The expected yield per acre from 200 tins of 5000/kg spats is about 1200 to 1400 grunny sacks (each sack is about 80 kg of adult cockles). The following densities are also recommended by farmers from various culture sites:

No. of spat (per kg)	Culture density (spats/m^2)
6700-8,000	3000-4000
3300-5000	1600-2000
1600-2500	1600-2000
1000-1200	650-900
250-400	320-640

The most sought after spats are those of about 8000/kg depending on the availability but spats often used range from 5000 to 6000/kg. Some farmers buy spats in bulk and stock them in an area where they are culled from time to time using a bigger core into the grow-out areas. The stocking rate can thus range from 220-320 tins/ha. Spats brought to the culture area are sown during high tide, to enable the boats to go around distributing the spats on the ground. Spats are poured off the sacks from the rear of the boat so that the propeller can help distribute the spats on the water column. Another method is to spread the spats by using a plate or scoop as the boat is moving. Spats are sown at a high density in a corner of the culture plot before being culled or spread into the grow-out area.

4. Maintenance

The first thinning or culling is done after two months and then a follow up after every three weeks. In deep water of more than 3-4 m, no thinning is required because of the difficulty in collecting and transplanting the cockles. The culture period is usually more than one year and the legal cockle size for harvest should not be less than 31.8 mm.

5. Harvesting

The culture period of cockles usually exceed one year depending on the size of the spat used. Cockles are harvested during high tide by means of a core (with a coarser mesh size) with a handle from a boat. The average cockle size allowed to be harvested under the Fisheries Act 1985, is no less than 31.8 mm for conservation purposes. About 10-15 gunny sacks (80 kg/sack) of adult cockles can be harvested by two persons engaged for 5-6 hours a day. Harvesting of marketable cockles depends on demand which is usually practiced on a contract basis. However, when a farmer can not meet the demand, the quotation can be met by getting cockles from other farmers in the area. Most of the harvested cockles are exported to neighboring countries like Singapore and Thailand. Some of it are canned or sold in dried form (Mohd. Noor, 1988).

B. *Crassostrea* spp.

About 300 oyster farmers have been reported to indulge in oyster (both species) culture operation throughout the country utilizing a total area of about 106,500 m^2. The grow-out activity of oyster spats is a simple process depending on the type or oysters needed, i.e. shell-on or shucked oysters. For shell-on oysters, the culture system is different compared to oysters sold for their meat only.

1. Grow out method

Shell-on oyster (single oysters) are usually obtained from netlon and coconut shell cultches as they are easily removed. Oysters on other cultches such as tires and shells are just on-grown until they reach marketable size, when meat is shucked. For shell-on oysters, the several culture methods make use of plastics trays arranged in tiers, modified motorcycle tires, or netlon trays.

2. Maintenance

The containers are hung from the various systems such as rafts, longlines and racks. During the culture period, the oysters have to be cleansed of mud and fouling organisms such as ascidians, sponges and barnacles that tend to settle on their body. This is easily done using water jets that are electrically operated and using water from the culture site. Another important aspect is to cull the oysters from time to time to reduce its density as they grow, to enhance better growth rate that may be affected by lesser food and space.

The farmers will need to remove dead oysters and predators (crabs) if any from the containers. Predators can be avoided by providing covers. The oysters take about 8-12 months to reach marketable size (7-8 cm) depending on the size of the spat used.

C. *Cerithidia obtusa*

The culture of this gastropod (*Cerithidia obtusa*) in Malaysia, is still at its infant stage. Several coastal fisherfolk in Peninsular and East Malaysia have been reported to indulge in its part-time culture involving 2-3 ha. The culture areas are in mangroves regions which are fenced using mangrove poles and 'nipa' or palm leaves to prevent the gastropods from escaping or being washed away to other locations. The spat of the gastropod are scattered in the fenced mangrove areas and left there until they reach marketable size. It usually takes about one year for gastropods of 1.0 cm to reach harvestable size of 5.0 cm.

V. Hatchery Production of Oyster Spat

Hatcheries play an increasingly important role in bivalve culture in the northern hemisphere (Thailand and Malaysia). Although still experimental some hatchery works have potentials as supplementary sources of oyster spat. The natural spat supply is often hindered by vagaries of nature in Malaysia, especially during the monsoon period which affects the east coast (main spat supplier of *Crassostrea iredalei*) during which salinity level drops to zero resulting in very high mortality rate of the oysters.

Some successful trials on the spawning of oyster (Ng, 1993) and larval rearing were carried out by the Fisheries Research Institute. The hatchery-produced spat had to be carefully tended in an intermediate stage before stocking in the grow-out systems.

This stage is referred to as "nursery culture" where there is actually not much work involved, taking 2-2.5 months to attain 2.0 cm size. The farmers only had to ensure that the collectors are not infested with fouling organisms or covered with silt.

Attempts to set the eyed larvae were first initiated at the hatchery (Devakie *et al*., 1993). Two ton fiberglass tanks lined with plastic sheet were used for this purpose. Some setting trials were done using marble chips and netlon cylinders.

Eyed larvae were released into setting tanks at a rate of 2 pc/ml. Setting occurred in phases, due to differences in the development rate of the larvae. Water was completely changed every other day, while 50% was changed on other days. Observation showed that setting rate was better on plastic sheet (20%) than on marble chips (12.5%).

As for netlon tubes, it was not possible to count the number due to the color of the spat which was almost the same as the netlon. The spat was then left to grow in the hatchery until 5.0 mm size (1.5-2.0 months). Although there was insufficient phytoplankton to rear the spat for long, the trials were successful and led to the development of a field station for remote setting.

Remote setting is being widely practiced in the United States which revolutionized the industry, eliminating the cost associated with the transport of cultch from farms to hatcheries, thus simplifying the hatchery operation and tedious production of algae was overcome. In Malaysia, the remote setting facility was established at one of the oyster farms in Batu Lintang, Kedah.

The system consists of a raft bearing a shed within which there are three setting tanks. HDPE plastic sheet strips are used as cultch. The tanks are also lined with the same material. Plastic sheet makes it very easy to remove the spat with minimal damage to the spat. By gently rubbing the reverse side or directing a steam of low pressure water on the film is enough to remove the spat. The aeration system (12v portable compressor) on the raft is powered by heavy duty marine storage batteries conveniently recharged ashore. The best setting rate has been observed in the water filtered through 60 micron material, but growth could be faster in the unfiltered treatment.

VI. Shellfish Depuration Systems

The Fisheries Research Institute has developed a depuration unit to process cockles with the assistance from the Australian Government through the ASEAN (Ismail, 1988). A modified system based on this unit was also developed for the oysters to be distributed to oyster farmers at various sites (Devakie *et al.*, 1993).

The system operates on a simple technology utilizing ultra violet irradiation as the source for sterilization and the unit works on a recirculating high density system. Five levels of plastic trays (64 cm x 42 cm x 16 cm) are stacked in a nest arrangement totaling 15 trays. The water holding tank (180 cm x 90 cm x 60 cm) is made of fiberglass. Two units of sterilizing ultra-violet lamps each of 30 W are placed in a box (110 cm X 47 cm x 30 cm) made of fiberglass lined with plywood and positioned on top of the depuration unit. A 0.4 Hp 300 W pump is used to circulate water through the system.

The bivalves should be processed within the same day of harvest to avoid high mortality rate at post depuration process which is 36 hours. In the case of cockles, about 160 kg/t seawater can be processed and for the oysters about 750 pieces can be processed at a time.

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AQUACULTURE OF SHELLFISH IN VIETNAM

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I. Introduction

Vietnam has a long stretched of sea shore which is about 3260 km from Mong Cai to Ca Mau. The coastal area available for culture of marine species is about 660,000 ha tidal area and 300,000 ha of pond and closed areas.

Coastal aquaculture in Vietnam is still underdeveloped compared to its neighbors in Southeast Asia. While countries most advance in coastal aquaculture (i.e., Republic of Korea and China) produce several hundreds of tons of commodities on every kilometer of coastline, Vietnam produces 8.4 ton/km, Malaysia 11.5 ton/ha and the Philippines 27.1 tons/km. Coastal aquaculture in Vietnam is still dominated by crustaceans and marine shrimp culture.

The Vietnamese are consumers of bivalves and gastropods. However, aquaculture of shellfishes is not a traditional industry in Vietnam. The people used to collect the bivalves from the wild for food, resulting in the continuous decreasing of the mollusc resources, year after year. The increased production from mollusc culture in the coastal areas is therefore important and necessary for the Vietnamese.

In order to conserve the mollusc resources in Vietnam, basic studies on biology, physiology and ecology of some shellfishes are therefore very important. In addition, the artificial production of bivalve seeds is also equally necessary, and this has become an important mission for fishery scientists.

Recently, mollusc culture was introduced in Vietnam. Some of the commercially important bivalve species in Vietnam (Table 1) are presently cultured in a large-scale (e.g., pearl oyster, ark shell clam) while about half is done at a low and very manageable level. In these cases, the source of the seeds is still dependent on the wild.

Production from mollusc culture in Vietnam, is fast increasing from 1996 to the present. Clams, cockle, ark shell, and scallops are the important species contributing to the total mollusc production.

However, the Vietnamese also consume gastropods and bivalves, as traditional sources of their daily high protein food. The prices of shells such as oysters, ark shell, clam, and snails are now rapidly increasing because these have become important export products in the country's fisheries trade.

Table 1. Commercially important gastropods and bivalve species of Vietnam

Scientific Name	English Name	Distribution area
Crassostrea rivularis	Oyster	Quang Ninh (QN)-Thanh Hoa
Anadara broughtonii	Arkshell	Hai Phong - Nam Dinh
A. granosa	Arkshell	Thanh hoa, Thai binh, Minh Hai
Meretrix lyrata	Clam	Bentre, QN, Thanh hoa
M. venerupis	Clam	Bentre, QN, Thanh hoa
M. meretrix	Clam	Bentre, QN, Thanh hoa
M. lusoria	Clam	Bentre, QN, Thanh hoa
Luthlaria philippinarum	Snail	Haiphong (HP)
Pinctada maxima	Pearl oyster	QN, HP, Khanh hoa
Pteria penguin	Black wing pearl oyster	QN, HP, Khanh hoa
Pinctada martensii	Black wing pearl oyster	QN, HP, Khanh hoa
P. margaritifera	Black wing pearl oyster	QN, HP, Khanh hoa
Haliotis diversicolor	Abalone	QN, HP, Thuan hai
H. asinina	Abalone	QN, HP, Thuan hai
H. ovina	Abalone	QN, HP, Thuan hai
H. varina	Abalone	QN, HP, Thuan hai
Mytilus smaragdinus	Blue mussel	HP, T. hoa, K. hoa
Chlamys nobilis	Scallop	
Amusium pleuronectes	Raditel scallop	Thuan hai, Vung tau
Babylonia aerolata	periwinkle	Vung tau
	in Freshwater	
Shinohyriopsis cunmigii	Freshwater oyster	Thanh hoa

II. Oyster Culture

A. *Crassostrea rivularis*

The river mouth oyster is one of the most important molluscs in Vietnam. From 1967 to 1968, the off-bottom hanging method of oyster culture including spat collection, was proven to be successful, although this is not yet very efficient due to inadequate technology.

1. Biological characteristics

River mouth oyster is one of large species of oysters, which includes the *Crassostrea gigas*. The meat of the oyster has a high protein content, that is why the Vietnamese consume oyster as a protein food for their every day meals.

The most common, C. *rivularis* lives in river mouth which has low salinity from 10 to 25‰ and its distribution is from central tidal to 5-6 m depth of water. Adult oyster reaches 20-25 cm in length, and it is distributed in Quang Ninh - Thank Hoa province. Bach Dang river mouth is famous for the production of the river mouth oyster. Spawning season is from April to September, concentrating from May and June to September and October. The river mouth oyster can be harvested after two years of culture.

2. Seed production

Seed production is one of the major problems in gastropod and bivalve culture, including the collection of oyster spat from the wild and collection of artificial spat reared from eggs in hatchery tanks. However, the use of artificially produced seeds in oyster culture was also found not economical at this stage because of the difficulty in handling and rearing the seeds to larvae due to inadequate modern technologies. Thus, spat collection from the wild is still widely practiced by the Vietnamese fishermen.

In the spawning season, female and male of oysters release eggs and sperm to the sea water. The fertilized egg develops through some state of larvae and becoming umbro state which sets on a settlement medium. This is summarized in the following illustration:

Mother of oyster ⟶ Spawning ⟶ Fertilization and development ⟶ Spat setting

a) Larvae sampling

Phytoplankton net is used in the daily larvae sampling of the collecting areas. Counting of the larvae is done under a microscope, and when the number of umbro state increased, spat collecting from such area may be set out. During the following larvae sampling season, sample spat collection of oysters or scallop shells are set out daily to check for the appearance and number of newly settled spat.

b) Spat collector

Spat collector may be made of shells of oysters and scallops, bamboo, and other materials. In preparing a spat collector, holes are bored through the center of the shells of oysters and scallops and connected by means of a string which is about two meters long with 50-60 shells per string.

c) Spat growth and transporting

Newly settled spat should be about 0.3 mm in size several days after settling with an average growth rate of about 0.3 - 0.4 mm per day. After 10-15 days, spat must have grown from 5 to 10 mm with a survival after setting of 10 to 15%. A problem usually encountered in spat collection is the presence of the larvae of "balauns." This organism also settle at the same time as the oysters in great number, making it difficult for the collection of the oyster spat.

In Korea or Japan after the spat are collected, these are transported immediately for stocking. In Vietnam, this is not done because of the temperature and the presence of some fouling organisms. Spat are usually cleaned first of the fouling organisms and transported when the temperature is low.

3. Rearing seed oyster to marketable size

Three culture methods are practiced in Vietnam. These are the floating culture or raft culture method; rack culture; and bottom culture. After one or two months during the spat collection, the cultches are taken out and the main string is made longer than the original string used in collecting the spat. A small pipe is placed between two cultches.

The culture of oysters is dependent on the condition of the area. The culture environment is of utmost importance. It has been observed that after one or two culture months , the oyster may die if the culture area is not good.

4. Harvesting

Harvesting of oysters is usually from October to March. A major problem encountered in the oyster culture industry is the processing and sanitation of oysters .

III. Clam Culture

A. *Culture of ark shell*

The ark shell belongs to the Genus: Anadara, and the two most economical species are *Anadara broughtonii* and *Anadara granosa* which are found in the tidal waters of North Vietnam. Since the price of ark shell (*A. granosa*) has rapidly increased some years back, the area for its culture in the tidal waters of Quang Ninh-Thai Binh province, also increased. However, mollusc farming in Vietnam is still at an infant stage of development.

Clam and ark shell culture take place only in Quang Ninh, Thai Binh, Nam Dinh province of North Vietnam. An estimated 12,520 mt of ark shells are produced mainly in Kien Giang and Quang Ninh. On the whole, about 100,000 mt of fresh clams are processed annually for export. Starting in 1995 frozen clam meat was exported to Thailand, Singapore, and Japan, while cockles are exported to China.

1. Ark shell culture sites

Ark shell is one of the bivalves found in the tidal areas, specifically in the muddy bottom where salinity of the water is from 15 to 20‰. In waters where the salinity is lower than 5‰, the ark shell can die after some days of culture. The spawning season of the ark shell is from May to September at water temperature of 28-30°C

2. Seed collecting and culture seed

Collection of the natural seeds is done during the spawning season by setting spat collectors. The collecting method used is the same as those for scallops. Since the larvae of ark shell after setting fall to the bottom, the spat are then collected from the muddy bottom.

3. Culturing method

The most important factor in the culture of ark shell is choosing the most suitable culture site in the tidal area. The bottom of the culture area should be 70%-80% muddy and sand should only be 20-30%. The proper management of their growth is another important factor to be considered in the culture of marketable size ark shells.

IV. Culture of *Meretrix lusoria*

The clam species *Meretrix lusoria* and *M. meretrix* inhabit the clean sandy beaches of the shore in which the rivers flow. The site for the culture of this clam is therefore possible in the tidal areas where freshwater flows.

The spawning season of these clam species is from July to October. The production of the seed clams for this species in hatcheries has not been successful, so that the seeds are still collected from the wild. The culture method for this clam is the same as the culture of the ark shell.

MARINE FISH-MANGROVE AQUACULTURE

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I. Introduction

Aquaculture has often been blamed by environmental lobby groups as one of the main causes of mangrove destruction. In the Philippines, large areas of mangroves were converted through the years into fish and shrimp ponds.

There are aquaculture practices that can be done without destroying the existing mangroves. Mangrove-friendly aquaculture practices of different marine species such as extensive pond culture, culture of marine fish in a modified pond/pen system in mangrove, and cage culture of marine fish near mangrove areas are environment-friendly. These practices are described in this paper.

II. Species Selection

One of the first steps to consider in any aquaculture venture is the selection of species for culture. There should be a ready market for harvested fish either for local consumption or for export. The fish farmer should decide whether to culture a high volume and low price species or a low volume and high price species.

Some cultivable marine species are among the highest priced commodities. Depending on the species, the farm gate price of grouper species for example, varies from about US$ 8 for *Epinephelus coioides* to about US$ 40 per kg for *Cromileptis altiveles*. Other species such as siganids, red snapper, and sea bass are relatively cheaper than grouper (US$ 4-8/kg). Milkfish (*Chanos chanos*) is much cheaper than the other species mentioned (US$ 1-2/kg) but can be produced in large quantities and has a larger domestic market in the Philippines.

Another factor to be considered is the seeds for stocking which should be readily available. Although the seeds of cultivable species such as grouper and snappers abound in the wild, supply is mostly unreliable and highly seasonal.

At SEAFDEC Aquaculture Department, considerable progress has already been attained in the hatchery production of some high-value marine species such as siganid *Siganus guttatus* (Duray, 1998), mangrove red snapper *Lutjanus argentimaculatus* (Doi and Sighairaiwan, 1992), sea bass *Lates calcarifer* (Parazo et al., 1998), and grouper *Epinephelus coioides* (Duray et al., 1997; Toledo et al., 1996 and 1997). Milkfish fry on the other hand, has been routinely produced in hatcheries in the Philippines, Indonesia, and Taiwan.

The fish farmer should have a background on the biology of species to be cultured. Sea bass spawns in coastal areas near river mouths (Parazo et al., 1998).

Milkfish on the other hand, spawns in clear waters near coralline areas (Bagarinao. 1991). Spawned eggs develop, hatch, and newly-hatched larvae develops into juveniles in coastal areas. Juveniles move upstream in freshwater areas where they grow to more than 1.0 kg. Maturing sea bass and milkfish move downstream where final maturation and spawning take place. It is not yet known whether mature fish return upstream or stay in the sea to remature.

Groupers and snappers are known to spawn in aggregation near coralline areas (Polovina and Ralston, 1987). Spawned eggs and larvae move to coastal areas where the larvae develop to juvenile stage. Early juveniles of about 1 inch are caught using shelters made of twigs, bamboos, stones or their combination.

Species for culture should have a wide range of salinity tolerance. While milkfish and sea bass may be cultured in full fresh water, it is advisable to culture groupers, mangrove red snapper, and siganids in salinities higher than 15 ppt. Although some species of grouper, snapper and siganid can tolerate salinities of about 5 ppt, constant exposure of the fish to fluctuating salinities will be stressful.

III. Culture of Marine Fish in Modified Pond/Pen System

A. *Technical considerations*

1. Modified pond/pen culture

The modified fishpond/pen site for aqua-silviculture should be within the middle to lower end of the intertidal zone. Soil texture should be clay to clay loam to retain water during low tide and to have a good source of dike materials. Water source should be free from domestic and industrial pollution. Salinity for grouper, snapper, and siganids should be more than 15 ppt although they can tolerate salinities lower than 15 ppt.

The dike of the pond should have a height of at least 0.5 meter. Nets supported with bamboo slats are installed around the dikes with a height of at least 0.5 m higher than the highest high tide. A wooden or cement gate controls the inflow and outflow of water. Screen nets and bamboo slats are installed in the gate to prevent the entry of predators. Peripheral canals and connecting central canals are provided as shelters and for harvesting.

Extra care should be done in order not to damage the roots of mangroves when constructing the canals. Canals should not exceed 30% of the mangrove area.

Stocking of grouper, snapper, or siganids should not exceed 5,000 pc/ha. During the early culture period, fish may feed on natural food and prey on mysids, shrimps, and small fish. Feeding the fish daily with chopped trash may be carried out as the fish grows. Depending on the available food, fish may be harvested selectively after 6 months of culture. Survival at harvest should be from 20% to 65%.

2. Extensive pond culture

Fish production in this system utilizes existing large ponds of more than 1.0 ha per compartment. Since this is done extensively without or with limited supplemental feeding, organic wastes from this system may be readily absorbed by the environment. Before stocking, ponds are drained of water, and soil is dried until in cracks. Lime and chicken manure are then added at 1.0 mt and 0.5 mt/ha, respectively.

Commercial fertilizers may be added to enhance natural productivity of the pond. Predators are eliminated before stocking by applying tea seed powder or a combination of lime and ammonium sulfate at a ratio of 1 part lime to 2 parts ammonium sulfate.

Omnivorous fish such as milkfish and siganids may be stocked at a density of about 2,000 to 3,000 fingerlings/ha. Chicken manure or commercial fertilizers may be added between the culture period to maintain natural food production. Depending on food availability, harvesting can be done after 6 to 10 months of culture. Yield at harvest varies from about 600-800 kg for milkfish and 300-500 kg for siganid per crop.

In the extensive pond culture of carnivorous fish such as sea bass, grouper, or red snapper, the ponds are prepared as previously described. Adult tilapia of at least 10,000 individuals/ha are stocked one month before the stocking of the desired species. Once the tilapia reproduce in the ponds, sea bass, grouper, or red snapper may be stocked at a density of 3,000 individuals/ha. These carnivorous fish will prey on tilapia juveniles. Fertilizers are added if needed to maintain the natural food for tilapia.

Towards the end of the culture period, supplemental feeding of trash fish may be needed once the tilapia juveniles in the pond are almost consumed. Harvesting may be done after six months of culture. Survival of 40-85% and a yield of 700 to 1000 kg of carnivorous fish and about 100-300 kg of tilapia, can be attained using this system.

IV. Culture of Marine Fish in Floating Net Cages

A. *Introduction*

The culture of fish in cages is a century old practice. Cage culture started in China by using wooden box-like structures to grow freshwater fishes in rivers. It has evolved and developed over the years and is now an established industry for a variety of species such as salmon, yellow tail, and European sea bass.

Most if not all of the present cage culture systems are located in bays or lagoons protected from adverse weather conditions. Recently, cage culture in offshore areas using the latest technological advances has become popular. The deep waterways and rivers near mangrove areas offer similar conditions but these areas have not been fully utilized. This section describes a sustainable way of producing several species of marine fish near mangrove areas without destroying the existing mangroves.

B. *Technical Consideration*

1. Site selection

The site for a floating net cage farm should have a water depth of at least 3.0 m during the lowest low tide. Salinity should be from brackishwater to marine ($\geq$ 15 ppt). Although some marine fish species can tolerate a wide range of salinity, a site with a highly variable salinity should be avoided to minimize stress to the cultured species. The site should be free from domestic and industrial pollution, near the source of trash fish, and secured from poachers. It should also be readily accessible to the source of seeds and the market.

2. Species selection

Species cultured in floating net cages are usually those of low volume but high priced commodities. Groupers, mangrove red snapper, and sea bass are popularly cultured in this system because of their high market price. Seeds are available from the wild and hatchery production of the fry of these species have made considerable progress in the past decade. They can also tolerate a wide range of salinities.

Milkfish is presently cultured in floating net cages in the Philippines at high densities using intensive culture system. However, it has been reported intensive culture of milkfish in pens and cages in the Philippines have resulted in nutrient overload and plankton blooms in the surrounding waters.

3. Design and construction

A floating net cage is basically made of a raft, floats, and nets and is anchored. The raft is the frame or structure that supports the nets and the workers. It may be made of bamboo, lumber, G.I. pipes, or HDP (high density polyvinylchloride). The floats may be empty plastic or metal drums, styrofoam, wooden box, or HDP.

Nets in box or rectangular shapes are used to keep the culture species in place. Net material varies from nylon, polyethylene, polyester, or kuralon. Choice of the materials depends on the financial capability of the farmer. Bamboo frames, empty plastic drums, nylon or kuralon nets are widely used because they are relatively cheap.

C. *Operations and Management*

1. Nursery Phase

Grouper, sea bass, and red snapper fry of about one inch size should be reared in the nursery cages until they reach 3.0 inches. Size of nursery nets should be manageable for one or two persons. Sizes vary from 1x1, 1x2, or 2x2 m by 1.5 m deep with a mesh size of about 1-2 mm.

Initial stocking density is between 60-100 fry/m^3. Stocking should be done early in the morning or late in the afternoon. Fish should be fed to satiation 3 to 4 times daily. Natural food such as copepods, mysids, and small fishes may be attracted at night using a strong incandescent lamp positioned at the center of the nursery cages.

Since grouper, sea bass, red snapper are highly cannibalistic during the nursery phase, "size grading" should be done at least once a week. Fast growers should be taken out and transferred into separate cages during each grading. The fish may grow to 3.0 inches between 45 to 60 days with a survival rate of as high as 90%.

2. Production phase

The fishes are grown from fingerling to marketable size in the production net cages. These cages vary in shape (square, rectangle, circular) and size (from 2x2 m to 5x5 m) with mesh size between 0.5 to 2.0 inches depending on the size of the fish stocked. Although stocking density may be as high as 60 fish/m^3 the recommended sustainable density should not be more than 30 fish/m^3. Stocking should be done early in the morning or late in the afternoon when the weather is cool.

Fish should be fed daily following the sliding rule: initially at 10% then slowly reduce to 5% of the total fish biomass daily as the fish grow. To compute for the feeding rate, randomly sample and weigh 20-30 fish from each cage every two weeks, compute the average weight, multiply the average body weight with the total number of stocks in a cage (total biomass), then multiply with the feeding rate used.

Nets should be regularly cleaned to allow sufficient water inflow and outflow, and should be changed when excessive fouling is observed which hinders water flow. Nets should also be inspected regularly of any hole or damage to avoid the escape or loss of stocks. Drifting objects should be removed from the net in order to avoid possible damage. The conditions of the fish such as appetite, swimming behavior, and any sign of diseases should be monitored every day.

Selective harvesting may be done from four to six months after stocking the fingerlings when some of the stocks are more than 400g/fish. Stocks should not be fed a day before harvesting to empty the stomach. Since grouper, red snapper, and sea bass are usually sold live, harvesting should be done carefully to minimize stress and injury.

Harvested fish are temporarily held in conditioning tanks before packing where the water temperature is slowly reduced to 20°C within one hour. The temperature of the packing water should be similar with that of the conditioning water. Fish from the conditioning tanks are scooped individually, weighed, and transferred in packing bags.

Three to four fish (weight: 400-500g each) should be placed in double lined plastic bags with water depth just enough to cover the nostrils and eyes of the fish. The bags are inflated and sealed with rubber bands, and placed in plastic bags with sufficient ice to maintain low temperature during shipment.

V. Economic Consideration

A. *Assumptions*

1. Technical

   a. Nursery phase (8 units 2x2x1.5m)

i.	Stocking rate	- 600 ind/cage
ii.	Survival	- 70%
iii.	Culture period	- 2 months

   b. Production phase (4 units 4x4x2.5)

i.	Stocking rate	- 800 ind/cage
ii.	Survival	- 80 %
iii.	Culture period	- 8-10 months
iv.	No. of crops per year	- 1.5
v.	Total harvest	- 2,560 pc
vi.	ABW at harvest	- 500 g
vii.	FCR	- 4 kg
viii.	Selling price	- P250/kg

2. Financial

   a. Miscellaneous cost is 2% of variable cost.
   b. Caretaker's salary will be P1,000 per month.
   c. Interest rate on investment is 8% per year.
   d. Sales tax 1% of revenues.

B. *Cost estimates*

1. <u>Development Cost</u>

a. Cage frame and floats

i.	30 pc bamboos at P60/pc	- P 1,800
ii.	12 pc plastic drums at P1,000 each	- P 12,000
iii.	4 kg monofilament #180xP100	- P 400

b Nursery net

i.	1 roll 5 mm black net	- P 2,000
ii.	2 rolls 5 mm nylon rope at P200	- P 400

c Production net

i.	2 rolls 210D/32 kuralon net at P15,000	- P 30,000
ii.	5 rolls 5 mm nylon rope at P200 each	- P 1,000
iii.	5 spools 210D/32 kuralon twine at 200	- P 1,000

Total of development cost - P 48,600

2. <u>Operating cost</u>

a Variable Cost

i.	4800 pc grouper fry at P15 each	- P 72,000
ii.	5120 kg trash fish at P10/kg	- P 51,200
iii.	2 caretakers at P1,000/mo x 13 mo	- P 26,000
iv.	Miscellaneous cost	- P 2,984

Sub-total of variable cost - P152,184

b Fixed Cost

i.	Interest on investment	- P 3,888
ii.	Subtotal of fixed cost	- P 3,888

Total Operating Cost - P156,072

Total Investment - P204,672

3. Cost and return and partial budgeting analysis

a.	Sales: 2560 pc x 0.5 kg/pc x P250/kg	- P320,000
b.	Less: Operating Cost	- P156,072
c.	Net income before tax	- P163,928
d.	Net income after tax	- P162,288.72

Conversion Rate: 1 US $ = 38 Philippine Peso (P38)

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CULTURE TECHNOLOGIES FOR SOME ECONOMICALLY IMPORTANT SEAWEEDS

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I. Values of Seaweeds

Seaweeds consist of algae species that have monocular and multicellular structure, which are distributed from the brackishwater tidal areas to the remote seacoast areas. The uses of seaweeds include the following:

A. *Seaweeds as human food*

A number of seaweed species used as food include *Ulva, Monostroma, Caulerpa, Enteromorpha, Laminar, Porphyra, Hypnca, Gigartina, Cantenella, Gracilaria, Kappaphycus, Eucheuma,* etc. Seaweeds are also processed into instant foods such as salad, agar-agar, etc. Seaweeds are used as food in many countries, consuming approximately 454,730 mt of dry seaweeds (Mehugh, 1991). South Korea, Japan and China have the highest production of seaweeds in the world, and every year South Korea and China used over 200,000 mt of dry seaweeds as food.

B. *Seaweeds as food for domestic animals*

In many countries, seaweeds are also used as main food for animals. A large amount of food for animals is produced annually from seaweeds in America, Norway, and Denmark. In general, the nutritive value of seaweeds is good In fact, the food produced from seaweeds for animals, are known to prevent diseases in the domestic animals. The very common species of seaweeds used as food for hogs include *Gracilaria* and *Ceratophyllum.*

C. *Seaweeds as fertilizer*

Seaweeds are also good sources of fertilizer. Seaweeds fertilizer are known to promote the process of sprouting and assimilation, and also in making plants disease- and cold-resistant. In many coastal areas, *Sargassum* is used as fertilizers in sugar-cane fields, coffee plantation, tomato gardens, watermelon fields, etc.

D. *Seaweeds for phycocolloids*

There are three types of phycocolloids: agar, carrageenan and alginate. Colloids agar and carrageenan are extracted from red algae (*Rhodophyta*), while colloid alginate is from brown algae (*Phacophyta*).

Every year, about 900,000 mt (wet weight) seaweeds are used for processing phycocolloid in the world, accounting for 1/4 of the global production of harvested seaweeds (Luning, 1990). About 50,000 mt of phycocolloid are processed in the world (Richards-Rajadurai), of which the production of alginates is 22,000-25,000 mt/year, carrageenan 15,000 mt/year, and agar 7000 mt/year, respectively (James, 1990). All these phycocolloids, have utilizable values in the industries as foodstuffs, cosmetics, medicines, textile, agriculture and biotechnology.

II. Seaweeds Production in the World

In 1998, the production of economically important seaweeds in the world was about 4 million mt (fresh seaweeds), which has been maintained since 1983 (Richards-Rajadurai, 1990). According to Luning (1990), the total volume of dry seaweeds in the world was approximately 3 million t. According to the statistics from FAO, the production of red seaweeds of the world was 1,256,981 mt in 1992.

The following countries have the highest yields of red seaweeds in 1992:

South Korea	383,773 mt
Philippines	350,554 mt
Indonesia	188,218 mt
China	158,990 mt
Chile	69,145 mt

A. *Production and utilization of phycocolloids*

Alginate colloids are mainly processed in the U.S.A., Norway and France. Alginates have varied uses in industries, but their most important use is in textiles (50%) and foodstuffs (30%). Japan and Korea have the most requirements of alginates both for export and domestic utilization.

Carrageenan colloid is mainly processed from *Eucheuma* spp. which are cultured in the Philippines, Indonesia and recently, in Tanzania. The U.S.A. and some European countries have high requirements of this product. On the other hand, agar colloid is processed in Japan, Spain, Chile, China, and South Korea, with Japan having the biggest need of this product, which is about 2000 mt agar per year. The U.S.A. and EC countries need 1000 mt/year and 1300 mt/year, respectively.

III. Production of Seaweeds in Vietnam

Since 1995 (Anonymous), a study was carried out on *Gracilaria* and some various commercial seaweeds in Quang Binh. In 1929, Petelot recorded some production of *Gracilaria* at Cua Viet, Quang Tri. Before 1975, Luong Cong Kinh (1964) mentioned the results of the investigation on seaweed resources for processing to agar in the coastal provinces of South Vietnam.

In North Vietnam, the investigation of seaweed resources was given more attention by the government since 1960. The Research Institute of Marine Products was the first institution to investigate the seaweed resources of Vietnam. Results from the investigation recorded some 653 seaweed species in the coastal regions of Vietnam, of which about 90 are economically important, including the species *Gracilaria, Sargassum,* and *Hypnea.*

In recent years, *Gracilaria* has been exploited and cultivated in many coastal areas in Vietnam with a production of about 3000 mt/year (dry weight). Specifically, the species being exploited and cultured are *Gracilaria asiatica* Chang et Xia *(G. verrucosa* Hudss. Papenf*), G. tenuistipitata* Chang et Xia, *G. blodgetti* Harv.

Studies on biology, culture techniques and processing of seaweeds were given attention for nearly 30 years. Many researches were conducted at the national and branch levels, in accordance with the above objectives. The technological processes of *Gracilaria* cultivation with high productivity (2-4 dried mt/ha/year) and agar processing from *Gracilaria* have already been adopted in Vietnam. However, *G. asiatica* cultivation and agar processing are still developing in many provinces of Vietnam. Hundreds of mt of agar are used domestically in the country as well as for export every year.

Moreover, culture of the red algae was introduced to Vietnam only in 1993. *Kappaphycus alvarezii* (Doty), which comes from Philippines, has been tried for culture in the coastal regions of the country.

IV. Biological Characteristics of Seaweed

A. *Morphology and structure*

Seaweed is a thalliform vegetation, where all thalli have the same functions as the autophyte. Some seaweeds belonging to the order of brown algae (Fucales), have main thallus looks like higher plants, with "stem", "blade", "holdfast", air bladder, and reproductive bodies. But the blade, stem, and holdfast have no specific functions as in higher plants.

Seaweeds come in varied sizes, the monocellular structure are small sized, which could not be seen with a naked eye. But the genus of brown algae (*Laminaria*), is ≥ 10 m while the size of brown algae (*Macrocystis*) could reach 100 m. The structure of the seaweeds is from simple to complex. Red alga which is more developed than the other species (order of *Gelidiales*, *Gigartinales*), has inter-structure with divisions such as columnar cell, pinned columnar cell, histiomonocyte, adventitial cell.

B. *Growth of seaweeds*

The growth of seaweeds involves direct segmentation of the cells in the thallophyte, increasing the mass and size of the thallus. The growth of seaweeds depends on species medium, and culture conditions. If the ecological condition is good, some species can reach a maximum growth of 20-30% /day. The average growth is 5-8% /day.

C. *Reproduction of seaweeds*

Reproduction of seaweeds is vegetative, asexual, and sexual. The organ of asexual reproduction is sporangium and its offsprings are spores. For the sexual reproduction are the male and female gametophytes. Some of the evolved red algae has male gametophytes called spermatocyst and female gametophytes called carpospore.

V. Relationship Between the Environment and Seaweeds

The main marine ecological factors effecting the life histories of seaweeds include physical, chemical,and dynamic factors. There are also factors that relate to other organisms in the environment.

A. *Physical factors*

1. Bed form

The bed form is not significant to floating alga this is very important for the distribution and growth of the attached alga. For the higher plants, the substrate is a direct medium that supplies minerals, nutritive salt, and water. For seaweeds, the substrate's function is for the adhesion of spores and gametes to form new algal thalli. In the growth process, the thalli do not absorb nutrients from the substratum, but directly from the water medium.

The living medium of seaweeds in the littoral regions is normally the bottom such as gravel, reef, rock fragment, coral, sand, mud, and shells. Some seaweeds only grow on solid substrates such as rock bottom because of the molluscs which it can attach to. The adhesion of the spores in seaweeds is suitable for the rocky bottom because of its rough surface. The other seaweeds however, can grow on gravel bed with a sandy layer covering.

The most general character of seaweeds is their distribution being scattered on the reefs of the littoral regions with developmental haptera. Some species which are distributed in brackishwater ponds belong to the bottom living form which can hardly have a haptera structure. There are many seaweed species that directly settle by adhesion in the substrate.

B. *Temperature*

Temperature affects the life history of algae, especially their distribution, growth, and reproduction.

1. <u>Effect of temperature on distribution</u>

Kjellman and Sberkoj divided seaweed flora by temperature scale. These are from 0°C to 5°C which is known as the cold seaweed flora; from 5°C to 15°C (average 10°C) as the sub-cold seaweed flora; from 10°C to 20°C (average 15°C) as the sub-tropical seaweed flora, and about 25°C as the tropical seaweed flora.

Some eurythermal algae have a world-wide distribution such as the *Cladophora,* while some stenothermal algae, which are suitable for the cold climate are distributed in the cold sea regions such as: *Macrocystis, Laminaria, Jaonica, and Porphyra tenera.* Their size is big, the longest being *Macrocystis* which can reach 100 m, while *Laminaria* can grow upto 10-15 m.

The seaweeds in Vietnam belong to the sub-tropical and tropical seaweed flora. The tropical seaweed flora are becoming increasingly popular from the north to the south of the country.

2. <u>Influence of temperature on growth</u>

The growth of algae distributed in different geographical regions, depends on the suitable temperature. *Porphyra tenera* can grow well at the temperature ≈ 10°C, *Padina* in 20°C-25°C, *Gracilaria asiatica* in 25°C attained at 6-8%/day and at the limited temperature < 10°C and > 32°C, at 1-3%/day. Some green algae can grow within water temperature of 50-70°C.

When algae are distributed in the same region, the temperature obviously affects their growth. In north Vietnam, *G asiatica* can grow best at the end of spring and beginning of summer with seawater temperature of 20°C to 32°C.

3. <u>Influence of temperature on reproduction</u>

Temperature affects the reproduction of algae. *G. asiatica* in the north formed carposporangia, which often bursts in April until June every year. *Porphyra tenera,* distributed in China is the big species of *Porphyra* which can grow in low temperature and in winter. Paraspore can be formed within the temperature range of 17°C to 20°C in summer. The small *Porphyra tenera* can also survive in autumn temperature. The process of projection and adhering of spores in many algae also depends on the condition of the medium.

C. *Light*

Light also affects the vertical distribution of algae. The energical solar radiation has the smallest wavelength known as violet ray (380-430 millicrometer), while the largest is red ray (600-780 millicrometer). Infrared ray could not be seen with the naked eye, its biggest wavelength is from 780-340,000 millicrometer. The rays, which are light violet, green, blue, yellow, and red, can influence the photosynthesis of the algae.

The distribution depth of light could also be influenced by geography, turbidity, time of day, and silence of the water body. If the light has the smallest wavelength, the distribution is deeper. The red light is distributed at the surface, while the green, blue and yellow lights are distributed at the middle layer, and violet is distributed at the bottom layer. The distribution ability of light in the water bodies can reach the highest depth of 1700 m. If light is abundant, algae can grow fast.

1. Relationship between seaweed, light and depth

Green algae (*Chlorophyta*) are adaptable to red light and its distribution is at the surface. Brown algae (*Phacophyta*) has a lot of sub-pigment such as *Phycophein* and *Fucoxanthyl*, which are adaptable to orange and yellow light and their distribution is at the middle stratum.

Red algae (*Rhodophyta*) have sub-pigment such as *Phycoerythirin* and *Phycocyanin*, with light adaptation to green and blue, and their distribution is at the deepest water stratum, which can reach over 100 m depth. In sea tropical region, seawater is normally clear. The light intensity is wide so that seaweeds can distribute within 300 m depth.

However, a few algae are not distributed following the abovementioned rule. For example, *Caulerpa* spp. is adaptable to weak light and their distribution is at the deeper layer (the sub-littoral regions). Red algae (*Bostrychia*), are adaptable to strong light and their distribution is at the supralittoral area. The color of the algae is different so their pigmental elements are different too. The light which could not be absorbed by the algae, is reflected in the light color of the algae.

2. Effect of light on growth and reproduction

Different algae have different growth ability in the various lighting conditions, as shown in the following table.

Species	lighting time (morning/night)	Adaptable limited light to the growth
Gracillaria verrucosa	16/8	40-50 $W.m^{-2}$
G. chorda	14/10	25$W.m^{-2}$
G. tenuistipitata	16/8	340 $MEM^{-2}.S^{-1}$
G. edulis	16/8	4000 lux
Porphyra tenera	14/10	100-1000 lux

Light intensity is one of the most important factors influencing the growth of the spores. In the intensity from 100 to 1200 lux, filamentous alga (*Porphyra tenera*) can grow well. If the light intensity reduces from 6 to 16 lux, the algae will be light in color and the filament is also smaller.

VI. Chemical Factors

A. *Salinity*

1 Efect of salinity on distribution

The adaptation of algae with the changes in salinity varies. Approximately 90% of the species, belong to the family of brown and red algae distributed in the sea, while the green and blue algae species occupy only 10%. The green and blue algae are mainly distributed in brackishwater and freshwater areas.

The adaptation of seaweeds with the changes of wide salinity range is also varied. Alga is divided into two groups: euryhaline alga and stenosalinity alga. The euryhaline alga can exist and grow in the change condition of euryhaline waters. For example, *Cladophora* species can grow in freshwater as well as in brackishwater.

The stenosalinity group can grow and exist in limited salinity. The group of stenosalinity alga can be divided into those that are adaptive to high salinity and those that are adaptative to low salinity.

2. Effect of salinity on growth

Salinity influences the process of photosynthetic respiration thus, affecting the growth of the seaweeds. For example, *Laminaria japonica* grow well within the salinity range of 30-31‰ while *G. asiatica* can grow in salinity 16-25 ‰.

3. Effect of salinity on reproduction

The process of spore release, attachment and growth of seaweeds, are influenced directly by the salinity. For example, the specific weight suitable for the attached and projectile process of spores of *G. asiatica* is 1.010 - 1.015. The species is suitable for growth in salinity range of 15-22 ‰.

B. *Nutritive Salt*

The nutritive salt in the life history of seaweeds, is the mineral salt which comprises the N and P elements. The nutritive salt comprising Si is necessary for diatoms. In addition, some mineral elements needed for the growth of some seaweeds are Ca, K, Na, Mg, Bo, Co, Cu, etc. The mineral nutritive salts affect directly the growth and reproduction of seaweeds.

In general, the required mineral nutrient P/N/C in the ratio 1/10/100 is necessary for the growth of seaweeds. The suitable method of fertilization is affected by the following factors: culturing mass (productivity, estimated harvested production), time, nutrient requirements, environment, etc., as well as the estimated rational time and volume of fertilization.

C. *pH*

Seaweeds can grow and develop well within the medium range pH of 7.0 -8.5. Except for the *Dermarestia* species which can grow in low medium pH of 1-3. Even in alga, there are many species which can adapt to a wide range of pH.

D. *Dissolved oxygen*

The air in the water medium such as CO_2, O_2 , NO_2, NH_3, H_2S, CH_4 and those of the air medium such as CO_2, O_2 directly affect the photosynthetic and respiratory processes of the seaweeds. However the influence of CO_2, O_2 in the seawater medium is not very critical.

The medium in brackishwater ponds especially in aquaculture lagoons fertilized with NO_2, NH_3, H_2S, CH_4 can badly affect the cultured seaweeds and fishes. Based on this characteristics, some authors opined that fertilizing the seaweed culture ponds in high amount of fertilizer to make H_2S, NO_2, limits the growth of harmful seagrasses. Seaweeds can tolerate higher levels of H_2S, NO_2 than the tolerable level for harmful seagrasses.

VII. Dynamic Factors

Dynamic factors such as tide, sea current, wave, and wind, also affect the life of seaweeds. Specifically, the phenomena of high and low tide have a relationship with the vertical distribution of the seaweeds while the natural currents facilitate changing of the water needed in the growth processes of seaweeds.

Sea current, and high and low tide enhance the propagation ability of the reproductive media and increase the horizontal distribution of seaweeds. Wave and wind actions also affect the distribution of the attached algae, and influence the cultivating area as well as the culture structure, such as in floating methods and pond culture. However, some seaweeds are also cultivated in areas where there is no wave nor wind movements.

VIII. Factors Related to Organisms

Seaweed also serves as food for some marine fishes: i.e *Haliotis* eats *Gracilaria* and *Sargassum*. *Rapana* eats *Porphyra* while *Actinia* eats *Ulva, Ostrea* eats *Chlorella,* and *Chanos chanos* eats green alga.

Moreover, in some attached seaweeds, the spores release out maternal thallus and then adhere to shells or thalli of other algae. Thus some green alga attaches on *Hippopus,* while *Polysiphonia sertulariodes* attaches on the thalli of *Gracilaria* in brackishwater ponds and *Fucus* attaches on *Undaria.*

The competition in the medium of distribution, light, and nutritive salt between *Gracilaria* and some harmful seagrasses in brackishwater pond, is very clear. The growth of some blue algae can produce toxicogenic substance for the medium used in the culture of *Gracilaria* and also for the culture of shrimps, crab, and fishes.

IX. The Relationship Between Seeweeds and Biotic Community of Mangroves

The biotic community in brackishwater lagoon consists of plants such as seaweeds, seagrasses, timber-trees (mangroves, etc.), and animals such as fishes, crustaceans, molluscs, benthos, etc. There is therefore a distinct competition for nutrition and distributive medium between seaweeds with seagrass and timber trees. However, seaweeds serve as food for some fishes such as *Chanos chanos* and breams.

When shrimps are cultured in a closed system, seaweeds (*Gracilaria*) play an important part in making the pond water clean for the shrimps. *Gracilaria* cultivation in a shrimp closed system increases the possibility of the controlled environment to be disease-free. Consequently, the income from such cultivation system also increases.

X. Techniques of Seaweed Culture *(Gracilaria)*

A. *Importance and biological characteristic of* Gracilaria

1. <u>Economic significant of *Gracilaria*</u>

Gracilaria. which has high commercial value, is a good material for agar extraction. Agar is used widely in industrial fields such as in foodstuff, textile, printed fabrics, in medicine, agriculture, etc. *Gracilaria* is also a good source of agarose, a product similar to agar but of higher quality than agar. Moreover, *Phycoerythirin* pigment which can be extracted from *Gracilaria*, has a great significance in biotechnology. *Gracilaria* can also be used as food for hogs, and for the abalone *Haliotis*. About 25-30,000 mt of dry weight seaweeds are used to extract about 5000 mt of agar per year (Mclachlan and Bird, 1986). In recent years, the world market demand for seaweeds and their products has significantly increased. The agar production of the world has also increased, about 9,000 mt/year.

However, the volume of agar which the world needs, is higher than the harvested production. The countries which have have high production of seaweeds are Chile, Argentina, Japan, and China. While the countries which have high production of agar are Japan, Spain, Chile, South Korea, Portugal, Taiwan, and Argentina.

In Vietnam, the production of seaweeds through natural exploitation and culture is about 3000 mt/year. There are agar processing factories and small enterprises (normally, household scale) in Vietnam, where hundreds of tons of agar are processed every year mainly for domestic consumption. Seaweed cultivation and agar processing have socio-economic significance for Vietnam in terms of job opportunities and increased income especially to the farmers living near the coastal areas.

2. Taxonomy of *Gracilaria*

The genus *Gracilaria* belongs to the Family *Gracilariaceae*, Order *Gigartinales*, Class *Florideae*, and Phylum *Rhodophyta*. There are more than 150 species of *Gracilaria* in the world, of which about 20 species have been identified in Vietnam.

The most common species of *Gracilaria* which are being exploited and cultivated in Vietnam include *Gracilaria asiatica* Chang et Xia, *G. blodgettii* Harv., *G. tenuistipitata* Chang et Xia, and *G. heteroclada* Zhang et Xia.

3. Formation and structure

a. Formation

In general, the thalli of almost all species of *Gracilaria* are cylindrical and filariform. A few have thalli which are blade-shaped such as *G. textori* and *G. eucheumoidex*. The style of the apex is thamniun alternate or irregular and dichotomous. A few species have holdfast which is somewhat constricted such as in *G. cacallina* (J.Ag) Dawson. The color of the thallus is pinkish, light pink or brown-yellow and a little bit green, depending on the medium and growth stage of each species.

Thalli are erect and the base of the thallus has small discoid holdfasts. The holdfast is composed of a ramified "root-like" structure of haptera which is also solid. When thalli are attached to the adhesion, the haptera develops. In brackishwater ponds, *Gracilaria* grows in vegetative reproductive form, thus the haptera may or may not develop at all.

b. Structure

Thallus is divided into three portions of transection. The medulla part is a row of central cell and 4-5 rows of pericentral cell. This layer comprises thin, small cell walls without color and contains reserve substance. The inner layer consists of multi-angulous cells. The wall is thick with few pigments making it darker and in tight order.

The external layer consists of a lot of small, thick cell walls that are tightly ordered and pigmented. This layer is the main anabolic layer of the body. There are 4-6 rows of oval cells. The inner cells are bigger than the external ones. The size and number of medullary cells and the change of cells which form cortex to the medulla are used for species identification.

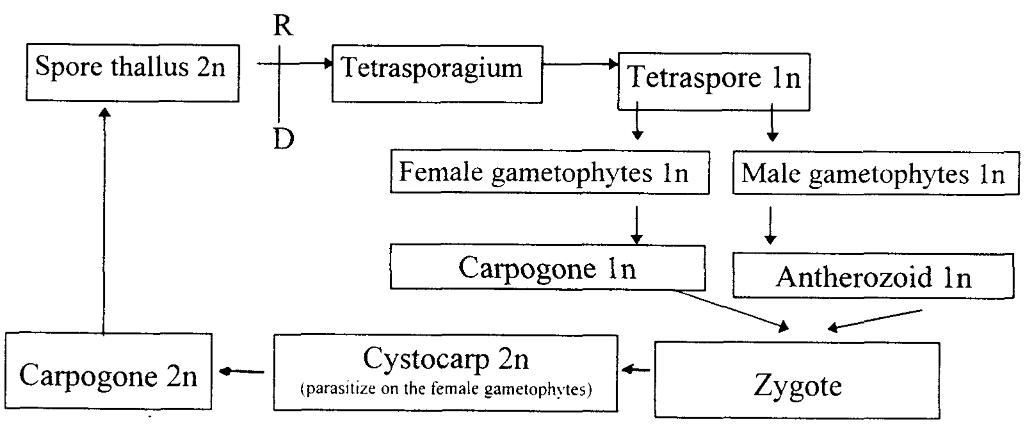
4. Reproduction

The life cycle of *Gracilaria* comprises three alternative stages: asexual, haploid, and diploid. In asexual reproduction, the cells have 2n chromosomes (diploid thallus) while in monoploid form (gametophyte) the cells have 1n chromosome. Diploid is a zygote, which has 2n chromosome and parasitic female gametothallus, and the gametophytes are the female and male thalli.

The male thalli produce small gametes (antherozoid) by cutting off the spermatangial cells from the surface cortical cells, producing antheridium, which has antherozoid. The female thallus produces carpogonial branches which have oogametes. The antherozoid and oogametes fertilize the zygote. The zygote develops into cytocarp which is a sphere coming out to the surface of the thalli.

Through the process of asexual reproduction, tetrasporagium is formed which divides into claviform or cruiciate form. One tetrasporagium has four spores. The process of sexual reproduction forms carposporagium by fertilization, which is a common form for some species of *Gracilaria*, growing in brackishwater areas.

5. Reproductive cycle of *Gracilaria*



6. Ecological characteristics of *Gracilaria*

a. Distribution

Geographically, the genus *Gracilaria* is widely distributed, especially in regions with a temperature range of 5°C-35°C. In the Asia Pacific region, production of *Gracilaria* is much higher than in other regions. *Gracilaria* is distributed from high tidal areas, but can also grow well at the middle of tidal areas.

b. Substratum

The attached population is suitable in areas with solid bottom such as rock, coral, shell, etc. On the other hand, the "free living" population is found in sandy-mud and muddy-sand bottoms.

c. Turbidity

Gracilaria can grow well in the ponds where the water is clear with limited light of 8 - 10,000 lux.

d. Temperature

Gracilaria can grow in warm weather, within the temperature range of 5-38°C. But its optimum growth can be obtained in areas with a temperature range of 20-25°C.

e. Salinity

Gracilaria can grow even in areas with the limited salinity of 3-25 ppt. However, optimum growth is obtained within the salinity range of 12-24 ppt.

f. pH

Gracilaria can grow rapidly in brackishwater ponds where the pH of the bottom substratum is less than 6.0 and water pH range is 7.5-8.5.

g. Fertilization

G. asiatica can grow well with supplementary fertilizer such as NaH_2PO_4, KH_2PO_4, KNO_3, NH_4NO_3, $(NH_4)_2SO_4$, urea, and manure from pig, chicken, cow, etc. The requirement for the nutrients NP is the ratio 6/1-10/1, and the use of NP depends on the culture density. The growth is suitable under certain ecological conditions such as cultivating time, temperature, etc. The mineral contents N=2-4mg/1 and P=0.2-0.4 mg/1 are suitable for the growth of *Gracilaria*.

h. Relation with community

The other plants in the community also influence the growth of *Gracilaria,* because they compete for the distributed medium, light, and nutrients. The more dangerous plants are some algae that attached on *Gracilaria* such as *Polysiphonis*, whose growth could cause rapid death of the *Gracilaria.*

Seaweeds are however, useful for the medium for mud crab, *P. monodon*, and tilapia culture. Seaweed makes water in the medium clean for the cultured aquatic animals.

i. Toxic elements in seaweed culture

The elements that make the medium of seaweed culture toxic are: H_2S, NO_2, AL^{+3}, Fe^{+3}, etc. These elements should therefore be avoided in the culture medium.

B. *Cultivation methods*

1. Monoculture

a. Site selection

Site selection is one of the important factors to be considered in seaweed culture. Infact, this could be the primary determining factor for the success or failure of any farming venture. The selected area should have a natural distribution of seaweeds.

If culture is to be done in an area where no support natural stock of the species exists, then this should not be selected even if it has comparable ecological conditions as the sites where natural stocks are found. The local geographical and sea conditions should also be considered and suitable measures should be taken accordingly (such as means of transport, social security, etc.). Specifically, the site must be protected from the direct effects of strong wave and wind; it must be near the sources of freshwater and seawater. The height of bottom pond must be placed in the best suitable position in order to promote early exchange of water during the local tidal regime. The best substratum is sandy-mud, but muddy or muddy-sand substrata could also be selected.

b. Ponds

The area of a pond may be equal or smaller than 1.0 ha, having a coffer-dam with gate (inlet) and drain (outlet) so that the flow of seawater can be controlled. The width of the gate should be 0.5 - 0.8 m, while the depth of the pond should be 0.6 -0.8 m. Bottom ponds should slope into the outletgate for water exchange. For this purpose, the seawater should first be drained and the ponds dried in the sun for days. The bottom pond should be ploughed and dried before manure is applied. Lime may be applied to improve the bottom pond and making it rich, but this depends on the pH of the bottom soil.

c. Method of cultivation

Before planting, the pond should be drained and dried for some days and then allow new water to enter the ponds. The best thalli are then selected as seedlings. Transport of the seedlings from the source to the pond should be carried out at dawn or when it is not sunny. If the distance of transporting the seedlings is far, water should be applied on the seedlings. Upon arrival at the site, seedlings should be immediately planted. Before planting, the thalli of seedlings must be cut into small portions by pruning them. These are then spread regularly on the bottom pond at a density of 500-600g/m^2.

d. Management

Changing water is very important for the growth of the seaweeds. It is therefore necessary to change water regularly according to the tide. The level of water in the pond should 30 - 40 cm deep. In summer, the water level in the pond may be increased to 60-80 cm. In winter, the level of water can be increased in order to limit the reducing temperature in the ponds. About 50-70% of water volume should be changed at each time, from 12-16 times/month since there are two tidal cycles in a month.

When there is no water exchange and a lot of harmful seaweeds appear, fertilizer maybe be applied, such as KNO_3, NH_4NO_3, $(NH_4)_2SO_4$, KH_2PO_4, NaH_2PO_4, urea, also organic and inorganic fertilizers. The dose of fertilizer depends on the growth and density but should take into consideration the content of nutritive salt at N=2-4 mg/l and P=0.2-0.4 mg/l which is very suitable for the growth of seaweeds.

Some species of green algae often grow in ponds such as *Cladophora, Chactomorpha, Enterromorpha, Polysiphonia,* and some weeds such as *Rupia, Myriophylum*, etc. Before planting, the ponds and lagoons should be cleared of the harmful seaweeds and weeds by ploughing and drying the bottom ponds and applying lime. Organic chemicals in high dosage to make H_2S and NO_2 in ordewr to get rid of the harmful weeds.

Seedlings should be selected carefully making sure that harmful seaweeds are eliminated. However, during the culture if harmful seaweeds appear, these should be taken out, and at the same time limit the inorganic matter by applying more water. If the harmful seaweeds grow well, the best measure is to improve the ponds and lagoons again, and replant with new seedlings.

e. Harvest and primary treatment

The first harvest can be carried out after a culture period of two months. Then after 20-40 days, a second harvest may be done, depending on the environmental conditions and culturing season. Boats, rake and some other simple equipment may be used to collect the seaweeds.

Harvested seaweeds should be washed with water from the pond to take out debris and mud. This will then be dried on bricks or cement ground or on the lawn. The dried seaweeds is tightly placed in plastic sacks and stored in a dry place.

2. Integrated seaweeds culture with shrimp, fish, crab

Seaweed culture can be combined with shrimp, fish, and crab in brackishwater ponds. A culture model from Taiwan integrates the culture of *P. monodon* and *Scylla serrata* in seaweed ponds. The volume of stocks for 1.0 ha is usually 400-5000 kg of seaweeds, 10,000 - 20,000 fry of shrimps and 500 - 10,000 fry of crab. The food of crab is fish waste and ground snail. After three months, crab may be harvested while shrimps will be harvested 4-7 months later. The rate of survival of crab is expected to be 80% while that of shrimps is 80-90%. This aquaculture model has attained the best harvest in Taiwan, where the profit has been reported to increase 2-3 times compared with monoculture.

In Vietnam, many ponds and lagoons used for shrimp, fish and crab culture, are also used for the integrated culture of seaweeds. For the inetgrated system, selecting ponds with the suitable environment for the growth of seaweeds should be the very first step. This is followed by the improvement of the pond by ploughing and supplementing with 1.0-1.5 mt of manure and 100-200 kg of NaH_2PO_4/ha. Then the best seaweed stocks are selected and spread at regular intervals on the pond bottom at a density of 200-300g/m^2. Water should be changed regularly according to the tide. When necessary, fertilizers may be supplemented on the harvest and cost, taking into consideration the mineral content of N=1 mg/l and P=0.1-0.3 mg/l, which is appropriate for the growth of seaweeds.

3. Seaweeds culture on the littoral areas

There are two forms of littoral areas: the first have high depth with high turbidity, where the bottom is rocky and sandy, and not too soft. During low tide, the bottom of the pond is not exposed.

The other type is with low depth and with low turbidity, so that as the tide rise, the depth of the water is 50-100 cm, and at low tide, the bottom is exposed. The bottom is muddysand making it convenient to put stakes. Two different methods of seaweeds culture can be applied in these two littoral forms.

a) Raft method

This method (Fig. 1) is used in deep areas where the water depth should be 50 cm at low tide. The turbidity is high, but the water movement is not too strong, that is, the water currents should be moderate near the estuaries in order to receive the nutrients.

Raft is constructed using bamboo frame 2x4 m with six empty plastic containers used as floats (30 cm in diameter). Anchors which are attached to the stakes, may be rocks or concrete. The distance from raft to the anchor depends on the water depth of the area. Bunches of the seedlings are attached to nylon lines, spaced at 30-40 cm intervals.

About 12-14 nylon lines are attached to stakes, which are set on the raft. The raft is 20-30 cm deep from the water surface. When the temperature is high, the depth of the raft may be ≥ 30 cm. This method can also be applied not only to plant seedlings but also for the seeds of the spores.

b. Rope farming

This method is used in areas with low depth or in lagoons which is over 1.0 m deep. Bunches of seedlings are tied to the nylon lines at 30 cm intervals. The lines are stretched tightly and the other ends attached firmly to the opposite stake in the next row. The line and the bottom should be parallel where the distance from the line to the bottom depends on the water depth. When tide is lowest, the lines of *Gracilaroid* should not be exposed to sunlight.

For this method, the lines should be tied in bamboo, wood or concrete. All stakes are firmly driven into the bottom making a 45-50° level. Rows are spaced at 50 cm interval and bunches of *Gracilariod* are tied to the stakes. After 2-2.5 months, the seaweeds can be harvested.

This method is more efficient because of the absence of competition for nutrient by seagrasses and harmful seaweeds. However, seaweeds culture using this method, should be managed properly to avoid losing the seaweeds by the wave and wind actions.

XI. Culture Technology of *Eucheuma, Kappaphycus*

A. *Economic Value*

The genera *Euchema* and *Kappaphycus* are two important carrageenophytes, which are abundant in the Philippines, tropical Asia and the Western Pacific region. More recently however, some species of red algae (*Acanthophora spicifera*) have been reported to contain certain lambda carrageenan which is not produced by either *Eucheuma* or *Kappaphycus*.

Eucheuma or *Kappaphycus* are at present the main base of the seaweed industry in the Philippines and Indonesia. The development of modern culture technology has increased the production tremendously in the Philippines to about 60,000 in 1987.

Lambda carrageenan, extracted from *Eucheuma* and *Kappaphycus*, is used in the industries such as in foodstuff, textile, print, cosmetics, pharmacy and agriculture. Statistical record indicated that the whole world uses about 15,000 mt of carrageenan annually.

B. *Classification*

The genera *Eucheuma* and *Kappaphycus* belong to the Family: *Solieriaccac,* Order: *Gigartinales,* Class: *Florideae, and* Phylum: *Rhodophyta.* There are about 24 species of this genus in the world, 6-7 species are found in the Philippines. In Vietnam, some species of this genus are the *E. okamurai, Kappaphycus alvarezii,* and *K. inorrme*

In 1993, *Kappaphycus alvarezii* (*Doty*) was transported from Japan to Central Vietnam, and has proven to have good potentials for culture. At present, *K. alvarezii* culture has been tried in some waters as Cat Ba Island (Hai Phong) and Van Don area (Quang Ninh).

Eucheuma alvarezii, Kappaphycus alvarezii and *E. denticulatus* are produced by floating and rope methods (rope is stretched tightly between two wooden stakes), in the Philippines and Indonesia. *Kappaphycus alvarezii* and *E. gelatinae* are also cultured in Hai Nam Island, China, and in several other Western Pacific island countries.

C. *Formation and structure*

The thalli of *Eucheuma* and *Kappaphycus* consist of cylindrical or compressed-terete and rameous. They are cartilagenous and may be prostrate or erect in structure. Except in *K. procrusteanum*, the whole thallus has thick and flatten blade.

Gametophytic and sporophytic thalli have also been reported. The color of the thalli is yellowish green or dark green. The inner structure of the thallus consists of rows of cells: the central and cortical cells. The sizes of above-mentioned species are different.

D. *Reproduction*

The life cycle of *Eucheuma* and *Kappaphycus* consists of three alternating somatic stages: asexual, haploid and diploid. The asexual form has 2n chromosome (diploid tetrasporophyte); the haploid form has 1n chromosome (tetraspores) with the terasporophyte and tetraspores have the same size and form; and the diploid form (carposporophyte) which is the zygote with 2n chromosome and is very small parasitic on the female gamethallus.

E. *Culture technology*

1. Site selection

In an attempt to expand the area for seaweeds farming, the first thing that should be done is careful site selection, unless farming of *Eucheuma* and *Kappaphycus* is already being carried out in the area. Reconaisance survey of the reef areas should be made to identify potential good localities. *Eucheuma* and *Kappaphycus* should be evaluated in terms of good growth rate.

Reef areas far from the freshwater sources are preferred because *Eucheuma* and *Kappaphycus* are stenohaline species and salinity below 30 ppt may have adverse effects on the plants. Areas with coarse, sandy to corally bottom substrata, moderate water currents are good sites.

Water movement in general favors the growth of the seaweeds by facilitating the rapid nutrient entry. It also prevents the extreme fluctuation of the other ecological factors such as temperature, salinity, pH, dissolved gases, which can adversely affect the growth of seaweeds. Areas with sand, coral reef, are also factors that support the culture system and reflect the existence of good water movement in the area. Substratum of fine sand or mud is not suitable as farming sites of the seaweeds.

Water depth at low tide is also an important factor because it influences the cost of farming. Areas of 0.6-1.0 m deep at the low tide are good and ideal because in very deep areas, it will be difficult to construct the cultivation system, making it more costly in terms of labour and materials. Sandy reef coral areas where *Eucheuma* and *Kappaphycus* are naturally distributed, are good potential sites for culturing the seaweeds.

After the site has been selected, test-planting should be carried out with the desired species. Test-plots consisting of a few monolines, each planted with 50-100 g of test plants are constructed at different locations in the area. Growth of the test plants is monitored at weekly intervals and their daily growth rates are determined. The area supporting the daily growth rates of 2-5 % or higher is a potentially good site.

A period of 2-4 months monitoring may be sufficient to begin a small family seaweed farm, and can be used as basis to construct a larger farm. In general, the areas where the yield increase is doubled within 15-39 days or less, are productive and suitable cultivation sites for *Eucheuma* and *Kappaphycus*.

2. Cultivation method

The development of a seaweed farm starts with the clearing of the site of seagrasses, harmful seaweeds, sea urchins, big rocks, and corals. Then the area is divided into small sections of 0.25 ha or smaller. Some common implements used are mangrove stakes, nylon monofilament line (>10 m), soft plastic material (for tying), large net bags, large rattan baskets, knife, hammer, bolo, etc.

a. Fixed, off-bottom monoline methods

This method (Fig. 2) is presently the most commonly practised in many countries because of its many advantages over the others. This net method is cheaper and easier to install and maintain. Stakes are driven deep into the substratum, spaced at 10 m intervals, in rows 1.0 m apart. The end of the nylon monofilament line (about 10.5 m long) is tied to one stake in the opposite row.

Selected *Eucheuma* or *Kappaphycus* cuttings (50-100 g) are tied to the monolines at 25-30 cm intervals, using soft plastic straw as tying material. The plants are allowed to grow to 1.0 kg or more before they are harvested. Depending on the growth rate, the crop may be harvested after 2-3 months. The whole plant would be harvested and replaced by new cuttings. This method can also be applied for the culture of *Eucheuma* and *Kappaphycus* in ponds with high water salinity.

The construction of the support system starts with digging holes in the substratum using a pointed iron bar (3-4 cm in diameter) and a sledge-hammer. Mangrove stakes with pointed head (60-80 cm long) are then firmly driven into the holes using the sledge-hammer. The wooden stakes are arranged in rows at 1.0 m intervals with distance of 10 m between the rows. A loop is made at the end of the monofilament line ($\geq$ 10 m long) and is attached to a stake then stretched tightly and its other end is attached firmly to the opposite stakes in the next row. The distance of the monofilament line from the ground is 0.3-0.5 m, depending on the depth of the water during low tide. Monolines may be positioned parallel or perpendicular to the direction of the current. In the areas where the current is relatively strong, the monolines are arranged parallel to the current and an extra stake placed midway between the original rows of stakes to provide additional support for the monoline. Site specific adjustment in the construction of the support system may be made to adapt to local conditions. One thousand lines (10 m long) will make one hectare of farm.

b. Floating method

In areas where space is limited and the fixed, off bottom monoline method is impossible to implement because of relative problems such as the existence of an animal community, diseases or changes in the degree of water movement brought about by typhoon, rain, etc., the floating method may be used. The advantages of this method include minimal or very limited grazing by bottom-associated animals; and the plants, being near the water column, are exposed to more moderate water movement caused by the waves. This method, however, is not recommended in sites exposed to strong wave action.

The same principles used in the fixed, off-bottom monoline method are employed. However, in this method, the cuttings are tied and attached to a raft system. Bamboo is used for constructing the floating structure or if wood is used as raft frame, floatation materials such as styrofoam or empty plastic boxes are used. In some areas, plastic bags filled with air are used as floats. The raft is anchored to the bottom by means of nylon lines. In order to maximize production per unit raft, good cuttings should be used. The distances between lines and cuttings attached to the monolines should be close enough.

The size of raft depends on the length of the frame materials. This method therefore maximizes the number of plants on a raft, while the adverse effects of intense sunlight near the surface of the water column is offset by the slightly crowded spacing of the plants.

On the other hand, long line floating raft may also be used where six nylon monofilament lines (10 m or longer) are attached to bamboos (2 m long) which are tied by nylon lines at 15 cm intervals. The four corners of the unit are anchored to wooden stakes. One hundred long lines can be accommodated in one-hectare farm. Recently, this method has been used in many areas where either the water current is weak or in protected areas, where water movement is mainly due to wave-action generated by wind. This method is also adapted in place where the water is deep and the bottom topography is very irregular.

The same principles applied to the fixed-off-bottom monoline method is used except that in the raft method the monolines are attached to the wooden frame (3x4 m) using bamboo as floats. A total of 15 lines 4.5 m long are spaced at 20 cm intervals and attached to the wooden frame. About 300-400 cuttings are planted on the rafts that are joined together and anchored to the bottom from the corner. Additional anchors may be used when necessary. A total of 100 rafts can be accommodated in one hectare farm.

In the floating method, 6 nylon monofilament line ($\geq$ 10 m) are attached to bamboo (2 m long), which are set at 5 m intervals. Monolines are attached 30 cm apart to the bamboo. Plants are tied to the monolines at 15 cm intervals.

3. Preparation of seedlings

Seedlings of selected species or variety are obtained from the nearest source, transported to the farm site in the shortest possible time and protected from direct exposure to sunlight, rain and wind. If the seedlings are in transit for a longer period, these should be occasionally soaked in clean water. In this case, the use of styrofoam boxes with holes in the upper sides to facilitate aeration, is the most efficient transport container. Seedlings should be drained of excess seawater before these are placed in covered boxes, and must be placed in seawater immediately upon arrival at the farm site. The cuttings (the volume of each cutting is from 50-100 g) are tied at 20-25 cm intervals to the monolines (Fig. 3).

The maintenance and management of the farm are facilitated by planting on a per unit area basis, that is one farm unit (0.25 - 0.125 ha), should be planted before proceeding to the next one. The plants are ready to be harvested when they are about 1.0 kg or bigger. The time required to grow *Eucheuma* and *Kappaphycus* to harvestable size vary, depending on the growth rate of the plants, as affected by site-specific ecological conditions. In good farming areas, the seaweeds may be harvested after 6-8 weeks.

4. Maintenance of the farm

The management of seaweed farms comprises weeding-out of poorly growing plants, repairing the support system, replacing lost plants, and removing benthic grazers and other species of seaweeds which grow in close association with *Eucheuma* and *Kappaphycus* as epiphytes or on the monofilament lines and stakes. The epiphytes compete with *Eucheuma* and *Kappaphycus* for nutrients, light, space and also add to the "drag" on line in areas with a strong current which result in breakage and loss of the plants.

Maintenance is a necessary component of farming that may also significantly influence production. In areas characterized by strong currents, a retaining fence made of nylon net (approximately 10 cm mesh size) should be constructed on the leeward side of the farm to catch the thalli that may be washed out by the current.

5. Harvesting

When the thalli of *Eucheuma* and *Kappaphycus* have grown to reach the desired size and volume, they should be harvested and replaced by new cuttings (≈100g) for the next cropping, using the best plants from the harvest are used for this purpose. This practice has replaced the pruning method, where the plants were pruned during harvest to approximately 100 g to serve as the seed for the next crop. This practice was found to be inefficient since branches left behind are the old portions of the thalli that grew slowly. In addition, the tying materials used usually last for only one growing season.

6. Drying of the produce

Drying is an important post-harvest activity that affects the quality of the product. The harvested crop is first cleaned of foreign materials such a old tying materials, weeds, attached animals, etc. and then spread on drying bamboo platforms under the sun to dry. The platforms may also be braided nylon nets. The product is regularly turned over to ensure complete sun drying. The drying crop must be protected from rain, so that before the onset of rain, the crop is piled into heaps by pulling the lining net to one side of the platform, then covered by a water proof sheet. During hot, sunny weather, the material may be dried for 2 or 3 days. Dry *Eucheuma/Kappaphycus* should not contain more than 40% moisture. The dried material is tightly packed in plastic sacks and stored in dry places.

Eucheuma/Kappaphycus are exported in four forms: as dried raw seaweed, as alkali-treated chip, as semi-processed powder, and as pure carrageenan. The semi-processed product is preferred by big processors of pure carrageenan and by users in the food and canning industry.

XII. Culture Technology of *Caulerpa*

1. *Economic value*

The genus *Caulerpa* is a common component of seaweed communities in tropical and subtropical waters. Some species of this genus are utilized as food such as salad and some food uses such as those of the green alga. *Caulerpa lentillifera* is big sized, succulent, with soft thallus and of high quality, which is widely collected and used in the Philippines. At present, there are over 400 ha of ponds utilized in the cultivation of *C. lentillifera* in the Philippines.

Since 1986, *C. lentillifera* has been cultured using the cage method in Okinawa, Japan. In recent years, the requirement for the use *C. lentilliferra* has increased rapidly. The cost of 1.0 kg *Caulerpa* is 28-30 pesos in Philippine markets.

B. *Classification*

The genus *Caulerpa Lanx, 1809* belongs to the Family: *Caulerpaceae Grev, 1930,* Order *Siphonales (Endl) Blockm et Tansl.*, Class: *Chlorophyta Kuetz,* and Phylum: *Chlorophyta* (green algae). Some species of *Caulerpa* are cultured in Vietnam such as: *C. pelltata, C. racemosa, C. verticillata, C. ashmedii, C. taxifolia, C. scalpelliformis, C. racemosa var corynophora Vietnamensis.*

C. *Form and structure of thalli*

The thallus is decumbent, cylindrical, and ramiform. The under-face of the thallus has holdfasts, which attached to rocks or into the sand and mud. Some erect branches grow from the upper-surface, they are cylindrical, stripe or compressed-terete. Some species have ramified "grape-like" branches.

The erect branches may be ramified ramuli or not, or they may be stalks or not. In the sinus of the stem, there are many cross strings from the cell walls. The size of the pigment is small and is not pyrenoid. In cortical cell, Xelluloza, which is inside of the cell cortex is replaced by Callosa with cytoplast.

D. *Reproduction*

The reproductive form of *Caulerpa* is mainly vegetative. One new cutting from old thallus can develop into a new plant. If vegetative reproduction does not occur, the thalli of *Caulerpa* will become gametes that are flagellate cells, or heterogamia in last blades by sexual reproduction.

The gamete escapes into the water through fuced-like hemispherical lumps that develop in the surface of the erect blades, sometimes in the apex of the prostare blades. Then they combine with zygote, which attach into the zygote segment and germinate to new thallus.

E. *Technology of cultivation*

1. Culture in ponds and open lagoons

Caulerpa lentillifera is cultivated in ponds and open lagoons in the Philippines (Trono and Ganzon-Fortes 1988, Trono, 1990). The aquaculture of *Caulerpa* consists of major activities, such as site selection, pond construction, planting, management and fertilization of the ponds, and post-harvest activities.

a. Selection of farm-size

Successful farming of *Caulerpa* depends partly on the location of the farm. The important factors tó be considered in the evaluation of the potential areas for cultivation include: proximity to a source of unpolluted seawater supply; the site must be far from freshwater sources such as rivers, creeks etc.; the level of the pond bottom should be at or just a little above the low-tide level; the site must be protected from the direct effects of wind-driven waves that can easily erode and destroy the dikes; and the substratum must be muddy-loam. Soft bottom or muddy substrata should be avoided. Ponds which were once used for fish culture and are being abandoned or has become inefficient, may be selected for *Caulerpa* cultivation.

b. Pond Construction

The maintenance of good water quality, achieved through proper pond management, depends on the appropriate design and construction of the ponds. The pond should be divided into 0.5 -1.0 ha area with two gates for supplying and draining seawater, respectively. The gates are arranged appropriately to change water easily. A canal system, which is suitable to supply and drain water easily in dry and rainy seasons, surrounds the pond.

c. Seaweed cultivation

The ponds are first drained of water to a depth of 30 m to facilitate planting. The initial stocking rate should be 100g/m^2 or 1000 kg/ha. The seedstock is planted on the pond bottom uniformly by burying a handful of seedstock at approximately one-meter interval. Another method is to scatter the seedlings from boats, but this not suitable because *Caulerpa* maybe washed out by the waves and will result in poor growth.

After planting, the depth of the water in the ponds should be adjusted to about 50-80 m. Flooding should be done slowly so that newly planted seedstock is not uprooted by the water currents.

d. Management of the pond

Water management in the pond is one of the key factors in the successful culture of *Caulerpa*. Ideally the pond water must be changed at least every other day to maintain adequate level of nutrients thus ensuring good growth and development of the plants.

In the *Caulerpa* culture ponds, usually some weeds and harmful seaweeds grow, which compete with *Caulerpa* for the medium, space and nutrients and badly affecting the growth of *Caulerpa*. Weeds and seagrasses should therefore be cleared by hand or by means of bamboo rakes. The dike system, bank pond, and sluice-gate system should be checked and repaired regularly to avoid breaking and eroding the pond.

The light green or slightly yellow color of *Caulerpa* means that it is growing slowly. Fertilizer may therefore, be added at 1.0 kg per ha (nitrogen). On the other hand, inorganic manure (urea or NH4)2SO4) if applied, should be dissolved first before scattering it in the pond.

e. Culture in lagoons

The following conditions should be taken into consideration, when culturing *Caulerpa* in the lagoons: water depth of 0.3 - 0.5 m at the low tide; seawater coming in and out easily; substratum is clay-mud; protected from strong wind and waves; and less weeds and harmful seaweeds.

Lagoons should be cleaned before cultivation. The cuttings of *Caulerpa* (30-50 cm) are cultivated in the bottom at uniform intervals. When *Caulerpa* is of high quality and glossy, it can be harvested but leaving some seedlings for the next crop.

f. Harvesting of the crop

Depending on the growth rate, the crop may be harvested after two months when seaweed dense in the pond bottom is green, glossy, succulent, and of high quality. The next harvest will be after 2 weeks. *Caulerpa* is usually harvested by hand when about 20-25% mass is observed in the pond. The seaweed is washed and then transferred into floating barrels or boats. Then the *Caulerpa* is washed again, classified and packed. At this stage, it can already be used as vegetable salad.

2. Cage Method

Cage culture method of *Caulerpa* is practiced in some warm areas in Yonaha Gulf, Miyako, Okinawa, Japan. The shape of the cage is cylindrical with some segments. The cuttings of *Caulerpa* (10 cm long) are tied into the bottom segments. Then, the cage is put into the sea where the current is moderate, and waves are not too strong. The cage should be cleaned regularly.

In the rainy season, the salinity at the surface layer should be lower than the depth layer. In this case, the cage should be put lower, about 50 cm from the surface water. Salinity suitable for growth of *Caulerpa* is approximately 25 ppt. *Caulerpa* can be harvested after one month if the growth is good. Harvesting makes use of knife to cut the thalli. Portions are left behind to serve as future plants.

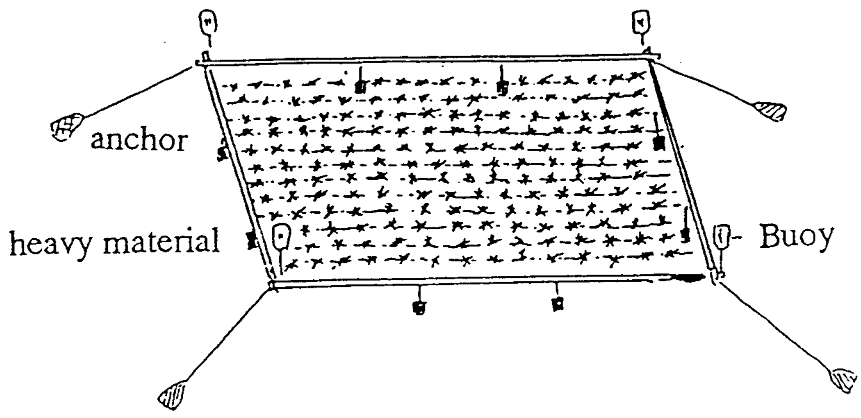


Figure 1. Raft method

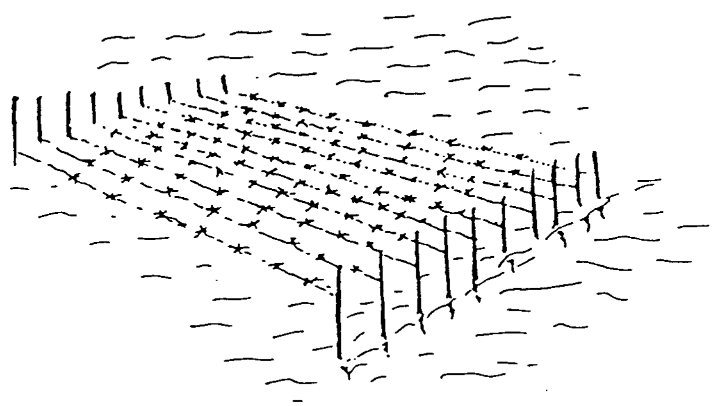


Figure 2. Fixed, off-bottom monoline method

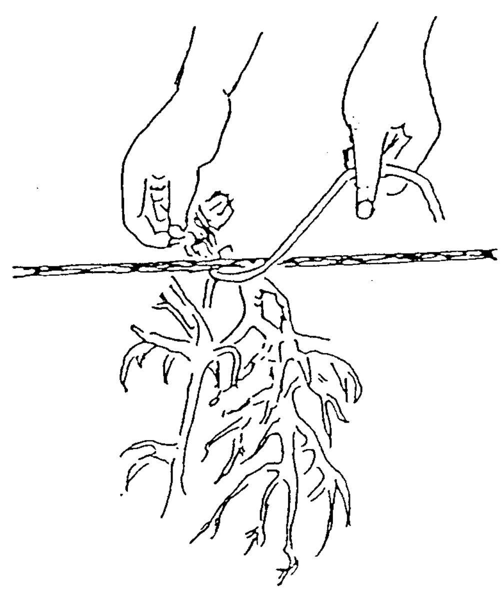


Figure 3. Tie cuttings of Eucheuma/ Kappaphycus

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REFERENCE PAPER

MANGROVE-AQUACULTURE TECHNOLOGY: PHILIPPINE EXPERIENCE

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I. Introduction

The importance of the mangrove ecosystems in the Philippines has been recognized only during the past years when the mangrove resources were almost at the edge of total destruction. Conversion of mangrove areas to various land uses like fishponds, agricultural, commercial, and housing sites were very rampant, such that out of the 450,000 ha of mangrove forests in 1920 (Brown and Fishes, 1920), only 141,713 ha were in existence in 1988 (Swedish Spare Corporation, SPOT Satellite images, 1988).

Efforts to save the remaining mangrove forests have been a concern of various government agencies and private organizations. Laws were promulgated, but enforcement has been a problem because of the urgent need for livelihood and survival of the foreshore communities associated with mangrove areas.

Cognizant of the dependence of the coastal fisherfolk on the mangrove forest products, the government started to focus its attention on a new approach of integrating the mangrove resource with management and livelihood. Thus, the mangrove-aquaculture was conceived as a good strategy.

This paper presents the history of one of the earliest mangrove-aquaculture projects in the Philippines which started in 1986. The site is part of the Bureau of Fisheries and Aquatic Resources (BFAR) Fish Farm for milkfish production in Son-oc, Poblacion, Ubay, Bohol, central Philippines.

Mangrove seedlings were planted in an area at a ratio of 80%-20%, mangrove to fish culture area. The project proved that mangroves and fish could live and grow in a harmonious relationship.

The project area now serves as a free entry for wild fishes so that fish production of no less than one-half ton yearly has been recorded in an area of over 2.0 ha. Fishes caught are usually grouper, snapper, tarpons, barracuda, siganids, tilapia, mullets, caravalle, slipmouth, whiting, scats, goby, sea bass, shrimps and blue crabs.

The mangrove-aquaculture project in Ubay, Bohol which has been successful, could be easily adapted by the fisherfolk living in coastal areas where mangroves can be grown. The forest products and fishery resources obtained from such activity could contribute to the sustenance of coastal communities.

II. The Project Site

The technology of mangrove-aquaculture was adapted by then Regional Director Fernando Bernardino of the Department of Agriculture Regional Office, Cebu City in 1987 after coming back from a cross-country visit to Indonesia. Upon his return to the Philippines, he decided to adapt the technology in a site which he appropriately selected, the Ubay Brackishwater Demonstration Fish Farm in Son-oc, Poblacion, Ubay, Bohol, in Central Visayas (Fig. 1).

The said project site was actually established in the mid 1980s as a demonstration farm for milkfish production under the Fisheries Regional Office No. VII, Cebu City of BFAR. In 1987, when BFAR was made a Staff Bureau, the administration of the project was turned over to the Department of Agriculture Regional Office No. VII, Cebu City.

The project site covers an area of 16 ha of which 10.24 ha are fully developed and productive. The strategic location of the area where mangrove trees are abundant, served as basis for the selection of the site.

The project then served a dual purpose: as a demonstration farm for milkfish production and as a site for mangrove-aquaculture study. Hence, the farm area was divided into: aqua-silvi pond (4.94 ha); open ponds (4.22 ha); experimental pond (1.0 ha); and infrastructure (0.08 ha) as shown in Fig. 2.

III. Developmental Scheme

The developmental scheme was started in 1987 when mangrove propagules were planted in rows inside the 4.94 ha intended as aqua-silvi pond (2.625 ha as MP#4 and 2.315 ha as RP2 and MP2 fishponds), taking into consideration the sufficient spaces between the dikes and the newly planted trees. About 20% of the pond area was utilized for fish culture, while 80% was planted to mangrove.

During the first five years of the project (1987-1993), the area was stocked with milkfish fingerlings at the rate of 1000-3000 pc/ha. No feed was given, but production was observed to be as much as 1.0 mt/ha/yr. Now that the trees are on its 15th year, still no harvest of mangrove trees has been done. Fully grown trees at the center of the fishpond now reached about 20,000.

In the spaces between the dikes and the trees, aquaculture is undertaken. At present however, the area is no longer stocked with milkfish fingerlings. It is now used as a free-entry area for various marine fish species coming from the sea through the main water supply canal.

In order to maintain ample spaces between the trees, regular thinning or removal of small old branches at the lower portion of the trees is undertaken every three months. This is done to avoid the overcrowding of trees and total shading of the pond bottom which could lead to anaerobic condition in the pond area.

Planting mangrove trees inside the fishponds along the periphery of the main dikes of the different pond compartments used for milkfish production was also done. The trees not only prevent dike erosion, but also make the soil compact and firm.

Likewise, along the outside portion of main dike and water supply canal, fully grown mangrove trees are also luxuriantly growing. Other benefits derived from mangrove trees could be the fertilizing effect of liters or fallen leaves that decay outside and inside the ponds. This provides organic fertilizer to the pond water enhancing the growth of natural food.

Noting the beneficial impact of the mangrove trees in the project, another pond compartment (1.6 ha) was planted with mangrove trees in 1995 with 20:80 percent ratio (20% pond space and 80% planted to mangrove). The trees are now five years old, and the area is used to grow milkfish fingerlings to marketable sizes. Figure 2 shows the pond compartments where mangrove-aquaculture is presently undertaken.

IV. Fish Production

Fish production in the mangrove-aquaculture ponds may not be much, but this consisted of several species of high commercial value fish. Although, no actual recording was made, reports seemed to indicate that about 500 kg of fish were recovered in 1998 from the 2.265 ha pond compartment. The fish were caught near the gate of the main water canal at the entrance of the pond.

The harvest consisted of siganids, tilapia, groupers, shrimps, mullets, barracudas, caravalle, slipmouth, whiting, milkfish, ten pounder, tarpons, scats, goby, snappers and sea bass. Crustaceans consisted of blue crabs and shrimps. Shellfish like oysters, clams and snails were also collected. The fishes collected were big, some weighing over 1.0 kg each (grouper barracuda, snapper, etc.).

V. Other Observations

The project area also serves as a refuge/sanctuary for marine aquatic fishes as well as wild birds and ducks which are observed in the area everyday usually in the morning. Birds usually found only in the forests, could now be seen in the mangrove trees.

The luxuriant growth of mangrove trees within the fishpond area and those along the main water supply canal and the areas between the creek and the fishpond proper indicate a harmonious co-existence of aquaculture and silvi-culture if properly managed. Benefits can therefore be derived from mangrove-forests products as well as fisheries from the aquaculture area.

VI. Problems Encountered

1. Fish monitoring and harvesting

The presence of mangrove roots and watered depressions in the mangrove forests inside the pond area could pose a problem in assessing the fish stocks. Likewise, recording the total fish harvest also became a problem particularly for groupers. The fish usually seek refuge in the roots of the trees or bury in the mud when the water has receded. During harvest, the fish becomes weak and sometimes dead, affecting the marketing of the fish, since live grouper are still preferred by customers.

2. Death of mangrove trees

Some species of mangroves are not resistant to prolong submersion of its aerial roots. This led to the high mortality of the mangrove trees.

3. Thick growth of filamentous algae

Mangrove-aquaculture ponds are usually observed to have overgrowth of filamentous green algae, covering the entire pond surface. Such condition is not very favorable to fish stock as it leads to oxygen depletion at night and oftentimes resulting to fish kill due to asphyxiation.

VII. Comments and Recommendations

1. Mangrove-aquaculture technology could increase the income of the fisherfolk from forest products and also from fish production. The technology will therefore, serve as a livelihood and also in promoting biodiversity conservation.

2. In ponds, polyculture should be practiced where herbivorous species like milkfish and tilapia should be stocked first. Carnivorous species can be added when the herbivores are already big enough to escape the predators. This will result to bigger fish at harvest because predation could be minimized.

3. Species selection of mangrove trees to be planted should be considered. Mangrove species with aerial roots that could resist prolong submersion in water, like the *Rhizophora* should be selected.

4. Water management is very important in mangrove-aquaculture systems. Canals maintained at appropriate water depth is necessary for the fish culture. Appropriate design should be taken into consideration to provide the needs of both resources..

5. Fish production in mangrove-aquaculture may be low compared to other fish production systems. However, since inputs are kept low and stocking is kept at a minimum or barely nothing as in the case of free-entry of species, fish production can reach 300-500 kg/ha/cropping. This is still profitable considering that production sustainability is attained and harmonious relationship with the environment is maintained.

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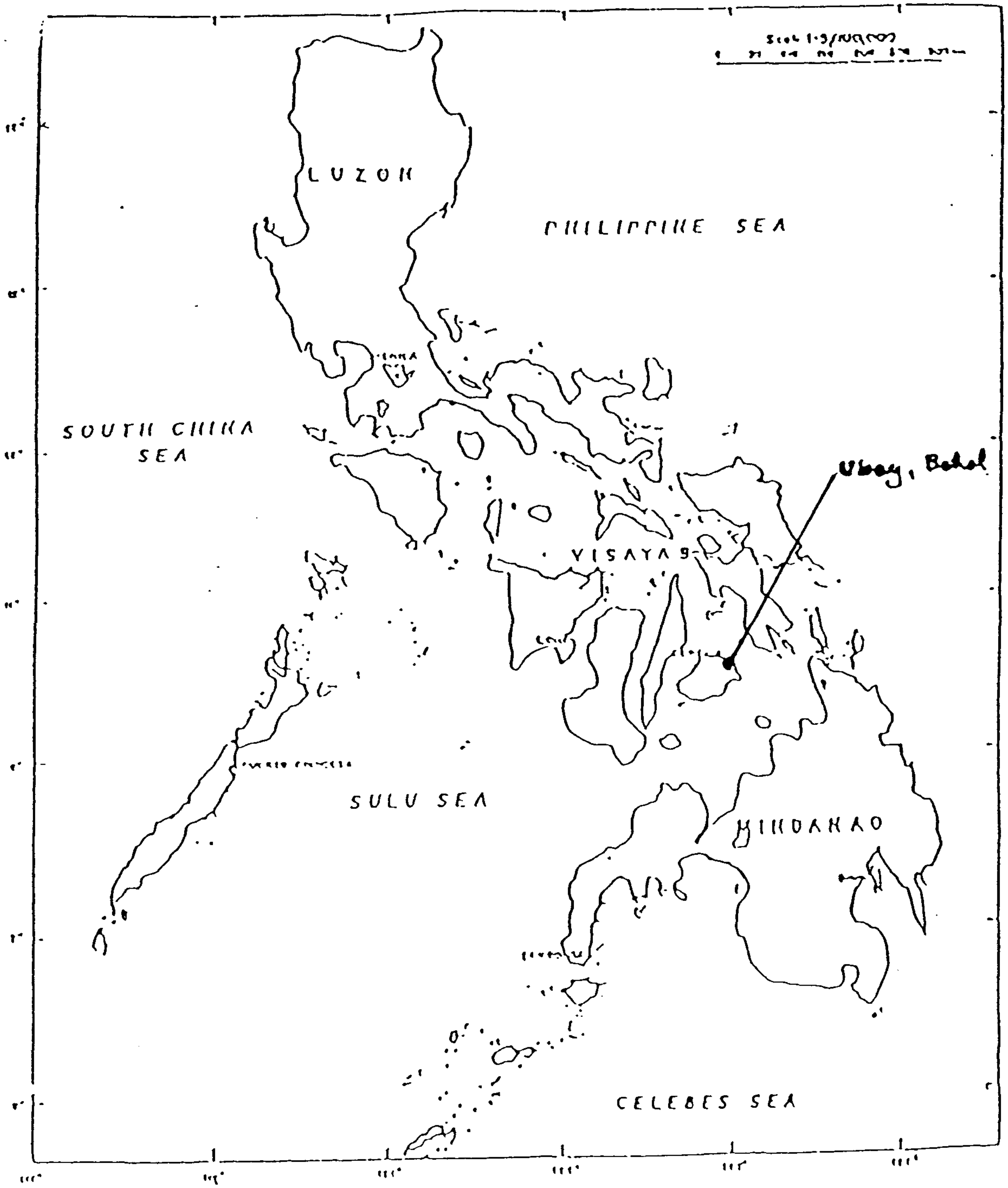


Fig. 1. Map of the Philippines

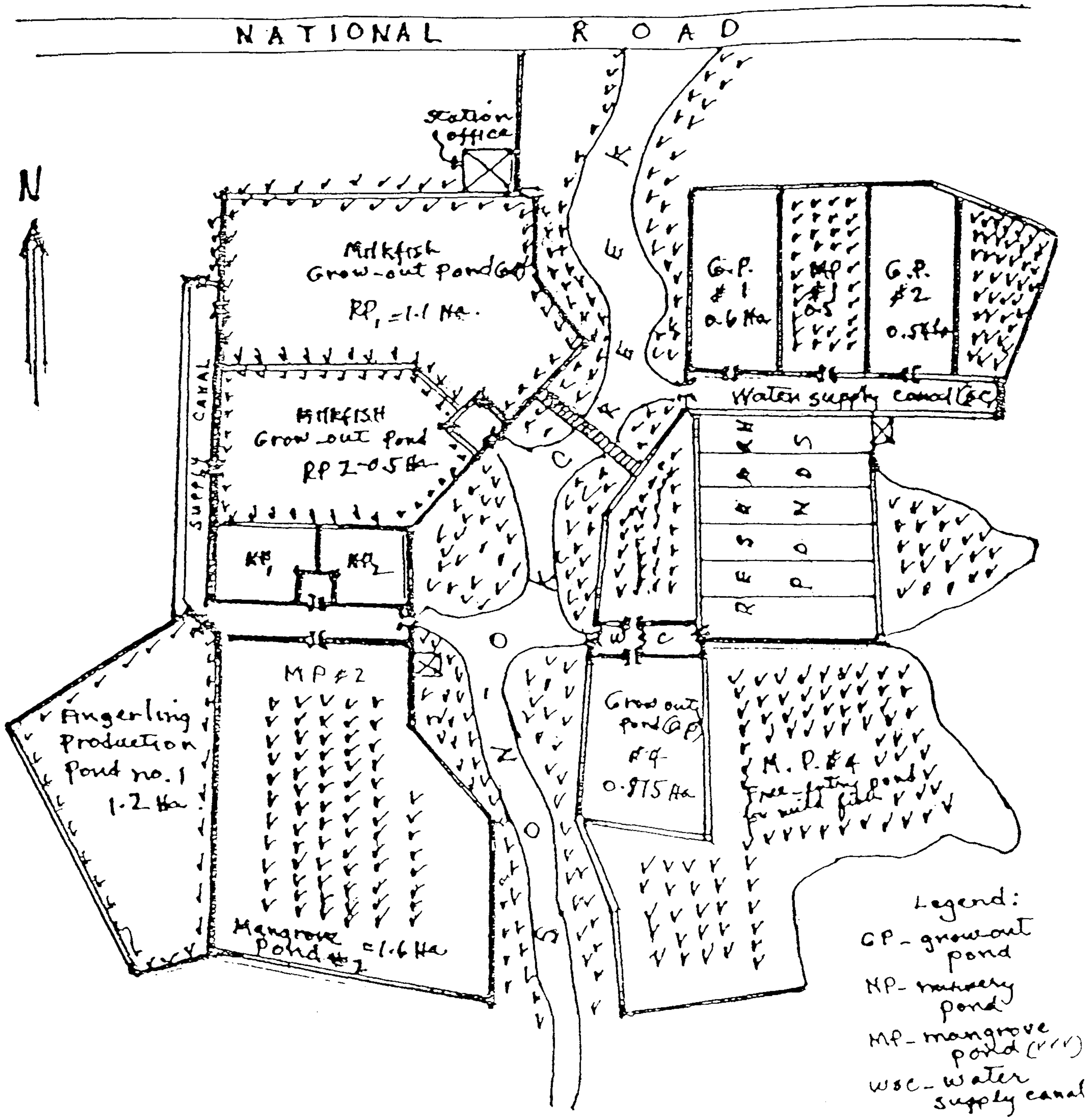


Fig. 2. Diagrammatic layout of Ubay Brackishwater Demonstration Farm, Son-oc, Poblacion, Ubay, Bohol, the Philippines

THE FIELD TRIPS

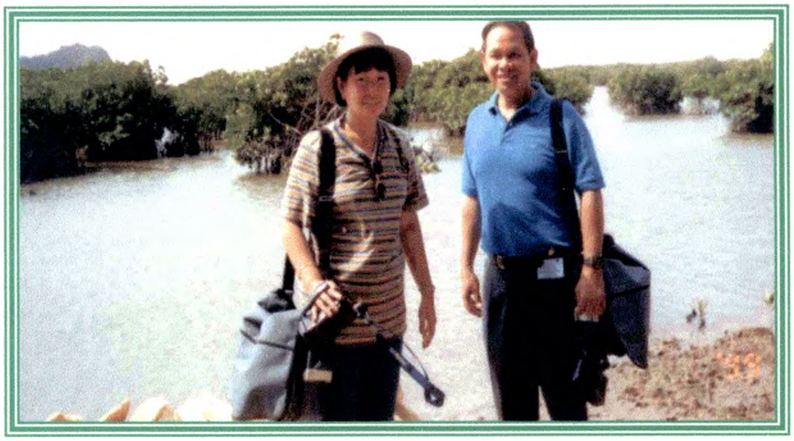
Field Trips Itineraries

Field Trip to Cat Hai District and Cat Ba Island
24 April 1999

0530	-	Breakfast at Sunflower Village
0600	-	Depart from Sunflower Village to Passenger Port at Ben Binh
0630	-	Depart for Cat Hai District by Boat
0800	-	Arrive Cat Hai
		Proceed to Phu Long by Boat
0820	-	Arrive Phu Long
		Visit mangroves
0840	-	Visit Thien Long Cave
0930	-	Leave for Cat Ba by Car
		Visit Cat Ba National Park
1100	-	Arrive Cat Ba Town
		Visit Fishing Port, Cat Ba Island
1200	-	Lunch at Restaurant in Cat Ba
1300	-	Visit RIMP's Mariculture Station
		Visit Eastern Part of Ha Long Bay
1500	-	Return to Cat Ba Town
1530	-	Get on the Express Boat at Cat Ba Town
1600	-	Return to Hai Phong by Express Boat from Cat Ba
1700	-	Arrive Hai Phong and Back to Sunflower Village

Field Trip to Research Institute of Aquaculture for Brackish and Salt Water
29 April 1999

0800	-	Departure from Sunflower Village
0830	-	Visit Research Institute of Aquaculture
0900	-	Visit Trung Dung Aquaculture Farm
		Visit Do Son Aquaculture Farm
1000	-	Visit Fish Landing Place and Do Son Beach Resort
1100	-	Return to Sunflower Village



Field trips: Phu Long mangrove area in Cat Hai District (*top photo*), Do Son Aqua Farm, near Hai Phong (*middle photo*), and RIMP's Mariculture Station, near Ha Long Bay, Cat Ba Island (*lower photo*).

THE GROUP PRESENTATION

SUMMARY OF GROUP PRESENTATION

Part of the activities of the participants in the On-Site Training was the preparation and presentation of strategies and recommendations for the development of mangrove-friendly aquaculture projects. In order to maximize coordination, the participants were grouped into four, namely, Group I (Northern Vietnam), Group II (Central Vietnam), and Group III (Southern Vietnam, and Group IV (Cambodia). Through this geographical groupings, it was expected that the participants could easily apply the knowledge they learned during the On-Site Training.

The attention of the participants were specifically drawn to the various major topics delivered during the lecture sessions, such as the ecology of mangroves, wise use technologies and different farming systems for variety of species, aquasilviculture, and the legal and institutional framework affecting the utilization of mangroves. The background information which the participants were asked to provide during the early part of the training included present status of resources, technology, socio-economic management, and policies/institutional framework in the management of mangroves and aquaculture development. This was first presented by each group. Then followed by the presentation of problems and constraints in the implementation of mangrove-friendly activities in their respective areas. Lastly, each group presented recommendations for the formulation of mangrove-friendly projects as well as for the preservation and rehabilitation of mangroves.

While the background information presentation by each group varied, similar problems and constraints were noted. Among the problems were sharp decrease of mangrove areas due to conversion to shrimp, fish or salt ponds; high population growth and poverty in coastal communities; lack of education of most of the people in coastal communities and lack of awareness on the role of mangroves in the ecology of the coastal areas; and mangrove trees are continuously utilized as firewood, charcoal, or building materials.

Moreover, conflicting and overlapping policies from different government agencies regarding mangrove conservation, were mentioned. Land tenure given is too short for the farmers to recover investments. Laws are formulated by the governments without proper consultation with the stakeholders. In addition, appropriate technology for sustainable aquaculture are not available to most farmers. These interconnecting problems often lead the stakeholders to chaos.

The participants from Vietnam also gave the following recommendations:

1. Direct management of mangrove areas should be given to district and local levels;

2. Mangrove areas which will be used for aquaculture should apply mangrove-friendly aquaculture practices with 70% for mangrove and 30% for the modified or semi-intensive culture methods;

3. Survey all mangrove areas given to fishfarmers. Non-productive areas should be returned to the government for replanting or rehabilitation;

4. Improve the productivity of existing ponds through transfer of sustainable aquaculture technologies;

5. Educate coastal communities on the ecology of mangroves and their importance in the coastal environment. Information campaign be conducted to all fishfarmers on the importance of mangrove-friendly aquaculture particularly shrimp culture in the mangroves;

6. Organize community and strengthen institutions and provide them information on the proper utilization of mangroves;

7. Seek financial support from the national government and international institutions for the implementation of mangrove-friendly aquaculture projects; and

8. Strict implementation of laws and regulations concerning mangrove protection and utilization.

On the other hand, the participants from Cambodia presented a Project Development Plan on Mangrove-Friendly Aquaculture with the following objectives:

1. To conserve coastal resources of Cambodia;

2. To promote sustainable aquaculture; and

3. To improve the living standard of the coastal communities.

The action plan for such development plan, includes:

1. Development of human resources to promote mangrove-friendly aquaculture;

2. Enforcement of existing laws;

3. Replanting and rehabilitation of mangrove areas;

4. Community building for environmental awareness;

5. Transfer of sustainable technologies to increase productivity of existing ponds;

6. Establishment of demonstration farms for mangrove-friendly aquaculture; and

7. promulgation of laws concerning mangrove-friendly aquaculture.

The participants from Cambodia added that although national laws such as the Environment Law and Law on Fishery and Management, were approved respectively in 1986 and 1987, these laws are not adequate.

The interaction during the training revealed similarities on the present state of mangrove areas as well as the problems and constraints in the formulation and implementation of mangrove-friendly aquaculture activities. After returning to their respective assignments, it is hoped that the participants are more equipped to prepare recommendations and undertake mangrove-friendly aquaculture operations.

Summary of Group Report Presentation

Group I: Northern Vietnam

Quang Nanh, in North Vietnam, has great potentials in terms of mangrove resources. The following recommendations were made as means to protect and develop mangrove-friendly and sustainable aquaculture in this area:

The Government and state should have some regulations and law on the division for direct management of the mangrove resources. This should be done as soon as possible as this will hopefully protect the mangrove forests. The division of authority should be given to the district levels. It will be the responsibility of the local levels to directly manage the resources by giving certain area of mangroves to each household.

The land area handed to each household will be used for culture, and shall have dike and gate. The technology of mangrove-friendly using the ratio 70% mangroves with 30% surface area for aquaculture applying modified extensive and semi-intensive, will be implemented. The main target species are: shrimps, crabs, fish and seaweeds. The culture shall make use of seeds from the wild and some from hatcheries.

In addition, a survey should be made in order to consider the mangrove forests that were earlier given to the fishfarmers. Those areas that have been deserted or not efficient should be given back to the government and replanted as a natural mangrove forest.

Lastly, the mangroves as well as the surface water should be given to the fish farmers, who shall be allowed to invest and manage their areas. They will be made to realize the importance of mangrove protection and the idea of keeping the balance of the ecosystem.

Summary of Group Report Presentation

Group II: Central Vietnam

The following culture systems will be employed in brackishwater pond and lagoons, specifically the Tam Giang Lagoon:

1. Shrimp culture using modified extensive and semi-intensive method;

2. Shrimp culture using less water change method and making use of seaweeds and cockles as biofilters to maintain clean water; and

3. Mangrove replantation outside the dike to protect the pond and maintain the balance of the ecosystem in the pond.

For bays and embankments with high salinity, net cage culture should be implemented. Species for culture shall include sea bass, red snapper, and lobster, as well as molluscs such as pearl oyster, scallop.

In other areas, the production of *P. monodon* with high quality should be intensified. The broodstock may be obtained from managed ponds, and artificial insemination in broodstock development. may be used

Generally, the existing mangrove areas may be maintained while the destroyed areas will be replanted. Educating the communities on mangrove and ecology should be intensified. The use of advance technologies for improved aquaculture should also be promoted.

The government should seek technical and financial aid to help improve the aquaculture systems in the country. One of the most urgent projects is the production of good quality *P. monodon* fry in order to support the aquaculture development plan of the country.

Summary of Group Report Presentation

Group III: Southern Vietnam

The following general recommendations were made in order to promote the conservation and protection of the mangrove areas in Southern Vietnam:

1. Fish farmers should be mobilized and made to understand the significance of mangrove-friendly aquaculture, especially the culture of shrimps in the mangroves;

2. The mangrove-friendly aquaculture projects should have financial support from the government and the state;

3. There should be regulations and laws on mangrove conservation, which should be strictly followed;

4. There should be a clear mechanism and management system; and

5. The promotion of new technology transfer for fisheries production should be intensified, with technical and financial assistance from the government and international organizations, because the local levels do not have sufficient resources to do this.

The Group also submitted a proposed plan on the replanting of mangroves in four areas located in southern Vietnam. These are the mangrove areas with existing fisheries activity; the protected zones where there are no fisheries activity; in the outer zones where mangrove-friendly aquaculture using the ratio 70%:30% can be applied; and the aqua zone where intensive culture may be employed.

The methodology may include: technology transfer; education of people on the conservation of mangroves; intensification of mangrove-friendly aquaculture; and collection of baseline data for financing purposes.

Group Report Presentation

Group IV: Cambodia

I. Background Information of the Project Site

Resources

1. Socio-economic attribute of the community

In general, the coastal communities in Cambodia are involved in marine fisheries including fishing, processing, gathering, and marketing. Some people are engaged in coastal aquaculture and some poor people are involved in mangrove cutting for charcoal production. At present, most fishing vessels exploit the inshore fisheries rather than the off-shore. Most of the marine fisheries production come from Koh Kong Province and are exported to Thailand while a small amount of fish production is used for local consumption.

2. Biophysical characteristics of the mangrove and land-based resources

The mangrove forest of Cambodia is located along the coastline, estuary, streams, and in some parts of the coastal region. The large area with dense forest is located in Koh Kong Province. According to the information from the Land Cover Map published by the Mekong River Commission and FAO/UNDP (1992-1993), mangrove areas in Cambodia cover an area of 85,100 ha of which 63,700 ha are in Koh Kong Province, 13,500 in Sihanouk Ville and 7,900 ha in Kampot Province. The mangrove flora of Cambodia belong to 35 families, 53 general and 74 species, of which *Rhizophora mucronata* and *R. apiculata* are significantly important.

Technology

1. Aquaculture practices in the area

Coastal aquaculture in Cambodia is nearly not an activity for development. At present, most of coastal aquaculture activities are small-scale farming (extensive culture). It was only from 1991 to 1995 that intensive shrimp farms were established in Koh Kong Province.

Shrimp farming in Cambodia can be classified into two different culture methods, namely, intensive and traditional extensive shrimp farming. The intensive shrimp farming were patterned after Thailand and the species cultured is the tiger shrimp, *Penaeus monodon*. The traditional extensive farming rely on natural seeds and natural feeds. However, intensive shrimp farming in Cambodia was not successful due to lack of technical know how and experience. Many of the shrimp intensive farms have been abandoned.

For fish culture, small-scale culture is maintained in cages and in abandoned shrimp farms. The species cultured are grouper, red snapper, and grey mullet. On the other hand, mollusc culture is not very attractive in Cambodia due to market constraint. However, green mussel is cultured and used for supplementary feeds in shrimp farms.

2. Status of mangrove-friendly aquaculture technology

Coastal aquaculture is implemented in abandoned shrimp ponds for fish as well as small-scale fish cage culture. Small-scale culture of green mussel is also practiced in the estuaries near the mangrove areas.

Socio-economic Management

At present, Cambodia is implementing a free market economy. Most of the economic activities in the coastal area belong to the private sector, including coastal and marine fishing, fishery processing, fish production marketing, and coastal aquaculture. The mangrove area on the other hand, is controlled by the government through the Department of Fisheries and the Ministry of Environment.

Policies and Institutional Framework

1. Fishery Law

The law on fishery management and administration passed in 1987, defines fishery and the categories of fishing areas. Permits for fisheries exploitation and aquaculture are determined by such regulation. Specifically, the law indicated that fishing exploitation and aquaculture in marine fishery domain in Cambodia can take place on the contingency provided that permission is acquired except for small-scale. Aquaculture with a total area of more than 0.5 ha in the coastal area should get the necessary permit to operate from the Department of Fisheries.

2. Environment Law

The important items related to the environmental management of coastal resources of Cambodia, based on the Environmental Law, are as follows:

a. Conduct of an Environmental Impact Assessment (EIA) for all investment projects and economic activities that may have an impact on the environment; and

b. Sustainable conservation, development, management, and use of natural resources.

Problems and Constraints

The following problems and constraints seem to hinder the development of mangrove-friendly aquaculture in Cambodia:

a. Illegal mangrove cutting for charcoal production, firewood, and construction materials;

b. Mangrove areas have been cut to give way to the establishment of shrimp farms and salt farms;

c. Mangrove lands are claimed as owned properties;

d. Lack of human resources to manage coastal aquaculture, and lack of technical know-how and experience;

e. There is an overlapping of management of the mangrove areas;

f. Market is a major constraint coupled with land use property problem;

g. The national policy for fisheries, environmental management, and conservation of natural resources are not focused specifically on the coastal zone. Hence, there is neither a coastal zone policy nor an integrated coastal zone management policy.

Potentials and Opportunities

Cambodia has a good mangrove area along the coast line. Most of these areas are suitable for mangrove-friendly aquaculture. Most of the fishing activities are small-scale, hence, there is no heavy destruction on the resources in the coastal as well as in the mangrove areas.

II. Proposed Project Development Plan (Mangrove-Friendly Aquaculture)

Objectives

1. To conserve the coastal resources of Cambodia;
2. To develop its coastal resources sustainably; and
3. To improve the standard of living of people in the coastal areas of Cambodia.

Methodology

1. Human resources development

Training of the government officials from the village to the provincial levels, on the management of the coastal zone to ensure its sustainable development.

2. Promotion of development law

Encourage the participation of the local communities in the formulation and development of any law so that they will understand the law better, and once adopted the law could belong to the communities.

3. Strengthening of law enforcement

Development of procedures, guidelines or other circulations in order to guide the local communities on the implementation of any law. This way, the communities will understand and can participate better in the implementation of the law.

4. Technology transfer

Conduct of actual farm demonstrations, training on mangrove-friendly aquaculture, and field visits.

5. Mangrove replantation

Development of a program on mangrove replantation and rehabilitation.

Conclusion and Recommendations

1. A campaign to improve the public awareness and understanding on the value of the coastal resources should be undertaken as soon as possible;

2. Local communities should be encouraged to form their own organizations with an objective of making their own clear vision about the sustainable development and utilization of the coastal resources;

3. Capacity building and institutional strengthening should be highly considered;

4. Resources conservation initiatives and rehabilitation projects related to coastal and marine environment management and development should be adequately supported;

5. Empowerment of the coastal communities for the conservation and management of the mangroves, and also co-management with the government; and

6. Development of a program on mangrove replantation in the coastal areas especially where massive mangrove destruction has already taken place.

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SUMMARY OF GENERAL INFORMATION

Group I. Northern Vietnam

A. Resources

- About 531 km coastline, 14 estuaries/river mouths, near the border between Vietnam and China, and also the Northern Red River delta.
- About 96,000 ha coastal area; 27,000 ha tidal flats; 42,500 ha ponds
- About 156 aquatic species, including: grouper, sea bass, *Mugil cephalus*, black finfish, *Penaeus merguiensis*, *P. orientalis*, etc., molluscs such as cockles, seaweeds such as *Gracilaria*, crabs, oysters, etc.
- Coastal areas are polluted, diminished, and exhausted to some degree but still rich in aquatic species although these are also diminishing.
- About 150 - 16,000 ha have recently been replanted with mangrove trees per Program 327 on Reforestation. Mangrove species are reduced due to over-exploitation, although some areas have been newly planted and have newly recovered. At present about 40-80% mangroves are utilized, while 20-60% are unutilized.

B. Technology

- Present (small-scale): extensive (200 ha/family); improved extensive; semi-intensive (3,000-10,000 m^2/pond; intensive shrimp culture near the Red River using water exchange system
- Present (large-scale): improved or advance extensive (400 ha/family), extensive (10%), and semi-intensive.
- Marine aquaculture: with dike, about 29,000 ha cultured with shrimp, seaweeds, fish; without dike, over 1,000 ha cultured with clams and pearls
- Extensive method production: 50-70 kg/ha to 100-150 kg/ha

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- Advance Extensive: seed input: 0.5 - 1.0 ind/in^2; production: 150-200 kg/ha

- Semi-intensive: inputs: 5 ind/in^2 PL_{45}; trash fish pellet; 105-120 days culture; production: 150-300 kg/ha/crop

- Intensive: 5 pcs/in^2, mollusc/trash fish, 5 months culture, production: 300-500 kg/ha/crop

- Clam culture: about 2,800 ha, 800 household, 2-3 ha/household. Annual production: 27,000 tons, 13-15 month culture period

- Species cultured: shrimps (tiger and *P. merguiensis*), crab, fish (grouper, sea bass, *Boshtrichthys sinensis*), seaweeds, tilapia, oysters, clams

- Coastal fisheries: traditional method of fishing using bamboo traps, number of boats decreasing

- Mangrove-friendly aquaculture development projects: Project 327 on Reforestation; projects on shrimp-crab-fish culture in accordance with the provision of the 1998 Fishery Export Program.

C. Socio-Economics

- Settlement area: communities are far from the mangroves; some communities are inside the national dike; and some are in coastal areas in the southeast portion of the Red River delta

- Major occupation: aquaculture, fishing, textile making, rice farming, salt producing, agriculture, research and technology transfer

- Minor occupation: fishery service, post-harvest, and feed processing

- Aquaculture has generated about 15 million VN Dong; while agriculture about 9 million VN Dong

- Clam farming has resulted in good living standards of the farmers, created job opportunities, and resulted in good infrastructures such as roads, schools, etc.

- Available facilities: schools/universities, fisheries/aquaculture training centers, cooperatives, credit system, transportation system, electricity system, water supply system

D. Policies

- National policies:
  (1) Technical assistance to farmers
  (2) Promotion and development of aquaculture
  (3) Handing of land to fishermen
  (4) Permit to invest in intensive aquaculture
  (5) Protection and rehabilitation of mangroves
  (6) National and provincial governments collaborate with other organizations within and outside the country
  (7) Application of the Program 327 on Reforestation
  (8) Policy on tenurial rights (land use by households and communities)

- Local policies
  (1) Bank loan with low interest for aquaculture development
  (2) Permit to use land and water surface for aquaculture
  (3) Plan to improve aquaculture industry by applying the technologies developed at Research Institute of Aquaculture (RIA) I, RIA II, and RIMP, with area of about 500 ha.
  (4) Recovery and rehabilitation of mangrove areas
  (5) Enforcement of ban on deforestation
  (6) Permit to promote and develop silvofisheries
  (7) Policy on reforestation and protection of marine resources
  (8) Limit on the period of land use for aquaculture
  (9) Promotion of coastal aquaculture
  (10) Plan of local authority to reforest mangrove areas near the national dike
  (11) Promotion of long-term land use (tenurial rights) with short-term contracts

E. Problems and Constraints

- On mangrove conservation and development
  (1) Environmental pollution and over-exploitation
  (2) Deforested and non-reforested coastal and aquaculture areas
  (3) Lack of awareness among people to protect the environment and resources, also resulting in over-harvesting and cutting of mangroves without permit
  (4) Habit of local people to cut mangroves for firewood

- On aquaculture practices
  (1) Absence of suitable farming system
  (2) Low fish yield from aquaculture because of application of low technology
  (3) Absence of suitable plan and lack of funds for aquaculture development

(4) Lack of seeds for culture, persistent environmental pollution, and low aquaculture technology
(5) Absence of institutional inputs regarding aquaculture development
(6) For fast development of aquaculture, more than 3,000 ha of mangroves were cut, thus reducing the natural fish seed resources
(7) Ratio between aquaculture and mangroves is not balance
(8) Lack of technical know-how on aquaculture

- On socio-economic management
  (1) Short-term loans from banks have high interest rates
  (2) Shortage of technical manpower including managers
  (3) Funds from government not concentrated
  (4) Lack of incentives for fishermen to produce more
  (5) Post-harvest technology still low, that some big production can not be sold
  (6) Local authority are not very much aware of suitable exploitation and the sustainability of mangroves
  (7) Absence of an organization for the management and protection of mangroves
  (8) Lack of capital and knowledge on the part of the local people regarding marketing of products

- On policies/institutional framework
  (1) No clear policy on people or communities on who should work for the protection and conservation program
  (2) Absence of policy to encourage households to avail of loans and grants for mangrove development
  (3) Lack of investment for mangrove development
  (4) Lack of awareness on conservation, on the part of farmers who still cut and destroy mangroves for shrimp aquaculture farms
  (5) No policy on tenurial rights
  (6) Absence of policy on mangrove program and the promotion of mangrove-friendly aquaculture, in particular and mangrove management, in general
  (7) Absence of plan to reconstruct canal system for aquaculture development

F. Potentials and Opportunities for Mangrove-Friendly Aquaculture

(1) Availability of human resources and land area of more than 2,700 ha for aquaculture of which only about 2,000 ha has been utilized
(2) Existence of abandoned estuaries which could be developed for aquaculture
(3) Presence of cold storage and post-harvest facilities
(4) Presence of few hatchery farms and few policies on aquaculture development
(5) Reforestation Plan of the Government

(6) The establishment of a Five Year Fishery Development Plan
(7) Manpower development through training to upgrade the technical know-how of local people
(8) Provision of enough seeds for use in aquaculture
(9) Assessment of marine high-value species
(10) Abundance of fishery resources for culture
(11) Plan to verify and transfer technology by the year 2000 could lead to production from 300-400 tons/year at present to 600-700 tons/year
(12) Mangrove and ecosystem habitat is suitable for the development of high-value species aquaculture
(13) Enforcement of policies on exploitation but keeping mangrove areas in tact
(14) Reforestation in order to recover the exploited mangroves
(15) Need to invest in high-intensive or semi-intensive culture for high production and profit (income) in order to minimize traditional extensive culture thus using less area and get back more areas for mangrove reforestation
(16) Reforestation of mangroves with the assistance of DANIDA
(17) Development of mangrove-friendly aquaculture model, and following 70% mangrove: 30% aquaculture farms ratio
(18) Culture of seaweeds in mangrove areas
(19) Available 6,000 ha of alluvial ground to be developed for culture of high value species such as tiger shrimps, oysters, molluscs
(20) The more than 100 km coastal line has 16,000 ha of mangrove areas, more than 2,000 ha of which are still undisturbed
(21) Abundant natural aquaculture species together with the mangrove replanting program could improve production from aquaculture
(22) Lessons from other countries such as Thailand and the Philippines where about 90% mangroves have been destroyed will encourage the government to implement policy on mangrove protection.

Group II. Central Vietnam

A. Resources

- About 35,000 ha of lagoons; short rivers; various estuaries

- Mangroves: relatively small area (mostly in estuaries); low usage density; low in height; 800 ha in 1981 and about 1000 ha at present

- Species: grouper, sea bass, red snapper, siganids, mugil; molluscs: abalone, oysters, clams, scallop; crustaceans: shrimps, crabs, lobsters; and seaweeds: *Gracilaria*, *Kappaphycus*

- Coastal resources are over-exploited and diminishing

- At least 790 ha mangroves, wetland - 4,000 ha, brackishwater - 26,000 ha

- About 80-88% of mangroves are utilized, and about 12-20% are unutilized. Mangroves have been cut and destroyed for shrimp farming starting in 1997

- There are more than 5 hatcheries, 5 cooperatives, and one factory

B Technology

- Present (small-scale): Shrimps: extensive - 60-70%, production - 150-200 kg/ha; advanced extensive - 20-30%, production - 250-300 kg/ha; semi-intensive - 2-10%, production - 500-800 kg/ha; 5,000 - 10,000 m^2/pond, improved extensive (1100-1200 ha)

- Present (large-scale): 1-5 ha/pond, semi-intensive - 20 ha. Culture of pearl oyster and scallops, and crab seed production; floating cage (broodstock) for lobster and grouper

- Species cultured: tiger shrimp, mud crab, grouper, seaweeds, mullet, shrimps, molluscs

- Coastal fisheries make use of very simple fishery technology

- Mangrove-friendly aquaculture development projects: Promotion of shrimp and crab culture, protection of wetlands, and Fishery Export Program

C. Socio-Economics

- Settlement area: communities around the fishpond area

- Major occupation: shrimp culture, aquaculture, fishing, forestry, saltmaking, harvesting from ponds

- Minor occupation: small-scale business, fishery services

- Aquaculture has improved living standards and alleviated poverty

- Replanting of mangroves with assistance from the Government of Japan has made the people aware of the importance of mangroves

- Available facilities: schools/universities, credit system, transportation system, electricity system, and water supply system

D. Policies

- National policies
  (1) Implementing the 327 Program of the Government on Reforestation
  (2) Suitable fishing/exploitation in coastal areas and estuaries
  (3) Reforestation of about 5,000,000 ha of forests
  (4) Policy of fishing resources protection
  (5) Decree signed by the Prime Minister banning the use of chemicals and dynamite in fishing

- Local policies
  (1) Plans on the development of aquaculture area
  (2) Policy on fishery protection
  (3) Policy on handling of land for use of fishermen in aquaculture area
  (4) Enforcement of forest protection
  (5) Punishment for those who violate the law on forest protection
  (6) Encourage the implementation of policy on reforestation
  (7) Increasing the area for brackishwater aquaculture
  (8) Provision of capital for aquaculture

E. Problems and Constraints

- On mangrove conservation and development
  (1) Lack of capital for reforestation and mangrove protection
  (2) Insufficient knowledge of the local people about mangrove conservation and protection
  (3) Decreased mangrove areas resulting in declining fishery resources

- On aquaculture practices
  (1) Low technology for aquaculture
  (2) For the development of shrimp farming, many mangrove forests were converted to shrimp ponds causing decline of the natural fishery resources
  (3) Lack of seed production technology especially for *Penaeus monodon*

- On socio-economic management
  (1) Conflict between the aquaculture and agriculture sectors
  (2) Decline in production because of poor fishery management

- On policies/institutional framework
  (1) Land tenure is for a very short term only
  (2) Absence of an over-all government policy to protect and rehabilitate the mangroves
  (3) Policy on mangrove should be suitable and sustainable for both fisheries and forestry

F. Potentials and Opportunities for Mangrove-Friendly Aquaculture

(1) The region has potential of about 26,000 ha brackishwater area and long coastline
(2) Suitable technology and proper investment
(3) Semi-intensive and intensive culture systems will make aquaculture develop fast
(4) Wetland area of about 4,000 ha must be protected in order to maintain the resources and conserve the biodiversity, as this area is the breeding ground of fish and shrimps
(5) Specifically in Nha Trang, the coastal area has decreased because of over exploitation and conversion to shrimp farms causing a decline in environmental quality and the reduction of the natural resources. Thus, a mechanism is needed to protect the ecosystem
(6) Policy on mangrove conservation should be established in the local governments and enforcement of such policy
(7) Promotion of the participation of the communities in the mangrove conservation
(8) Establishment of a system to include mangrove conservation in school curriculum
(9) Promotion of mangrove forest sustainability and protection
(10) Promotion of the combination of aquaculture with mangrove conservation and rehabilitation
(11) The long coastline and vast mangrove areas are suitable for aquaculture of important species
(12) Authority and support should be given to provincial government to manage its aquaculture industry

Group III. Southern Vietnam

A. Resources

- Mangrove resources about 200,000 ha, is the largest area in Vietnam. More than 80,000 ha have been used for shrimp farms, and about 55,000 ha is left.
- The coastal area is near the ocean and in the southwest part of the country
- Mangrove forests have been reduced due to destruction of mangroves for aquaculture purposes and also because of disease problems
- About 40% of the mangroves is utilized, the remaining 60% is unutilized.

B. Technology

- Present (small-scale): extensive has been practiced for a long time, semi-intensive, improved extensive, average of 3.5 ha/pond
- Present (long-term): intensive (3 companies), semi-intensive (200 ha), and intensive (50-100 ha/pond)
- *P. monodon* seeds are produced from hatchery, 400 hatcheries producing about 1.5 billion fry in 3 years
- Mud crab seeds produced in the laboratory
- Species cultured: tiger shrimp, crab, oysters, tilapia, mullet, white shrimp
- Coastal fisheries: fishing and aquaculture
- Mangrove-friendly aquaculture development projects: development of a model for integrated aquaculture and mangrove forestry; and development of a project with the assistance of Holland and Portugal

C. Socio-economic Management

- Settlement area: population not concentrated
- Major occupation: aquaculture, shrimp culture, and fishing

- Minor occupation: labor work, fishery services

- Aquaculture has generated about 150 million US dollars annually

- Population is dependent on natural resources for livelihood

- Unwise use of mangroves for livelihood

- Available facilities: schools/universities, fisheries/aquaculture training center, cooperatives, credit system. transportation system, electricity system, and water supply system

D. Policies

- National Policies
  (1) Policy on tenurial rights to farmers and communities, although short-term, it will be increased to recover investment
  (2) Existence of an institution for mangrove management
  (3) Management/replanting more people-oriented
  (4) Awareness of people on mangrove-friendly aquaculture

- Local Policies
  (1) Land and forest tenurial rights to farmers for aquaculture
  (2) Improvement of the existing policy and condition of mangrove protection in order to give way to aquaculture development
  (3) Law on utilization of mangroves localized
  (4) Pressure of local officials to utilize mangroves for the people
  (5) Revised laws on mangroves: provincial to district level

E. Problems and Constraints

- On mangrove conservation and development
  (1) Absence of a proper aquaculture design
  (2) Continuous cutting of mangroves for firewood
  (3) Lack of knowledge on mangrove conservation

- On aquaculture practices
  (1) High mortality of cultured shrimps
  (2) Fish diseases and low quality of seeds for aquaculture
  (3) Insufficient supply of fish seeds for aquaculture
  (4) Insufficient supply of feeds and lack of aquaculture technical know-how
  (5) Absence of appropriate aquaculture models

- On socio-economic management
  (1) High population growth especially among the fish farmers
  (2) Immigration problems

- On policies and institutional framework
  (1) Absence of suitable tenurial rights for households
  (2) Unsuitable policies on aquaculture
  (3) Absence of policy on land handling in long-term basis in order to encourage investors to come and invest in the country
  (4) Absence of policy on rights-use of mangroves for fishermen

F. Potentials and Opportunities

(1) Government assistance for replanting mangroves and promotion of mangrove-friendly aquaculture
(2) The region has long coastline with good conditions for aquaculture because of natural mangroves
(3) Existing model for integrated aquaculture and mangrove seems effective
(4) As mangroves developed and expand, conditions for aquaculture also improved
(5) Extension is important to transfer the technology to the farmers, especially on mangrove protection and aquaculture
(6) Vast areas of mangroves means big potential for aquaculture
(7) Government should have suitable policy for the development of aquaculture
(8) Possibility of dividing the big areas into smaller areas for easy management
(9) Government should have policy on environmental protection

Group IV. Cambodia

A. Resources

- The coastal areas is along the coastline of Cambodia and is under threat due to over-exploitation

- Mangrove areas totaled 851 km^2 in 1993, about 40% utilized and 60% unutilized

- Some mangrove areas are not in good condition. The mangrove areas are concentrated in the coastal, estuary, and rivers, and mostly located near Cambodia-Thailand border
- Mangrove trees belong to 35 families, 53 genera, 74 species mostly the Rhizopora species.

- There are about 25 aquaculture farms: 8 shrimp farms, 10 fish farms, 6 green mussel farms, and one cockle farm

B. Technology

- Aquaculture technology is not developed after the war
- There is abundant supply of freshwater fish
- Inappropriate and unsustainable aqua-farming practices
- Intensive shrimp farming is practices near the Thai border, and produce is exported to Thailand
- Mollusc culture is not fully developed due to lack of technical know-how
- Green mussel culture production is used mainly to supply the needed feeds of the shrimp farms
- A switch has now started from shrimp to grouper culture
- Species cultured: Red snapper, grey mullet, green mussel, tiger shrimp, grouper, white shrimp, blood cockle
- Coastal fisheries: overfishing, fishery products exported to Thailand, most of the fishing gear used is small-scale

C. Socio-economic Management

- The settlement area is along the coastline
- Major occupation: small-scale fishing, salt-making, mangrove cutting for charcoal production, coastal fishing
- Minor occupation: small trading, labor work, upland crop farming
- Existence of an open market
- Mangrove management is controlled by the government
- Facilities available: marketing system, cooperatives, transportation system, water supply system

D. Policies

- National Policies
  - (1) Mangrove forest is presently under the responsibility of the Department of Fisheries
  - (2) Although aquaculture is under the responsibility of the Department of Fisheries, until at present, the policy is not clear regarding the development of coastal aquaculture
  - (3) Fishery laws for the coastal areas, with few areas covering coastal fishing
  - (4) License for fishermen, allowing to operate if area is greater or equal to 0.5 ha for aquaculture
  - (5) Environment law requires environmental impact assessment for new projects

- Local Policies
  - (1) Following the policies of the central government

E. Problems and Constraints

- On mangrove conservation and development
  - (1) Illegal mangrove cutting for charcoal production, for firewood, and for construction materials
  - (2) Displacement of mangrove areas to give way for the establishment of shrimp farms and salt ponds
  - (3) Proposed privatization of the mangrove areas

- On aquaculture practices
  - (1) Lack of knowledge and experience in aquaculture systems
  - (2) Lack of technical know-how on hatcheries and coastal aquaculture management
  - (3) Shrimp diseases
  - (4) Lack of technical support
  - (5) Absence of a proper marketing system

- On socio-economic management
  - (1) Market is dependent on the Thai market
  - (2) Land property problem, claim of mangrove land as owned property
  - (3) Less educated population

- On policies and institutional framework
  - (1) Conflict between government and the coastal communities
  - (2) Overlapping management of mangroves between the Ministry of Environment and the Ministry of Agriculture through the Department of Fisheries
  - (3) Existence of loopholes in existing laws affecting coastal resources

(4) Laws were formulated with less consultation with the communities
(5) Exploitation of mangroves instead of upland forests

F. Potentials and Opportunities

(1) Excellent mangroves still remaining along the coastline
(2) Most of the coastline areas are suitable for aquaculture
(3) Fishermen are artisanal
(4) Most of the aquaculture ventures are still small-scale
(5) Intensive farming are practiced by the rich, but this is not suited for coastal communities
(6) The coastal fishery activity is small-scale thus the effect of the destruction of the mangrove areas is not heavy on the natural fishery resources

Recapitulation

Yasuho Tadokoro
Deputy Chief
SEAFDEC Aquaculture Department

During the first five days of the On-Site Training, the concept of mangrove-friendly aquaculture was introduced starting with the background, mangroves in general, and the ecosystems. The taxonomy of mangroves was also introduced including the distribution of mangroves and the various mangrove species. Mangrove conservation and management including mangrove-friendly aquaculture technologies were given emphasis.

"Mangrove-friendly aquaculture," a newly coined word, is appropriate for the system that AQD is now dealing with. Its definition generally connotes the aquaculture methodology used in conserving the mangrove areas without sacrificing the development of sustainable aquaculture. However, this definition is still undergoing metabolic changes as there are many terms that somehow relate to this definition. Some examples are the terms silvofisheries, aquasilviculture, and agri-nipa-aquaculture, which are being used interchangeably because of the little difference in their meanings, to the extent that these terms have created confusion and misunderstanding.

As an example, it should be noted that mangrove-friendly aquaculture does not necessarily mean water treatment, *per se*, because in mangrove-friendly aquaculture, one must properly manage the water quality in the mangrove areas used for aquaculture. The most important aspect here is the relationship between water treatment and the mangrove area. There may be cases when water treatment is discussed without considering the mangrove area. This should not be emphasized under this concept of mangrove-friendly aquaculture.

In the presentation of the aquaculture systems and mangrove-friendly aquaculture technologies in Southeast Asia, focus was placed on the recommendations during the January 1999 Workshop on Mangrove-Friendly Aquaculture, and the problems raised by the Workshop participants regarding such aquaculture technologies. It should be noted that mangrove-friendly aquaculture technology does not necessarily mean extensive system. It could be semi-intensive or even intensive in the proper way as indicated in this paper.

We are aware that traditional aquaculture is very simple and could be primitive, but the impact against the ecology is minimal. Therefore, we can say that traditional aquaculture is mangrove-friendly aquaculture. However, we do not necessarily promote traditional aquaculture during this age of modern technologies. We promote the adoption of semi-intensive or intensive method in the mangrove areas with careful management of the mangrove areas. This is in fact the most important factor in mangrove-friendly aquaculture. It is for this reason that when we planned the lectures for this On-Site Training, efforts were made to include not only the extensive method but also semi-intensive or intensive, and even water treatment in shrimp aquaculture which is practiced in Thailand. The intention was to include the application of modern technologies wisely in the mangrove areas.

The experiences of Indonesia, Thailand, Vietnam, and the Philippines on silvofisheries were also presented. Silvofisheries is actually the integration of mangroves and fisheries including mangrove-friendly aquaculture. An integrated approach is essential in mangrove-friendly aquaculture. This involves two aspects such as the natural science and social science aspects. Although varied in nature, it is important to integrate or combine these aspects for the effective and efficient management of the mangrove areas. The natural science aspect relates to the technology and ecosystem considerations, while the social science aspect involves co-management of the mangrove-friendly aquaculture system. In co-management, many organizations are usually involved, such as the central and local governments, the communities, non-government organizations, etc.

Another important factors in mangrove-friendly aquaculture are legal framework and community-based management. The On-Site Training included lectures on these topics based on the experiences in Vietnam and the Philippines. However, because of the different natural, social, and economic conditions of the countries in the region, no single answer or model but a best model could be developed for mangrove-friendly aquaculture taking into consideration such varied conditions. Although this will not be an easy task, this should pose a challenge for the researchers and aquaculturists in the region.

It is a known fact that our fishermen in this region are poor and are working hard to increase their income. We can still recommend aquaculture in the mangrove areas for our fisherfolk. However, such aquaculture system should be environment-friendly in order to protect and conserve the mangroves for the sake of the future generation. It is mainly for this economic and social reasons that SEAFDEC promotes the adoption of mangrove-friendly aquaculture.

The culture of shrimps, mud crab, molluscs, seaweeds, and fishes in mangrove areas were also introduced. The information will be useful as these provide guidelines on the mangrove-friendly aquaculture of economically-important species. A big task for the participants may be to decide on the aquatic species desired for culture in the mangrove areas. This would depend largely on the government policies.

However, whatever aquaculture endeavor it may be, there is only one thing that the participants should bear in mind, that is the conservation and preservation of the mangrove areas.

The background information provided by the participants during the early part of the On-Site Training were very impressive. The summary of such information presented a good picture of the present status of mangroves and aquaculture in these parts of Southeast Asia. Thus, the focus of the lectures were deviated a little towards such information, making sure that the enthusiasm presented by the participants are in a way, satisfied.

The field trip to Cat Hai District and Cat Ba Island was a good break from the monotony of the lectures. It was also an opportunity to see an example of mangroves in that part of Vietnam. The mangroves in Cat Hai had some aquaculture operations. From its definition as mentioned earlier, it was an example of mangrove-friendly aquaculture with some eco-tourism as part of it.

On the other hand, the Mariculture Station of RIMP at this early stage, may not have directly demonstrated the concept of mangrove-friendly aquaculture. However, it could be a source of technologies that could serve as initial inputs in any mangrove-friendly aquaculture operation in the future

From the concepts and technologies introduced during the On-site Training, it is expected that the participants present good recommendations and strategies on mangrove-friendly aquaculture for their respective governments after the On-Site Training.

Annex 6

SUMMARY OF EVALUATION OF THE ON-SITE TRAINING

Yasuho Tadokoro
Deputy Chief
SEAFDEC Aquaculture Department

At the beginning of the On-Site Training, the participants were asked to indicate their expectations. Generally, the response showed that the participants expect to learn and gain more knowledge and information about mangroves, the ecosystem in the mangrove areas, some aquaculture methodologies, and the socio-economics of mangrove-friendly aquaculture.

Specifically, the responses of the participants could be summarized as follows:

1. To learn new aquaculture technologies in the region such as the culture of crustaceans, molluscs, fishes, and seaweeds;

2. To be able to come up with suitable mangrove-friendly aquaculture models, which are technically appropriate, economically viable and socially acceptable for local conditions;

3. To gain knowledge on community-based management of aquaculture; and

4. To learn how to formulate policies, mechanisms in order to promote sustainable development of aquaculture.

During the recapitulation, the concept and technology of mangrove-friendly aquaculture as well as the need for an integrated approach, were emphasized. It is worth repeating these issues in the summary of the evaluation because of their importance and in order that the participants will be able to grasp these issues thoroughly.

The issue started with the definition of mangrove-friendly aquaculture which is not yet final and complete at the moment. May be at this time, we could use the term "silvo-aquaculture" for mangrove-friendly aquaculture, in order to avoid confusion.

It was noted that "silvofisheries" denotes fisheries in the mangrove areas. This definition implies not only aquaculture but also fishing activities. Therefore, this can not be used for the exact meaning of mangrove-friendly aquaculture.

On the other hand, "aquasilviculture" may have the same meaning, but this could be misunderstood to mean mangrove culture or mangrove planting. The most appropriate term could be "silvo-aquaculture", which clearly denotes the important relationship between mangroves and aquaculture.

As mentioned earlier, some lectures may not have been directly related to the mangroves. Without taking into consideration the relationship between mangroves and aquaculture, the whole system could be meaningless. Therefore, it is important to mention such relationship in order to be consistent with the definition of mangrove-friendly aquaculture.

In the recapitulation, it was also indicated that the technology of mangrove-friendly aquaculture may not necessarily be extensive, for it could be semi-intensive or even intensive. Although extensive method is much safer than semi-intensive or intensive. There is therefore the possibility of introducing such methodologies in silvo-aquaculture. By mangrove-friendly aquaculture, we do not mean going back to the traditional method of aquaculture. It is actually the wise use of modern aquaculture technologies in the mangrove areas. Efforts should therefore be made towards this objective in the promotion of mangrove-friendly aquaculture.

To reiterate some of the issues, it should be noted that an integrated approach is essential for mangrove-friendly aquaculture, especially the concept of co-management. This may be complicated and difficult to undertake. However, the participants should make sure that they understand these concepts and technologies so that they will be able to apply them when they return to their work areas after the On-Site Training.

At the end of the On-Site Training, the participants were asked to assess the course to determine what the participants have learned from the training course and to verify whether their expectations were met. This is very important for AQD to confirm that the course was carried out effectively and efficiently. As mentioned by the SEAFDEC Secretary-General, this first On-Site Training will serve as the backbone of the future activities of the Mangrove-Friendly Aquaculture Program of AQD.

Upon examination of the evaluation by the participants, it is noteworthy mentioning that they responded positively with excellent remarks. The presentation of the group reports were very impressive. The participants really showed their confidence in implementing and promoting mangrove-friendly aquaculture technologies in their areas of work.

In behalf of AQD, as Coordinator for this On-Site Training, I sincerely hope the participants will apply what they have learned from the On-Site Training. At this initial point, allow me to extend my special thanks to my Co-Coordinator for this On-Site Training, *Prof. Dr. Bui Dinh Chung,* for the support and cooperation of the RIMP staff under his leadership.

Message

Nguyen Ngoc Hong
Vice Minister
Ministry of Fisheries-Vietnam
and SEAFDEC Council Director for Vietnam

On behalf of the Ministry of Fisheries of Vietnam and as SEAFDEC Council Director for Vietnam, it is my honor to give you all a warm welcome to Hai Phong City, one of the biggest fisheries centers in North Vietnam. Hai Phong has also the second biggest mangrove forest areas in the whole country, after the famous Cuu Long estuary.

Today, you are here to take part in the On-Site Training on Mangrove-Friendly Aquaculture organized by the Aquaculture Department of SEAFDEC. I think that the contents of the training course is very suitable and significant for the fisheries development of Vietnam at this period, because of many obvious reasons.

Firstly, the mangrove forests area in Vietnam has been reduced because much has been destroyed during the long war against some invaders. Recently, it had been seriously depleted because of unsuitable use of mangrove mainly for wood and illegal aquaculture. Investigations have shown that before the Second World War, the mangrove areas in Vietnam was around 400,000 ha of which the famous primary forests had trees as high as 25 to 30 meters, and 50 - 60 cm in diameter, such as those found in Ca Mau Peninsula. In 1982, data showed that the mangrove area has remained at 250,000 ha and in 1995 it was reported to be around 160,000 ha.

Secondly, the main objective of our Fisheries Development Plan to the year 2010 is to produce more than 2 million tons of fish, which means that production from aquaculture will have to be increased from 32.3 % of the total fish production in 1998 to at least 50% of the total fish production in 2010. This points out to the fact that the aquaculture sector plays an important role in our fisheries development plan. We have taken note of the fact that aquaculture contributes much more catch than commercial fisheries and it has led to the creation of more jobs for people living in the coastal areas. Its major role is the dollar contribution it brings for the country's economy.

Lastly, I believe that while developing silvofisheries, the social-economic sectors as well as education will also be developed, thus contributing largely to the general development of the society.

In order to achieve all these objectives, aquaculture in general, and mangrove areas in particular, should be developed.

For the past years, SEAFDEC has had several activities to assist Vietnam in its fisheries development in which aquaculture is considered as the top priority. Such assistance has helped the development of our fisheries. However, until at present, aquaculture in Vietnam has not developed its full potential.

Organizing this training course once more has occupied the attention of the Ministry of Fisheries-Vietnam and SEAFDEC, especially AQD. I sincerely hope that in order to develop aquaculture in Vietnam, all the experiences from other countries in the region through this training, will be received by the Vietnamese scientists as well as managers and producers. They should be able to apply silvofisheries effectively by way of sustainable development and protection of such significant area as the mangroves.

The Ministry of Fisheries-Vietnam was informed that the Governments of Japan and Canada have supported the conduct of the training through their special funds. I would therefore wish to express my gratitude to these governments for their financial assistance.

I would also like to express my thanks to Mr. Panu Tavarutmaneegul, Secretary-General of SEAFDEC, to Mr. Yasuho Tadokoro, Deputy Chief of the Aquaculture Department, and all the lecturers from Indonesia, Malaysia, the Philippines, and Thailand, and the support staff, who have wholeheartedly committed themselves to assist in the conduct of this training course.

I would also wish to take this opportunity to extend my thanks to the institutions in Hai Phong, that have provided all the conveniences and facilities for this training course in this beautiful City of Hai Phong.

I also wish to extend my warm greetings to the trainees who come from all the areas in Vietnam. I hope that they will learn more experiences from this training that could be applied in their areas of work.

I would like to extend my best congratulations to the trainees from Cambodia, who come and participate for the first time in this training course of SEAFDEC held in Vietnam. I wish that Cambodia will soon become an official member of SEAFDEC as announced by the Government of Cambodia. This will give SEAFDEC more responsibilities in regional fishery development.

Lastly, I wish you will all have nice days in this beautiful City of Hai Phong. And I wish you a successful training course. Thank you and good day!

Message

Panu Tavarutmaneegul
Secretary-General
SEAFDEC

Ladies and gentlemen, it is with great pleasure to be here with you today at the Opening of the On-Site Training on Mangrove-Friendly Aquaculture. Being new to SEAFDEC, having been appointed as Secretary-General only last month during the Thirty-First SEAFDEC Council Meeting in Japan, this is one of the few opening ceremonies that I have attended so far. Although still new to SEAFDEC, I have been following its activities. Now, I am very happy to see one of the activities of SEAFDEC which is this on-site training under the Mangrove-Friendly Aquaculture Program of AQD, being implemented.

I would therefore wish to commend AQD for pursuing this very important activity and at the same time extend my deepest gratitude to RIMP and the Government of Vietnam for offering to host this on-site training. This session signals the start of a series of on-site training sessions under the Mangrove-Friendly Aquaculture Program. The conduct of this training in Vietnam is therefore very appropriate for this country has also experienced significant damage of its mangrove areas.

As we are all aware, the Mangrove-Friendly Aquaculture Program is SEAFDEC's response to the universal concern on the loss of mangroves in the region which has been attributed to the fast development of aquaculture in general, and shrimp culture in particular. Thus, such Program was formulated by AQD to promote the conservation and preservation of the mangrove resources in the region without necessarily sacrificing the development of sustainable aquaculture.

Under such Program, a series of on-site training sessions have been planned in order to benefit a greater number of participants and to open avenues for the possible participation of the private sector in the region. This is also an alternative way of training on site, a number of personnel from the Member Countries of SEAFDEC and the ASEAN.

This first on-site training here in Vietnam is made possible because of the financial support from the Government of Japan. We also received support from the Government of Canada through the Canada-ASEAN Centre, for the participation of trainees from Cambodia. To our donors, SEAFDEC is most grateful.

We have also tried to invite the participation of a few representatives from Myanmar. However, we were not successful in seeking funds for their participation. The allocation of the Government of Japan for this training is limited to the Member Countries of SEAFDEC. Thus we are seeking for donors to fund participants from non-SEAFDEC member countries.

I could foresee a bright future for the Mangrove-Friendly Aquaculture Program of AQD. During the First ASEAN-SEAFDEC Fisheries Consultative Group Meeting in early March 1999, one of the programs recommended for collaboration between SEAFDEC and ASEAN is the promotion of mangrove-friendly aquaculture in Southeast Asian countries. The objective is to develop and promote appropriate mangrove-friendly aquaculture system for the ASEAN countries.

Moreover, during the 31st Meeting of the SEAFDEC Council, the Government of Japan signified its support for the implementation of the said program under the ASEAN-SEAFDEC collaborative mechanism. The same program was also endorsed by the SEAFDEC Council for implementation upon confirmation by the ASEAN Sectoral Working Group on Fisheries.

With the support of ASEAN and the efforts made by SEAFDEC, I am sure the planned activities under the said Program will be pursued. All these activities are necessary in order to achieve the ultimate goal of the Program which is the formulation of the Technical Guidelines which shall form part of the inputs for the forthcoming SEAFDEC project on the regionalization of the Code of Conduct for Responsible Aquaculture Development.

The SEAFDEC Secretariat will extend its full support in the implementation of this very important Program for the sustainable and responsible development of aquaculture in this region. We shall see to it that the Program will get the necessary financial and technical support from our donors as well as other collaborators.

To the participants in this on-site training, let me tell you that you shall play a very significant role in the Mangrove-Friendly Aquaculture Program of AQD. The strategies and recommendations that you shall be formulating towards the end of this training for your respective governments, are essential for the successful formulation by AQD of the Technical Guidelines that I mentioned earlier. I therefore encourage you to take active participation in the discussions and to make sure that the strategies and recommendations that you will formulate are relevant to the region.

Allow me to congratulate you for your participation in this training. The results of this training shall comprise the backbone of the forthcoming activities under the Program. You shall also serve as models for the forthcoming on-site training session participants.

Finally, without further ado, on behalf of the organizers of this training, AQD and RIMP, I declare open this on-site training on mangrove-friendly aquaculture in Hai Phong City, Vietnam. Thank you and good day!

Closing Remarks

Masao Shimomura
Deputy Secretary-General
SEAFDEC

Guests, trainees, ladies and gentlemen, good evening! I am indeed grateful to the Aquaculture Department for inviting me to the Closing Ceremonies of this On-site Training on Mangrove-Friendly Aquaculture. I was informed by our Secretary-General, Mr. Panu Tavarutmaneegul of the successful Opening Ceremonies of this training. I have also been informed of the progress of the training, and I am happy to note of the enthusiasm and active participation of the trainees. I am very confident that the participants have learned much from the training.

Therefore, for the successful conduct of the training, allow me to commend AQD for its efforts in trying to get the most qualified resource persons from the Philippines, Malaysia, Indonesia, and Thailand. The Ministry of Fisheries - Vietnam and the Research Institute of Marine Products also contracted the very qualified resource persons from Vietnam. The services of the best lecturers especially chosen for this training, made us confident that the participants would learn more from the training.

I have also been apprised of the case study presentation of the participants which was very successful. I am glad that through this training they were able to formulate recommendations and strategies which they can submit to their respective governments after this training.

Now, I expect that the participants will take note of what they have just learned. As indicated in the objectives of the training, they are expected to echo what they have just learned to their co-workers in their areas of work and assignment. On the other hand, I hope that the strategies and recommendations that the participants have just formulated will be considered by their respective governments so that the mangrove-friendly aquaculture program of AQD will have good results.

With their excellent performance, I could very well say that the participants did not fail the Government of Japan's good intentions of allocating special funds for this project. I am sure the participants will have good reports on the training, which would make their governments proud of them.

Allow me to reiterate here that it is not only the Government of Japan who provided funds for this training. We are also very grateful to the Government of Canada through the Canada-ASEAN Centre, for providing additional funds in order to bring to Vietnam five participants from our neighbor Cambodia. I hope these five selected participants will be able to relay the knowledge they have just gained from this training to their countrymen. Make them also aware of the importance of mangrove conservation and preservation, and the strategies of doing aquaculture in the mangrove areas without destroying the mangrove ecosystem.

We regret that we can not fund the participation of Myanmar at this training. The funds allocated was not enough to bring them to Vietnam. But we hope they will be able to join us in future training sessions.

After having successfully completed this On-Site Training on Mangrove-Friendly Aquaculture, I wish to reiterate my sincerest gratitude to the Government of Vietnam through its Ministry of Fisheries for making available the facilities and staff of RIMP for this training, not only for the lecture sessions but for the field trips as well.

On behalf therefore of the Government of Japan and also of SEAFDEC, I wish to thank the organizers of this training, the Aquaculture Department and RIMP. Specifically, I wish to express my heartfelt gratitude to RIMP Director, Prof. Dr. Bui Dinh Chung; the Deputy Director, Dr. Do Van Khuong; and all the technical and support staff of RIMP for their efforts and services that made this training a complete success. I also wish to thank Mr. Yasuho Tadokoro and the rest of the AQD staff for their efforts in bringing this on-site training to this beautiful City of Hai Phong, Vietnam.

I also wish to make special mention of the interpreters. I wish to thank them for their contributions to the success of the training. Without them, it should have been very difficult for our lecturers and the participants to understand and communicate with one another. Taking note of the fact that the 20 participants came from all over Vietnam, it was expected that there would be some language barriers. That is why we considered the request of RIMP and AQD to contract some of the very qualified interpreters for this training.

Lastly, I wish that the participants will be successful in their future endeavors. To one and all, good luck and may you have a safe journey to your homes.

Good evening and thank you very much!