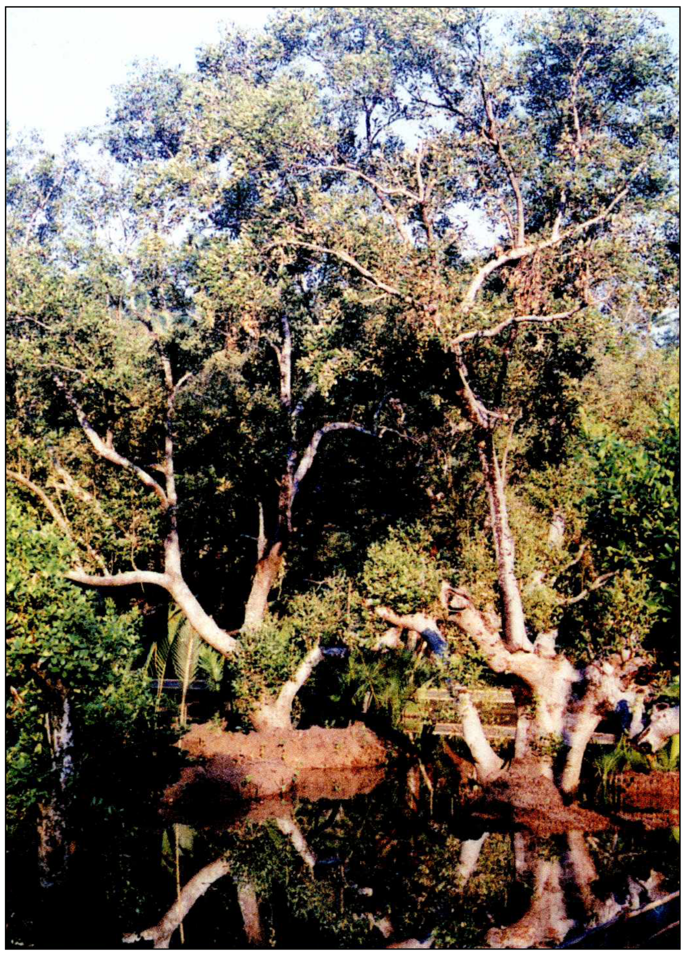
Mangrove-Friendly Aquaculture

J.H. PRIMAVERA, L.Ma.B. GARCIA,
M.T. CASTAÑOS, and M.B. SURTIDA
Editors



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

Mangrove-Friendly Aquaculture

Proceedings of the Workshop on
Mangrove-Friendly Aquaculture
organized by the
SEAFDEC Aquaculture Department
January 11-15, 1999
Iloilo City, Philippines

J.H. Primavera, L.Ma.B. Garcia,
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ON THE COVER
Aquasilviculture pond in Bugtongbato, Ibajay, Aklan (west central Philippines) integrates old growth *Avicennia* trees with the culture of mudcrabs.

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PUBLISHER'S NOTE

In the year after the Mangrove-Friendly Aquaculture (MFA) workshop was organized by SEAFDEC Aquaculture Department, our MFA program has moved on. While we continue to work on community aquaculture in the context of sustainable coastal resources management as documented in this proceedings, additional activities focused on environment-friendly shrimp farming have been initiated and are in progress.

Shrimp farming is a major dollar earner for SEAFDEC member countries in particular and for the entire ASEAN in general. However recent events in the form of disease outbreaks and production failures have made it increasingly clear that its sustainability depends on a high regard for the environment - both within and outside the growing area. Interest is therefore high within the entire Southeast Asian region for the countries to collaborate with each other and find ways to make shrimp farming benign to the environment not least of which is the mangrove ecosystem.

The clearing of mangrove forests to make way to shrimp farms has, in recent years, already abated due to both growing public awareness and the realization among growers that the inter-tidal mangrove area after all is not an ideal site for high density shrimp culture. However discharges from shrimp farms continue to be a threat to both the mangrove and marine ecosystem often with negative repercussions on the livelihood of the coastal poor who relies on the coastal resources for their sustenance, as well as to the sustainability of shrimp farming itself.

Our vision is to develop a zero-discharge system where wastewater is treated using biological agents such as seaweeds, molluscs and fishes or even the mangrove itself and returned to the growing ponds. Trial runs are in progress in Thailand, Vietnam and the Philippines.

The Mangrove-Friendly Shrimp Culture Technology Development Project is a major component of the SEAFDEC/AQD MFA Program. The shrimp project is funded by a Trust Fund from the Government of Japan with SEAFDEC/AQD as lead institution for technology development and Thailand as the coordinating country for promoting the technology within the ASEAN countries. Collaborators include Thailand's Department of Fisheries and Vietnam's Research Institute for Marine Products. Research and verification runs are conducted side-by-side. Two other important components of the project are technology dissemination and on-site training.

Rolando R. Platon, PhD
Chief, SEAFDEC/AQD

Iloilo, July 2000

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FOREWORD

In the world of fisheries, capture fishery has already reached its full capacity. Many fishing grounds have been grossly overexploited. Meanwhile aquaculture continues to give strong promise to fill the gap between fish supply and demand. However, the rapid expansion of aquaculture, particularly shrimp culture, in Southeast Asia and South America, is often identified as one of the major factors in the denudation of the world's mangrove resources. Furthermore shrimp farm effluents particularly from intensive operations continue to negatively affect mangrove stands and the marine environment in general.

The important role of the mangrove ecosystem as a nursing and feeding ground of various fish species and other valuable marine organisms has long been known but is only recently appreciated. Its role as a potential source of livelihood to coastal communities is becoming more important as population continues to grow. Finally it now appears that the mangrove ecosystem may even contribute to the sustainability of shrimp farming by acting as a biological filter.

In order to ensure the continued production of shrimps from aquaculture without the negative impacts to the environment that are often perceived to be associated with shrimp farming, the Government of Japan made a commitment to provide SEAFDEC with a trust fund that will be used for the development of a mangrove-friendly shrimp culture technology. To initiate the project the first Workshop on Mangrove-Friendly Aquaculture was held in 1999 during the incumbency of my predecessor Mr. Udom Bhatiyasevi. I am most thankful to the Government of Japan for its far-sightedness and its financial support.

The new SEAFDEC Strategic Plan has set the SEAFDEC program orientation towards regional issues. On aquaculture, the SEAFDEC Aquaculture Department has initiated the formulation of a regional guideline for the implementation of the *Code of Conduct for Responsible Fisheries* with regards to Aquaculture. The regional guideline is envisioned to address environmental problems arising from intensive aquaculture including those affecting the mangrove ecosystem.

It is my hope that this *Proceedings* will benefit all countries in the region.

Panu Tavarutmaneegul
Secretary-General, SEAFDEC

Opening Program, 11 January 1999, Mangrove-Friendly Aquaculture Workshop *(from left):* **Mr. Cesar Drilon**, *Department of Agriculture Undersecretary for Fisheries and Legislative Affairs and SEAFDEC Council Director for the Philippines',* **Dr. Rolando Platon**, *SEAFDEC/AQD Chief*; **Mr. Udom Bhatiyasevi**, *SEAFDEC Secretary-General*; **Mr. Yasuho Tadokoro**, *SEAFDEC/AQD Deputy Chief,* and Dr. Jurgenne Primavera, *SEAFDEC/AQD Senior Scientist*

Participants of the first workshop on mangrove-friendly aquaculture; 11-15 January 1999; Iloilo City

BACKGROUND OF THE WORKSHOP

A *Mangrove-Friendly Aquaculture Program* was proposed by the SEAFDEC Aquaculture Department back in the early '90s when the SEAFDEC Council promoted the globalization and regionalization of fisheries development perspectives. During the 27th Meeting of the SEAFDEC Council in Singapore in 1994, the Council urged SEAFDEC to strike a balance between fisheries and the environment, suggesting action plans that included efforts towards making fisheries "very environmentally friendly." This was confirmed again by the SEAFDEC Council in 1996, when it specified the conduct of studies on mangroves in relation to aquaculture. The mangrove-friendly aquaculture studies were to be implemented by SEAFDEC/AQD.

In response, AQD in 1997 proposed a collaborative project with SEAFDEC's department in Malaysia, the Marine Fishery Resources Development and Management Department (MFRDMD). The project was on shrimp culture and mangroves. Although approved by the SEAFDEC Council in principle, the project could not be implemented due to technical and financial constraints.

The recommendations were confirmed and strengthened in the new SEAFDEC Strategic Plan which was approved by the Council during its 1998 Meeting in Brunei Darussalam. The Strategic Plan's major strategies include: (1) placing emphasis on regional issues and anticipated external problems, and (2) promoting efficient and sustainable use of fishery resources. The importance of mangrove preservation was again specifically mentioned during the Meeting and reiterated in the Strategic Plan.

It was also during the 1998 Meeting of the SEAFDEC Council that the Government of Japan signified its support to 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 aquaculture and marine turtle conservation project to be implemented by SEAFDEC.

The mangrove project starts with the *Workshop on Mangrove-Friendly Aquaculture* which aims to (1) assess the status of mangrove-related aquaculture activities in the region; (2) identify problem areas affecting such aquaculture; (3) identify appropriate technologies to deal with various situations; and (4) formulate strategies and recommendations for sustainable aquaculture in mangrove areas. AQD envisioned that the workshop shall formulate recommendations on practical technologies and strategies for the development of aquaculture in mangrove areas. The proceedings of the workshop are contained in this volume.

SEAFDEC noted that in the *Code of Conduct for Responsible Fisheries* adopted by FAO in 1995 some concerns of developing countries are not included. One is mangrove preservation which is considered important to the Member Countries of SEAFDEC as well as ASEAN, in achieving sustainable fisheries and aquaculture. As part therefore of an overall SEAFDEC program, the establishment of the *Regional Code of Conduct for Responsible Aquaculture Development* will be carried out by SEAFDEC, mainly by AQD. The output of the *Mangrove-Friendly Aquaculture Program* shall form part of the regional code.

Moreover, the progress of the *Mangrove-Friendly Aquaculture Program* shall be used as reference material for the proposed JICA *Third-Country Training Programme on Responsible Aquaculture Development* which AQD intends to undertake starting 1999. Trainees will be invited from non-Member Countries in Africa, Middle East, South Pacific, and South America.

review papers

Harvest of mudcrabs in aquasilviculture pond in Bugtongbato, Ibajay, Aklan

Mangroves of Southeast Asia

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Abstract

This paper provides an introduction to Southeast Asian mangroves covering taxonomy, distribution and ecological factors; discusses mangrove goods and services and their valuation; and recommends guidelines for mangrove conservation and management, including mangrove-friendly aquaculture.

Introduction

Thirty-five percent of the total 18 million ha of global mangrove forests (Table 1) are found in the Southeast Asian countries of Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Vietnam (Table 2, Figure 1). Indonesia alone has 4.5 million ha of mangroves (Spalding *et al.* 1997). At the same time, the region also leads in brackishwater aquaculture, producing for example, 446,000 mt of shrimp or 60% of 1997 global yields (Rosenberry 1997).

Conversion to shrimp ponds, in addition to settlements, agriculture, salt beds, overexploitation and other factors (Primavera 1995), have led to high rates of mangrove loss over the last three decades ranging from 25% in Malaysia to 50% in Thailand (Low *et al.* 1994). In Vietnam, a total of 102,000 ha of mangroves have been cleared for shrimp farming from 1983 to 1987 (Tuan 1997). By 1988, the increase in shrimp culture area in the Mekong Delta to 123,000 ha means a decrease in mangroves of the same magnitude (Trong 1995). In Thailand, shrimp farms accounted for 32% or 65, 150 ha of the total 203, 600 ha of mangrove area destroyed between 1961 and 1993 (Menasveta 1997). For example, in Ao Ko Nok, Chanthaburi province, most of the prawn ponds which grew from zero in 1975 to 1, 836 ha in 1991 were built in mangrove forests which declined by 1, 428 ha in the same period (Raine 1994).

Taxonomy, distribution and environmental factors

The term mangrove refers to intertidal communities of tropical trees and shrubs or to their constituent plants (Tomlinson 1986). Mangrove plants belong to 20 families, 22-27 genera and around 60 species (Tomlinson 1986; Duke 1992), of which around 40 exclusive species and 65 non-exclusive species are found in Southeast Asia (Japar 1994; Spalding *et al.* 1997) (Table 3). Mangroves are confined between 30°N and S latitude with outliers in Bermuda, Japan, Australia and New Zealand (Figure 2). The Indo-Pacific or Eastern group has 40 species compared to only 8 species for the Western group (Tomlinson 1986).

Table 1. **Global area of mangroves** (Spalding *et al.* 1997)

Region	Mangrove area (x 10^5 ha)
South and Southeast Asia	75.2 (41.5%)
Australasia	18.8 (10.4%)
The Americas	49.1 (27.1%)
West Africa	28.0 (15.5%)
East Africa and the Middle East	10.0 (5.5%)
Total area	181.1

Table 2. **Mangrove area in Southeast Asian countries** (data from Spalding *et al.* 1997)

Country	Area (x 10^5 ha)
Brunei	0.17
Cambodia	0.60
Indonesia	45.4
Malaysia	6.4
Myanmar	3.8
Philippines	1.6
Thailand	2.6
Vietnam	2.5
Total	63.2 (34.9% of world)

Mangroves are found in salt water with water temperatures ≥24°C, substrates that are predominantly muddy but also sandy, and protected coastlines (Tomlinson 1986; Hutchings & Saenger, 1987; Duke 1992). Mechanisms evolved by mangroves to cope with extreme conditions of salinity, desiccation and anoxia, include salt glands, a variety of root structures including prop roots, cable roots and pneumatophores and viviparous propagules (Tomlinson 1986).

Whereas neotropical mangroves have been classified by Lugo & Snedaker (1974) into overwash, fringe, riverine, basin, scrub and hammock forests based on physiography and structure, Old World forests may be river-dominated or tide-dominated, or interior mangroves, according to dominant physical processes (Woodroffe 1992).

Functions of mangroves

Mangrove functions may be classified into information, regulatory or carrier and resource function.

1. **Information**. This may be aesthetic, religious, cultural, historical and educational in nature. Many Philippine towns and villages are named after mangroves (Table 4) —Matabao

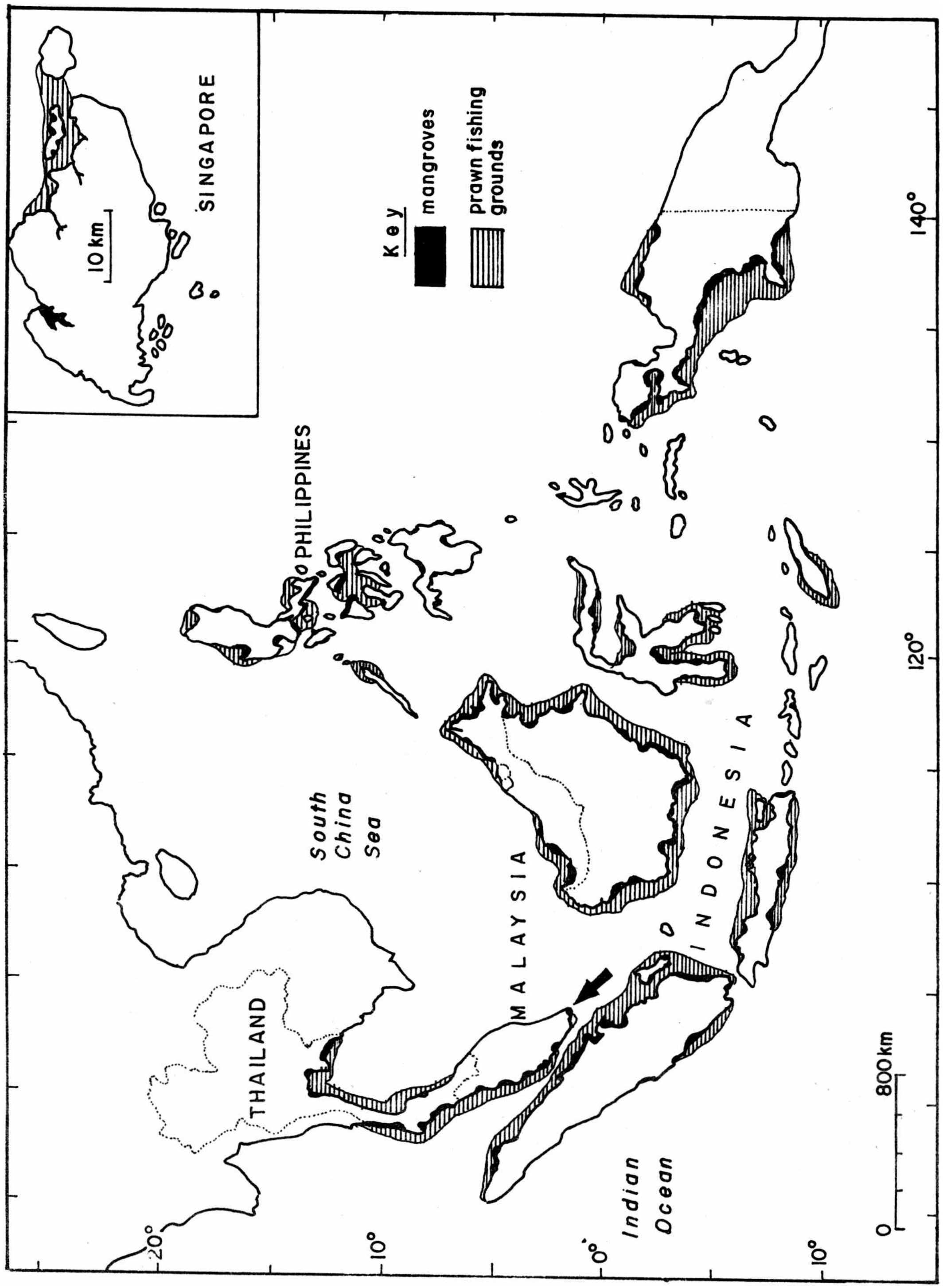

Figure. 1. **Major mangrove areas and prawn fishing grounds in Southeast Asia**. Arrow is Singapore (inset) (Chong *et al.* 1994)

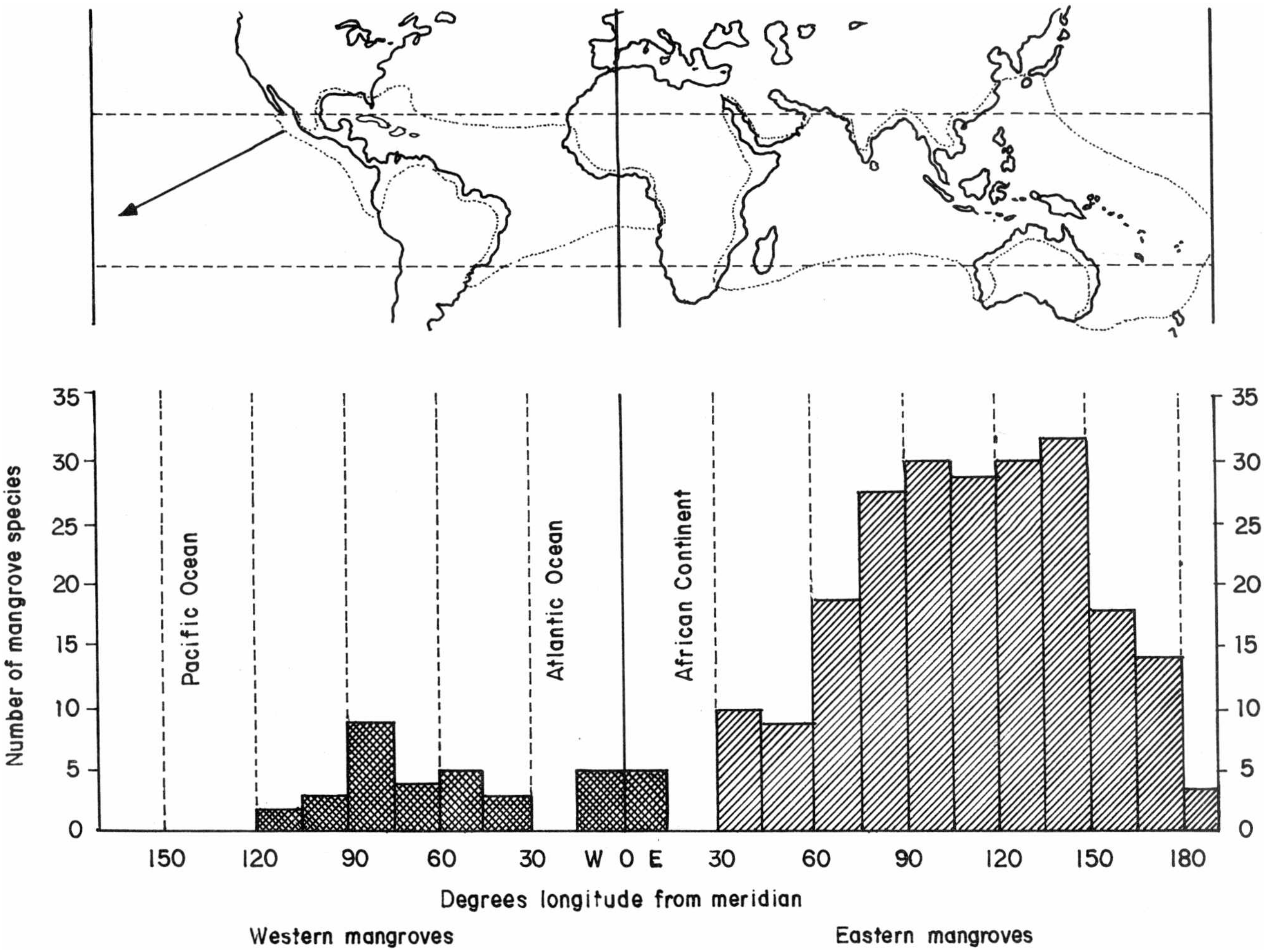

Figure 2. **Generalized distribution of mangroves:** approximate limits for all species; eastern and western groups do not overlap except for possible extension (arrow) in the Western Pacific. Histogram shows approximate number of species per mangroves per 15° of longitude (Tomlinson 1987)

Table 3. **Mangrove species list for South and Southeast Asia** (Spalding *et al.* 1997)

		Bangladesh	Brunei Darussalam	Cambodia	China and Taiwan	Hong Kong	India (west)	India (east)	Indonesia	Japan	Malaysia	Myanmar	Pakistan	Philippines	Singapore	Sri Lanka	Thailand	Vietnam
1	*Acanthus ebracteatus*		•		•			•	•		•			•	•		•	•
2	*Acanthus ilicifolius*	•	•		•	•	•	•	•		•			•	•	•	•	•
3	*Acrostichum aureum*	•	•		•		•	•	•	•	•	•		•	•	•	•	•
4	*Acrostichum speciosum*		•		•				•		•				•		•	
5	*Aegialitis annulata*								•									
6	*Aegialitis rotundifolia*	•						•				•					•	
7	*Aegiceras corniculatum*	•	•		•	•	•	•	•		•	•	•	•	•	•	•	•
8	*Aegiceras floridum*								•					•				•
9	*Avicennia alba*	•	•				•	•	•		•	•		•	•		•	•
10	*Avicennia marina*	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	*Avicennia officinalis*	•	•				•	•	•		•	•		•	•	•	•	•
12	*Avicennia rumphiana*								•		•			•				
13	*Bruguiera cylindrica*		•		•		•	•	•		•	•		•	•	•	•	•
14	*Bruguiera exaristata*								•									
15	*Bruguiera gymnorrhiza*		•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
16	*Bruguiera hainesii*								•		•						•	
17	*Bruguiera parviflora*		•				•	•	•		•	•		•	•		•	•
18	*Bruguiera sexangula*	•	•		•				•		•	•		•	•	•	•	•
19	*Camptostemon philippinense*								•					•				
20	*Camptostemon schultzii*								•									
21	*Ceriops decandra*	•					•	•	•		•	•		•		•	•	•
22	*Ceriops tagal*	•	•		•		•	•	•		•	•	•	•	•	•	•	•
23	*Cynometra iripa*																•	
24	*Dolichandrone spathacea*		•						•		•			•	•	•	•	•
25	*Excoecaria agallocha*	•	•		•	•	•	•	•	•	•	•		•	•	•	•	•
26	*Excoecaria indica*	•							•		•	•			•			
27	*Heritiera fomes*	•						•				•					•	
28	*Heritiera globosa*		•						•									
29	*Heritiera littoralis*	Ex	•		•			•	•	•	•			•	•	•	•	•
30	*Kandelia candel*	•	•		•	•	•	•	•	•	•	•			•		•	•
31	*Lumnitzera littorea*		•		•			•	•		•				•		•	•
32	*Lumnitzera racemosa*		•		•		•	•	•	•	•			•	•	•	•	•
33	*Lumnitzera rosea*													•				
34	*Nypa fruticans*	•	•	•	•			•	•	•	•	•			•	•	•	•
35	*Osbomia octodonta*								•		•			•				
36	*Pemphis acidula*								•	•				•	•	•	•	
37	*Rhizophora apiculata*	•	•	•			•	•	•		•	•		•	•	•	•	•
38	*Rhizophora mucronata*	•	•	•	•		•	•	•		•	•	•	•	•	•	•	•
39	*Rhizophora stylosa*				•				•	•				•	•			•
40	*Rhizophora lamarckii*							•	•		•							
41	*Scyphiphora hydrophyllacea*		•		•				•		•			•	•	•	•	•
42	*Sonneratia alba*		•		•		•	•	•	•	•			•	•	•	•	•
43	*Sonneratia apetala*	•					•	•				•				•		
44	*Sonneratia caseolaris*	•	•	•	•		•	•	•		•	•		•	•	•	•	•
45	*Sonneratia griffithii*							•			•	•					•	
46	*Sonneratia lanceolata*								•									
47	*Sonneratia ovata*		•		•				•		•				•		•	•
48	*Sonneratia gulngai*		•						•		•							
49	*Sonneratia urama*								•		•							
50	*Xylocarpus granatum*	•	•		•		•	•	•		•	•		•	•	•	•	•
51	*Xylocarpus mekongensis*	•							•			•			•		•	

Ex - extinct in that country

(*Lumnitzera*), Pagatpatan (*Sonneratia*) and Tangalan (*Ceriops tagal*). The premiere 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).

2. **Regulatory.** The carrier function of mangroves, also called services or amenities, are geomorphic and hydrologic (coastal protection, erosion control and sediment trapping) and ecological (nutrient, supply/regeneration, storage and recycling of pollutants).

3. **Resource** (Table 5). Utilization of mangrove products may be traditional, small-scale extraction for domestic needs (e.g. fish, crustaceans and molluscs for food; plants for housing, firewood, fodder, medicines and dyes) or commercial scale (charcoal, logs, timber, wood chips, shrimps, molluscs and fish).

   A positive correlation between fish and shrimp nearshore catches and mangrove area (Figure 3) has been documented for Indonesia (Martosobroto & Naamin 1977), Malaysia (Gedney *et al.* 1982; Sasekumar & Chong 1987) and the Philippines (Camacho & 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 nursery function of mangroves, particularly for shrimp (Primavera 1998) may be traced to the provision of shelter and food (Primavera 1996, 1997).

Valuation

Mangrove goods and services may be produced on-site or off-site and marketed or non-marketed (Hamilton & Snedaker 1984). Conventional financial analysis generally covers only traded goods ignoring non-marketed products and services like medicines and coastal protection. Nevertheless, high values of US$1,000-11,000/ha/yr place mangroves at par with intensive shrimp culture systems with net profits of $ll,600/ha/yr (Chamberlain 1991) when complete ecosystems are considered (Table 6).

Conservation and management

Mangrove conservation and development can only be meaningful within an integrated coastal zone management (ICZM) framework. Such ICZM programs need to be community-based in order to harmonize the varying interests and needs of various stakeholders in the coastal zones, e.g., fisheries, aquaculture, settlements and navigation.

The mangrove forest itself can have designated zones for protection, production, recovery and development. The protected forest or preservation-conservation zone provides coastal protection, biodiversity, maintenance, ecotourism and scientific research. The productive or sustained yield zone is mainly for the harvest of forestry and fisheries goods for domestic or commercial use. The conversion zone (marginal and landward portions) can be developed into culture ponds, salt beds, agriculture, etc., and the recovery zone is for mangrove rehabilitation by replanting seedlings or

Table 4. **Philippine towns and villages named after mangroves**

Town/village	Mangrove species
Manila (Maynilad)	*Scyphiphora hydrophyllacea*
Bakhaw, Jaro, Iloilo	*Rhizophora* spp.
Bakawan, Concepcion, Iloilo	*Rhizophora* spp.
Alipata, Aklan	*Excoecaria agallocha*
Tangalan, Aklan	*Ceriops tagal*
Matabao, Siquijor	*Lumnitzera littorea*
Pagatpatan, Misamis Oriental	*Sonneratia* sp.

Table 5. **Products of mangrove ecosystem** (Saenger *et al.* 1983)

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, panelling
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
Tea substitute
Alcohol
Fermented drinks
Cooking oil
Dessert topping
Vinegar
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 kind

Other products
Packing boxes
Wood for smoking sheet rubber and for burning bricks
Medicines from bark, leaves, and fruits

OTHER NATURAL PRODUCTS
Fish
Birds
Crustaceans
Mammals
Shellfish
Reptiles and reptile skin
Other fauna (amphibians, insects)
Honey
Wax

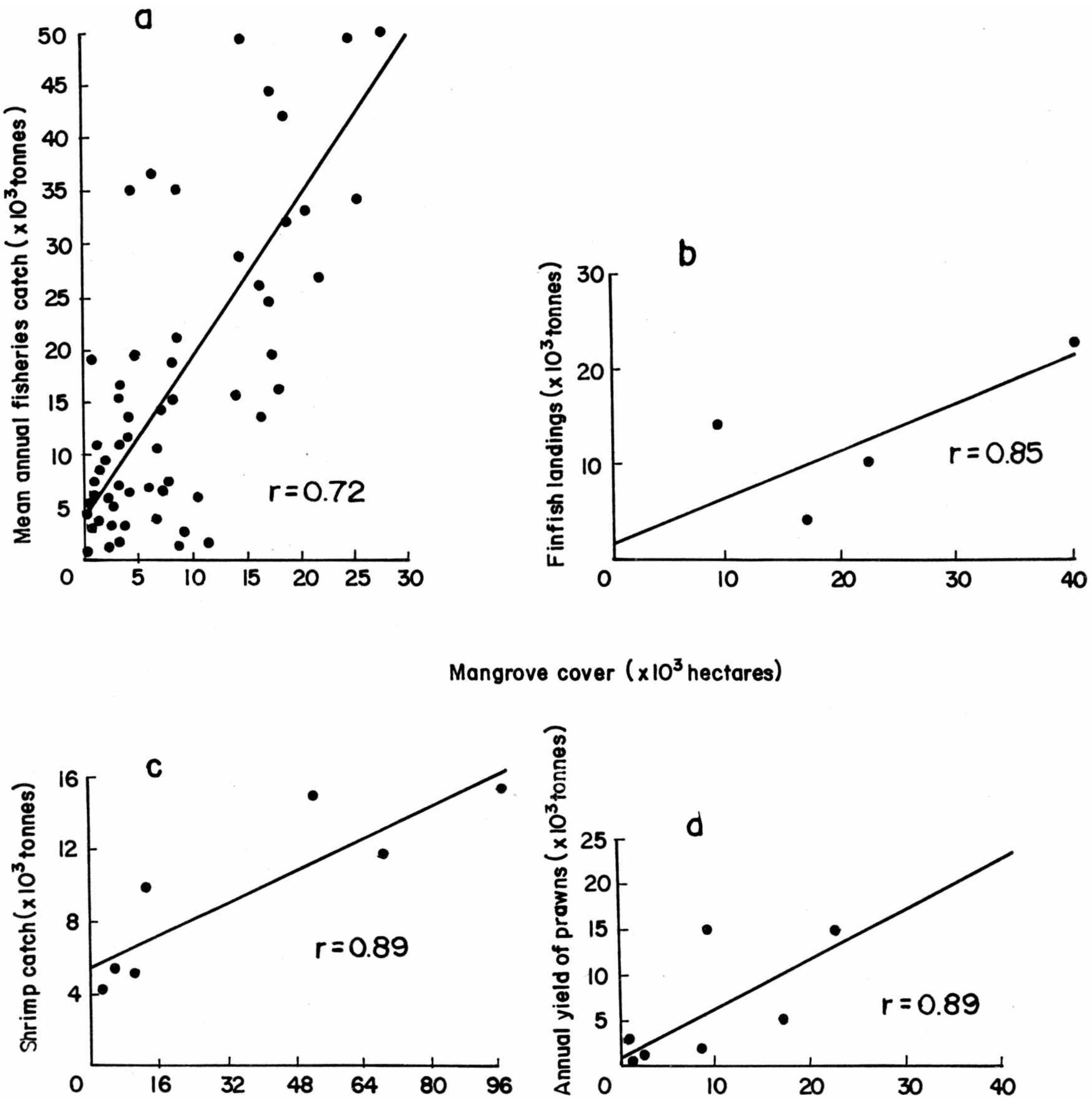

Figure 3. **The relationship between fisheries landings and mangrove areal cover in the ASEAN region:**

a) *Philippines.* Annual fisheries catch by province (Camacho & Bagarinao 1987)
b) *Malaysia.* Mangrove-dependent fish 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)

Table 6. **Economic values placed on products and services of mangroves systems** (After Primavera 1993)

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	600	Hamilton & Snedaker 1984
		Fishery products	125	
		Forestry products	70	
Fiji	1976	Complete mangrove system	950-1,250	Hamilton & Snedaker 1984
		Fishery products	640	
Indonesia	1978	Fishery products	50	Hamilton & Snedaker 1984
Indonesia	1978	Forestry (charcoal, woodchips)	10-20	Hamilton & Snedaker 1984
Thailand	n.d.	Charcoal production	4,000	McNeely & Dobias 1991
Thailand	1982	Fish & shrimp	30-2,000	Hamilton & Snedaker 1984
		Forestry products	30-400	
Brazil	1981-1982	Fish (based on extent of open water)	769	Kapetsky 1987
Malaysia	n.d.	Fishery products	750	Ong 1982
		Forestry products	225	
Malaysia	n.d.	Managed forest (sustained harvest)	11,561	Salleh & Chan 1986
India	1985	Complete system (including fishery products)		
		Maintenance of fauna, air and water purification	11,314	Untawale 1986

n.d. - no data

wildlings or natural regeneration. A good rule of thumb is to develop not more than 30% of a given mangrove area. An equally important guideline is the retention (or planting) of greenbelts or buffer zones between aquaculture ponds and adjoining waterways (shoreline, riverbank, etc.) or between adjacent uses (e.g. shrimp pond and rice field) of the coastal zone.

Not all aquaculture requires clearcutting of mangroves. Examples of mangrove-friendly aquaculture exist either in waterways (seaweeds; bivalves such as mussel, oyster and cockles; and cages for crab and fish) or land-based (ponds and pens for crabs, shrimps and fish). These technologies, particularly mangrove ponds and pens (also called aquasilviculture or silvofisheries) integrate the utilization of mangroves for both forestry and aquaculture production (Primavera and Agbayani, 1997).

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Silvofishery: an aquaculture system harmonized with the environment

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Abstract

Mangrove forests are valuable biologically and economically, but these have been decreasing yearly. It is usually converted into human settlement and for brackishwater aquaculture. To arrest the massive decrease of mangrove forests, reforestation of mangroves has been done but most failed because of conflict among users. To resolve such problems, a system that combines utilization and conservation called silvofisheries has been introduced.

Costs-and-returns of silvofishery ponds per year differ depending on scale and type of species cultured. The following are necessary to maintain the silvofishery pond in good condition: good site and design, suitable vegetation, high economic value of target organisms, good water quality and quantity, and optimal rearing conditions (stocking density, adequate feeding, etc.).

Introduction

The mangrove forest that grows along the coast has a high value both biologically and economically. The mangrove forest has a role as spawning, nursery, and feeding ground for many economically important species of fishes and crustaceans (Matthew & Kaptesky 1988; Saclauso 1989; Caddy & Sharp 1986). Moreover, mangrove forests also function as shields against storms, floods, and erosion (Christensen 1978). The trees can be utilized for charcoal, construction materials and leather dyeing (Saenger *et al.* 1983).

The mangrove area is decreasing yearly. It is usually converted into human settlement and for brackishwater aquaculture. The decrease of mangrove forests has a great influence on the coastal fisheries, causing reduction of catches of fishes (Caddy & Sharp 1986) and shrimps (Clark 1992). Moreover, Kapetsky (1987) pointed out that the production pattern of coastal fisheries might be shifted from production based on detritus feeders to production based on plankton feeders, and noted how large the mangrove area has been degraded.

Reforestation of mangrove has been carried out in some tropical and sub-tropical countries, but these efforts are not always successful because of conflicts of interest in using the area for human settlement, agriculture, aquaculture, or industries. To resolve these problems, a system which attempts to combine utilization and conservation called silvofishery has been introduced.

Silvofishery defined

In the Webster's dictionary, silvoculture is defined as "a phase of forestry that deals with the establishment, development, reproduction, and care of forest trees." According to this concept, the system of unique aquacultural method that allows to rear both aquatic animals and mangrove trees in the same pond is termed silvofishery in Indonesia. This system is also called "tambak tumpangsari" which means brackish pond with multi-crops.

Brief history of the system

It is said that silvofishery was initially developed in Myanmar about 50 years ago by the government in order to make artificial forests with low operation cost. This system allowed the farmers to use the land by contract, obligating them to plant trees. Silvofishery was introduced in Indonesia in 1978 by the Department of Forestry so that the farmer could cultivate fishes and shrimps in addition to trees. The purposes of this system in Indonesia are to minimize planting cost (the farmer does the planting), increase farmer's income, and conserve the mangrove forest (Hartojo 1991). In the 20 years after introduction, several national or local government silvofishery model ponds have been constructed. Some interesting data are described below. In this paper, the author wishes to introduce the two pilot farms at Segara Anakan in Cilacap (West Java, facing the Indian Ocean) and at Cikinon Farm in Karawang (West Java, facing the Java Sea).

Types of system

There are basically two types of silvofishery pond. The first consists of a shallow water area ("caren") which is exposed to the air at low tide, and a deeper area surrounding the "caren" (called "pelataran"). Another type consists of a water area (pond) and a neighboring land area with mangrove trees. The land and water areas are located alternatively.

Design and management

Construction of the pond (Figure 1)
Based on the layout of pond and channel, land is cleared and marked. The pond and channel are formed by cutting and digging. The internal channel ("caren") is usually deeper than the inlet and outlet of water. Pond gate must also be constructed. The "pelataran" is about 1.0 to 1.25 meters in depth. After construction, young mangrove trees like *Rhizophora* are planted on the shallow area ("pelataran") with a distance between plants of about 3.0-4.5 meters by 1.0-1.5 meters. The relative area for the tree ("caren") is usually 80%. Water is introduced to the pond, and seed fish later on. The cost of pond construction was about US$20 in 1981.

Silvofishery ponds in Indonesia's Cilacap project are arranged in series, consisting of two rows. The

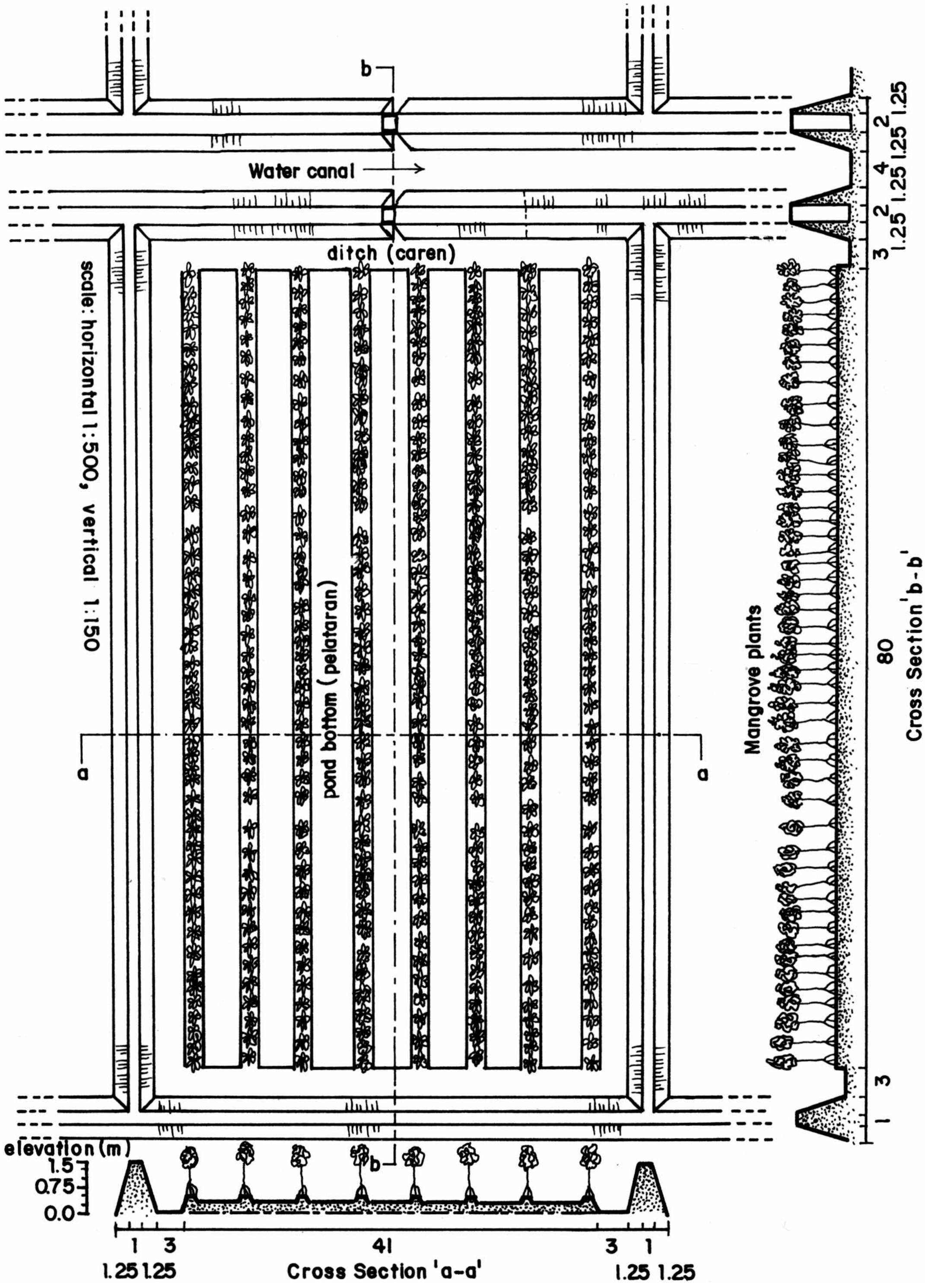

Figure 1. **Layout of one of the "tambak tumpangsari" and its cross-sections** (Takashima *et al.* 1994)

first row has 19 ponds and the other 11. Between the rows is the main water channel which supplies the ponds. The main water channel (for intake and drainage) has the following dimensions: 5.0-6.5 meters in the upper part, 4.0-4.5 m in the bottom, and 1.6-2.0 m depth. The slope of this channel is about 7% to 9%.

The main gate is made of concrete cement. It is 0.85 m in width, 1.9 m in length and 1.9 m in depth. The dike of the water channel is 2 m in width in the upper and 4.5 m in the lower part. The gate for each pond is wood, with or without wings, and is 0.45 m in width and 0.3-0.4 m in depth.

Mangrove vegetation
There is scarce information about suitable species of the mangrove. Usually, *Rhizophora* sp. is selected as in the case of the Cilacap Project.

Main aquatic species for aquaculture
The main species cultured in the pond are: (1) milkfish *Chanos chanos,* (2) tilapia *Oreochromis niloticus,* (3) mullet *Mugil cephalus,* (4) sea bass *Lates* sp., (5) black tiger shrimp *Penaeus monodon,* (6) shrimp *Metapenaeus* sp. and (7) mudcrab *Scylla* spp. Juveniles of black tiger shrimp usually migrate into the pond with incoming tide, but fry of milkfish and tilapia are released artificially. Birds, turtles and snakes are sometimes harvested as by-products.

Environment
In the case of Indonesia's Karawang project, water parameters such as temperature, transparency, salinity, nitrate, nitrite, phosphate, pH, dissolved oxygen (DO), biological oxygen demand (BOD) and total organic matter (TOM) have been analyzed (Table 1). Salinity fluctuated from 0 ppt (at low tide) to around 30 ppt (at high tide), but did not seriously damage the euryhaline species. Other parameters showed slight fluctuation within narrow ranges. Concentration of TOM was higher in the thick mangrove area.

Table 1. **Water quality of silvofisheries pond**

Parameters	Without mangrove	With mangrove cover (40-60%)	(70-80%)	(>80%)
Transparency (cm)	48.0	29.0	44.0	40.0
pH	7.5	7.5	7.5	6.5
Dissolved oxygen (ppm)	7.0	6.5	8.5	5.1
Total organic matter (ppm)	41.0	78.0	39.0	170.0
Ammonia (ppm)	0.270	0.250	<0.001	<0.001
Nitrate (ppm)	<0.001	<0.001	<0.001	<0.004
Nitrite (ppm)	0.027	0.048	0.039	0.061
Phosphate (ppm)	<0.001	<0.001	<0.001	<0.001

Productivity of silvofishery
Production from aquaculture from one site is as follows: milkfish, 467 kg/ha/year; tilapia, 67; shrimp, 150; and crab, 20. This amounts to 703 kg/ha. In another site, milkfish harvest was about 625 kg/ha/

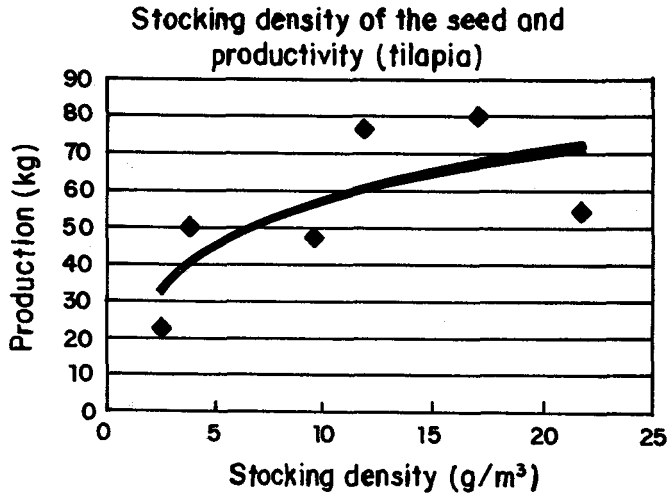

Figure 2. **Production of tilapia at different stocking densities in silvofishery**

year; tilapia, 50; shrimp, 130; and others, 5; or a total harvest of 811 kg/ha. Productivity of fish is relatively low when compared to the intensive system (with artificial feeding). However, the productivity of shrimp seemed high (Table 2).

Total 2. **Total production of wild shrimp in brackish pond with and without mangrove cover** (Karawang project)

	Without mangrove	With mangrove cover 40-60%	With mangrove cover 70-80%	With mangrove cover >80%
Productivity (kg/ha/year)	171	181	355	414

Optimum seed density

There are few data about optimum stocking density of either fish or shrimp. In the case of tilapia, juveniles are released into the pond and reared for several months. Relationship between the stocking density and production was analyzed and is indicated in Figure 2. Production increased with stocking density but reached a plateau after 20 g/m^2

Costs-and-returns

According to Rusdi & Jasin (1994), cost-and-revenue per year of silvofishery differs depending on scale and type of species cultured. The cost-and-revenue of a typical silvofishery pond of size 3-8 ha is indicated in Table 3. This pond contains naturally recruited shrimp juveniles and artificially stocked

Table 3. **Costs-and-returns of silvofishery** (rupiah/ha/year)

Item	Pond covered by dense mangrove trees (> 80%)		Pond covered by sparse mangrove trees (40-60%)	
Farm (area)	6 ha	3 ha	4 ha	8 ha
Operational costs	172,550	609,200	501,000	2,353,700
Variable costs				
Seeds	0	191,400	217,500	360,000
Fertilizer	0	53,000	40,500	50,400
Chemicals	0	29,000	30,000	0
Harvesting	37,500	40,000	25,000	41,300
Fixed costs	1,688,000	295,800	284,000	1,902,000
Gross revenue	360,000	1,235,000	1,128,000	1,385,000
Net revenue	154,000	625,000	529,000	933,000
Total net revenue	924,000	1,875,000	2,116,000	7,464,000

tilapia and milkfish fry. Total net revenue of each farmer varies from 920,000 to 7,500,000 rupiahs in 1994. This income is thought to be reasonable for most farmers until the recent economic crisis.

Problems

The condition of pond and dike always changes because of erosion. The soil in mangrove area is relatively non-compact and has low stability. It is clay sand with high organic matter. Therefore, the dike should have a talus (or slope) of 1:2 or 1:1.25, and the shrinkage factor must be about 40%. To overcome seepage, the soil in the center of the dike has to have low permeability, for example clay. To avoid erosion, it is suggested to grow some grass common in the locality.

Although one of the objectives of silvofishery is to increase income of local peoples, conservation of mangrove must be considered deeply. At the beginning of this system, when mangrove trees are still young, there are less problems. However, when the trees are bigger, fish production decreases because of shading effect and the appearance of fish predators. The ponds in Cilacap project were covered totally with mangrove within 4 years. Therefore, it is recommended to plant gradually. For example, mangrove is planted in 10-15% of the area for every 6 months or one year.

Factors associated with silvofishery

Listed below are the parameters necessary to maintain silvofishery in good condition:

(1) *Selection of the site*
Water quality, type of soil, tidal changes, inlet and outlet of water, species of mangrove trees and surrounding flora, road, worker, market or consumer

(2) *Construction*
Design, supply of the materials, labor, legal permit

(3) *Mangrove vegetation*
Suitable species, quality of young plant, price, supply source, transport

(4) *Selection of fish and/or shellfish*
Adaptability, economic value of target organisms, introduction of the seed, artificial seed production techniques

(5) *Environment check*
Water quantity and quality, stability of water supply, natural fry supply, natural predators (carnivorous animals)

(6) *Observations during rearing*
Growth and survival, stocking density, water quality (daily observation), amount of fertilizer, additional food, fish health, harvesting, sales, visitors, accident record, balance sheet

(7) *Harvesting and marketing*

(8) *Relationship to local community*
Population, number of farmers interested, their ways of work, available services, infrastructure

(9) *Official financial and technical support*

[Literature citations in full may be requested directly from the author.]

Integrated mangrove forest and aquaculture systems in Indonesia

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Abstract

Silvofisheries is a form of integrated mangrove tree culture with brackishwater aquaculture. It is a form of low input sustainable aquaculture. This integrated approach to conservation and utilization of the mangrove resource allows for maintaining a relatively high level of integrity in the mangrove area while capitalizing on the economic benefits of brackishwater aquaculture. Silvofisheries is being promoted in Indonesia as part of a mangrove rehabilitation, conservation and management program.

Pond-based silvofisheries follow three design models: (1) the basic "empang parit" model that is essentially identical to an extensive aquaculture pond with maintenance of mangrove trees on the central platform; (2) modification of the basic model to include a dike constructed around the treed central platform so that the water level within the mangrove area and the open water perimeter culture area can be controlled separately; and (3) further modification of the second model to completely separate the open water culture area from the mangrove area by a gated dike with the pond culture area consolidated to a square or rectangular shape at the end of the enclosed diked area. The ratio of mangrove tree to open water culture area is 8:2 to 6:4. In addition, various methods of minimizing the costs associated with pond construction are being considered. This includes the cultivation of mangrove crabs (*Scylla* sp.) in pens.

The State Forestry Company in Indonesia has successfully developed and implemented silvofisheries sites (e.g., 6,000 ha in West Java-Cikiong with 1,508 farmers; 5,300 ha in Blanakan with 2,060 farmers). A conditional lease program with non-government organizations providing technical assistance to farmers has been successful. This program exemplifies what can be accomplished in mangrove rehabilitation and management within a controlled and enforced program.

Production and financial return from silvofishery varies with the system, site characteristics, the level of energy input (mainly from mangrove litter - green manure) and utilization by cultured species, among other factors. Annual profit of up to \$2,000/ha/yr for a milkfish and shrimp polyculture silvofisheries system has

been reported. There is a need to refine data and analysis, since all costs are often not included, and revenue projections are often based on expected production rather than actual production. Farm interviews in West Java showed a range in gross income from $313 to $946/ha/yr while net profit per individual farm (1.5-10 ha farm size) ranged from $943 to $1,558/farm/yr. There was greater production effort per unit area by farmers with smaller farms. Individual silvofishery farmers often combine incomes from multiple sources.

The application of silvofisheries practices requires reasonable measures of caution as with any activity in an environmentally sensitive area as the mangroves. Additional important considerations in the development of silvofisheries as part of an activity within the mangrove ecosystem include the issues of land ownership, integrated coastal zone planning and development, comparative economic assessment, systems models, optimizing use of inputs, selection of mangrove tree and aquaculture species, better understanding of trophic production and food web utilization, and improvement of economic return.

Introduction

Mangrove forests have great ecological and economic potential. The mangroves play an important role in the ecology of the coastal zone area and in support of the marine species that utilize the mangrove ecosystem during part or all of their life cycles. The mangroves' physical location in the coastal zone transitioning between land and sea makes it a unique habitat.

Conservation of the mangrove resource has drawn the attention of national agencies and international environmental non-government organizations (NGOs). There is growing pressure from these NGOs to stop the destruction of mangroves. The major target is the aquaculture industry, specifically shrimp culture. Some NGOs are moving towards promoting an international boycott on the importation of cultured shrimp. This pressure, along with high profile environmental conferences (e.g., United Nations Conference on Environment and Development in Rio De Janeiro in 1992), are impacting national policies on many environmental issues including preservation of the mangrove forests.

There is a need to balance development pressure and conservation of the mangrove resource. Social issues are closely linked to sustainable development. The economic needs of the coastal populations for jobs and income must be addressed. The mangroves are a coastal resource that have been impacted substantially (e.g., clearing for villages, for wood, construction material, and agriculture) by this growing coastal population pressure. Aquaculture is one of the economic activities that has utilized the mangrove area as a resource.

There are a number of ways the further conversion of mangroves to pond aquaculture can be minimized. These include the intensification of aquaculture on existing sites, the promotion of aquaculture which can be developed with minimum impact on the mangrove ecosystem, better pond siting procedures in mangroves, the integrated management of sustainable uses of the mangrove ecosystem, a shift of pond development to outside the mangroves, and non-land based culture systems (i.e., mariculture).

Two main sustainable alternatives to aquaculture pond development are silvofisheries and mariculture. Silvofisheries is a form of low input sustainable aquaculture integrating mangrove tree culture with brackishwater aquaculture. This integrated approach to conservation and utilization of the 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 more a cultivation system recognizes and mimics natural ecosystem functions, the less resource inputs are required and the less negative environmental effects occur (Folke & Kautsky 1992). Integrated systems strive for increased efficiency, reduced use, avoidance of chemical and medicinal products, less waste generation and the recycling of nutrients. Further extension of aquaculture to meet the needs of the rural poor may be tolerable, provided it is carried out in a controlled manner outside those areas already heavily exploited and environmentally sensitive. The effort must be within an integrated program of conservation and utilization, such as silvofisheries.

Silvofisheries

There are two basic silvofishery models (Figure 1). One model (Type I A, B) consists of mangroves within the pond with a ratio 60-80% mangrove and 20-40% pond canal culture water area. The second model (Type II C, D) consists of the mangroves outside the pond with similar mangrove to water ratio. The pond/mangrove forest (Type II) should be constructed with mangrove strips perpendicular to the coast so that the flow of surface runoff or rainfall is allowed to be transported through the mangroves coastward (not obstructed by pond dikes). The advantages of the Type II model, with the mangroves outside the pond, include greater manageability of the brackishwater pond, greater control, greater flexibility of culture practices, higher potential production, and lower construction cost. It also avoids the potential toxic levels of tannin from the mangrove trees. In addition, it allows for a natural species diversity and flushing of the mangroves. The disadvantage would be that the system is more susceptible to development abuse with encroaching on the mangrove area; however, that can be controlled with lease conditions and regulation enforcement.

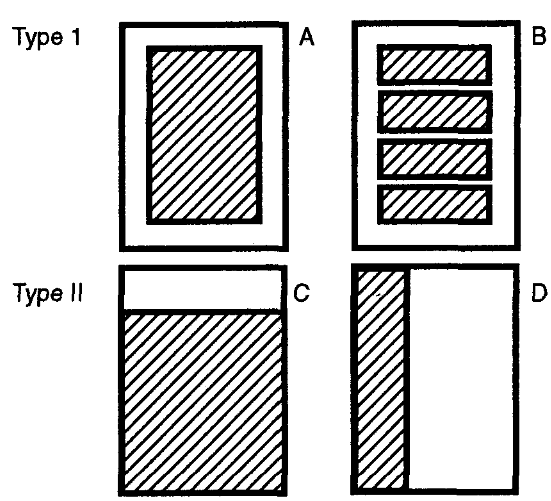

Figure 1. **Silvofisheries models** (cross-hatched areas represent mangrove forest)

There are a variety of designs within these basic models that attempt to balance the conservation issue while maximizing economic opportunity. A number of countries are pursuing a form of silvofisheries, including Hong Kong, Thailand, Malaysia, Vietnam, Philippines, Kenya, Tanzania, and Jamaica. Some of the systems are traditional long-term practices and others are new approaches.

The productivity of the pond is based essentially on the use of “green manure.” The organic enrichment of the pond is from plant material, in this case mangrove tree debris. The amount of debris varies by the size and density of trees and rate of litter fall. This debris has to undergo a decay process before it becomes usable within the food chain of the cultured species.

"Empang parit" model, Indonesia

Indonesia’s mangrove forests (4.25 million ha) represents approximately 25% of the world’s mangroves and is a biogeographical center for a number of mangrove genera. Various entities from university research programs to national programs within the Ministry of Forestry and the Directorate General of Fisheries of the Indonesian government have been studying, demonstrating and promoting silvofisheries. These silvofisheries development range in size from one hectare to thousands of hectares at each site. “Empang parit” (sometimes referred to as “tambak tumpangsari”) is the traditional application of this integrated aquaculture in the mangrove area. It is a silvofisheries model that is being promoted in Indonesia.

The Southern Sulawesi Province Fisheries Office has three demonstration “empang parit” sites that have been recently initiated. A fourth is to be built (1998) in the Luwu District This is part of a national program to promote silvofisheries through the Directorate General of Fisheries Office. The *Mangrove Rehabilitation and Management Project* in Sulawesi (Ministry of Forestry) has “empang parit” demonstration sites in Luwu and Kwandang. As part of the *Island Sustainable Livelihood and Equity Program* (University of Hasanuddin), there is a community development project that includes a demonstration “empang parit” project in Sinjai, Sulawesi. In addition, there are large-scale silvofisheries programs in Cikiong and Blanakan in West Java. Unfortunately, controlled production trials, with the collection of production data and inputs and an economic analysis of these systems have been very limited.

The “empang parit” model represents the greatest level of reforestation or maintenance of existing forest to pond area. The model is illustrated in Figure 1 A. It essentially consists of an unexcavated central platform (80% of total pond area) that alternates between being flooded and exposed depending on the tide. A canal that runs parallel to pond dikes surrounds this platform. The canal is normally 3-5 m wide and 40-80 cm deeper than the platform. Fish, shrimp, and crabs are cultured extensively in the canal and they can enter the central platform area during periods of flooding.

The density of the planted mangrove trees on the platform area ranges from 0.17 to 2.5 trees/m^2. Tree density influences the quantity of litter production and organic load in the pond along with non-mangrove flora and fauna (e.g., algae), among others. Non-mangrove flora/fauna may form an important part of the diet of cultured species. Tree density also influences aquaculture production, with farmers preferring a more open density (approximately 0.2 trees/m^2) for milkfish. The higher openness of the forested areas allows accessibility to the platform area in milkfish culture while a greater tree density can be used in shrimp and mangrove crab culture as these species prefer additional structural habitat and shelter afforded by the mangroves.

The "empang parit" model has a number of disadvantages compared to a brackishwater pond or open pond, as follows:

- greater construction cost per unit of culture area
- greater difficulty to manage
- reduced water circulation and greater potential for stagnant areas with low oxygen levels
- limitation on species cultured (e.g., seaweed would be shaded by trees, reducing growth)
- mangrove trees reduce the penetration of sunlight to the ponds, lowering the productivity of phytoplankton and benthic algae
- potential toxicity of tannin from mangroves

Sinjai (South Sulawesi) site

The "empang parit" operation located in Tongke-Tongke, Samataring, Kecamatan Sinjai Timur (South Sulawesi) was constructed in 1994. It is a cooperative project of the Ministry of Forestry (Province Office), District Government, and the University of Hasanuddin. This evolved out of a community-initiated mangrove replanting program that started in 1984. The replanting consisted mainly of *Rhizophora* (85%) and minor planting of *Avicennia, Bruguiera,* and *Sonneratia* covering an area of 559 hectares. The replanting was an effort to stop the increasing coastal erosion of the fishing village.

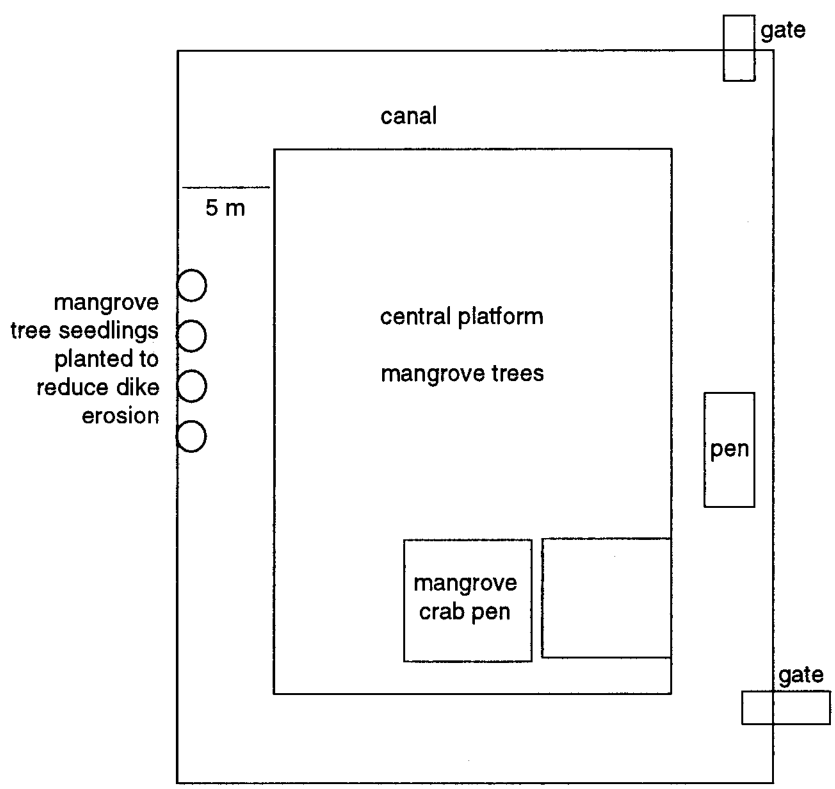

Figure 2. **"Empang parit" pond layout in Sinjai**

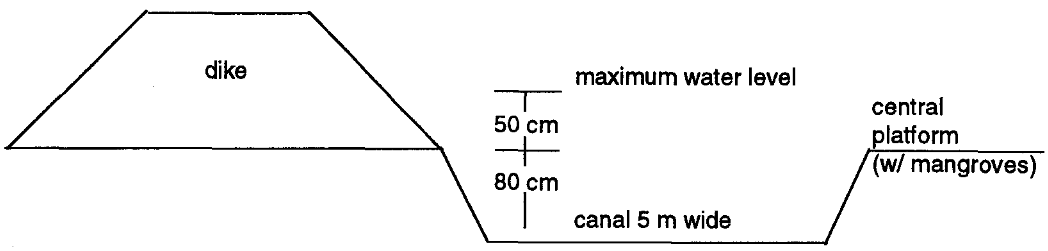

Figure 3. **Cross section of "empang parit" pond at Sinjai, South Sulawesi**

The planted mangrove area consisted of 11 -year old *Rhizophora mucronata* trees that were planted 0.5 m apart. They provided a very dense growth (2.5 trees/m^2) that had to be thinned to 0.6 trees/m^2 to accommodate pen culture in the central platform.

The "empang parit" pond was constructed within the planted mangrove (Figures 2 and 3). Its design and operation is advanced compared to other demonstration or private efforts implemented within the *Mangrove Rehabilitation and Management Project in Sulawesi.* However, it exemplifies the standard or traditional "empang parit" model.

The pond is one hectare in size with two wooden gates. The screened gates are left open all the time to allow the water level inside the pond to fluctuate with the tides. The canal that runs around the inner perimeter of the pond is 5 m wide and has a maximum depth (below the central platform area) of 1.0 m and a minimum of 0.7 m (average 0.8 m). The tide range in the pond is 50 cm (relatively small tidal range which reduces pond flushing capacity). The central platform has a water depth range of 50 cm to complete exposure at the lowest tide, but the average depth is 20-30 cm.

Potential problems with the system include the following:

- The two gates are located on the same side of the pond. This reduces water flushing especially along the opposite canal and would tend to have a greater build up in organic matter on the bottom and potential stagnation of water with lowered oxygen levels.

- The mangrove trees are extremely dense in the central platform area. These will contribute a large amount of organic matter to the pond. With the reduced flushing of water in the pond, this has the potential of high BODs and reduced oxygen levels.

- The construction of pens for mangrove crab culture in the central platform area will further add to the organic matter and associated decomposition of by-products. The additional input of trash fish — 5% of the mangrove crab weight daily -- may increase the BOD to a detrimental point and build-up hydrogen sulfide in the pond bottom.

- With the tidal height of only 50 cm in the pond, water exchange potential is reduced.

- The pond canals cannot be completely drained since the bottom of the canal system is below the lowest tide level. This results in greater stagnation potential and eliminates the periodic drying and oxidizing of built-up organics in the pond bottom.

- Large amounts of organic debris in the pond dike make the dike susceptible to shrinkage, leakage, erosion.

The pond is stocked naturally with juveniles of species entering with incoming tides. These species include siganids (*Siganus* sp), mullet (*Mugil* sp), milkfish (*Chanos chanos*), tilapia (*Oreochromis* sp), shrimp (*Penaeus monodon*, *P. merguiensis*, and *Metapenaeus* sp), mangrove crab (*Scylla serrata*), jacks (*Caranx* sp), and seabass (*Lates calcarifer*). These are harvested by gill net during low tide when they are concentrated in the perimeter canal.

Hasanuddin University is conducting a research project with the Ministry of Forestry and the District Government to improve the aquaculture production of the “empang parit” system. The project is part of a multi-faceted community empowerment and development program called *Island Sustainability, Livelihood and Equity Program.* It has international counterpart.

One of the project's innovative approaches is the addition of mangrove crab (*Scylla serrata* and *S. oceanica*) pen culture (stocking density is 3 crabs/m^2; average size is 70 g). Initially, 12 pens (10 x 10 m; 100 m^2) were constructed within the central platform area (8 pens by Hasanuddin University and 4 pens by the District Government). They intend to construct additional pens to fill the platform area. When completed, there will be 36 pens with a total area of 3,600 m^2. The pens are spaced 1 m apart. There are two smaller pens that are constructed in the canal as part of a Fishery Office experiment. The pens have been stocked with 16.6 crabs/m^2.

Initial results show that the crab culture in the central platform has better water flushing conditions compared to the pens located in the canal. It may be recalled that the canal has about 80 cm of water and is below the lowest *tide* level. Options should therefore be explored to maximize production and to make the system more attractive as a viable option for less productive brackishwater ponds.

Two alternative and innovative designs of the “empang parit” model are being planned. One consists of reducing the pond dike to a low wall 50 cm in height but placing a net on top, effectively increasing dike height while allowing greater water exchange. The central mangrove planted area would be the same. The advantage of this model is lower construction cost with the lower dike wall and elimination of gates. The greater water exchange would minimize water stagnation and the possibility of low oxygen levels that can result in fish mortality. However, there is still a need for a mechanism to drain the pond (e.g., gate or stand pipe). There will also be problems with the extended submergence of mangrove trees.

A second design is to eliminate the pond dikes completely and to construct the bamboo pens within the standing mangrove forest. The pens would be for the culture of mangrove crab as described above. The advantage of this design is the elimination of capital investment associated with the construction of pond dikes, canals, and gates. Furthermore, it reduces aquaculture impact on mangrove forest. The disadvantage is the elimination of profits associated with raising fishes/crustaceans in canal areas.

Cikiong and Blanakan, West Java

Cikiong and Blanakan are part of a government mangrove management and rehabilitation program that includes silvofisheries. The program is administered by Perum Perhutani (State Forestry Company). The sites exemplify what can be accomplished by a controlled and enforced program. All silvofishery farmers must sign a conditioned lease.

Cikiong has 6,600 ha of silvofishery brackishwater ponds with 1,508 farmers involved. All farms use the traditional "empang parit" model with an 8:2 ratio of mangrove: water. The State Forestry Company has experimental projects that modify the design. The modification consists of an additional dike around the central mangrove platform of the pond with separate gates for the canal and mangrove portion of the pond. This would allow the water level to be controlled separately for the trees (which cannot tolerate being submerged for extended periods) and the canal (to maintain a maximum water level during fish culture). Shrimp are harvested daily using a bamboo trap with a kerosene lantern during the evening hours. Average harvest is about 1 kg of shrimp per ha per night (mainly *Metapenaeus ensis).*

Blanakan has an area of 5,300 ha of silvofishery brackishwater ponds with 2,060 farmers. The majority use the traditional "empang parit," however, there are silvofishery models similar to Type IB (Figure 1). There are also ponds with different mangrove to water area ratios up to fully cleared brackishwater ponds. The annual rental fee is US$90/ha (220,000 Rp/ha) for brackishwater ponds (no mangroves), US$37/ha (90,000 Rp/ha) for 1:1, and US$12/ha (30,000 Rp/ha) for 8:2. The main cultured species is tilapia.

A study in 1991 compared production data for the different West Java silvofishery operations (Table 1).

Table 1. **Production from "empang parit" in West Java (kg/ha/yr)** (Anon. 1991)

Location	Total "empang parit" area (ha)	Tilapia	Milkfish	Trash fish	Shrimp	Crab
Bogor						
Tanggerang	1,113		700	200	200	
Ujung Karawang	7,934		600	200	200	
Purwakarta						
Cikiong	6,268		600	250	250	1
Pamanukan	4,263	1,500	500	50	300	
Indramayu						
Indramayu	6,421	1,500	500	50	300	

Full economic analysis of silvofisheries is limited. Annual profit from milkfish and shrimp polyculture was reported to be US$2,091/ha/yr (5,122,000 Rp/ha/yr) (Anon. 1991). However, these figures do not account for all costs of production (e.g., hired labor, annual leases, construction, depreciation, supplies, and equipment). Therefore, they can be overly optimistic and misleading.

Widiarti & Effendi (1989) conducted a more complete economic evaluation of operations under the Perum Perhutani at Blanakan and Cangkring in West Java. Results showed an annual net income of US$248/ha (608,500 Rp /ha) for farms at Blanakan and US$408/ha (1,000,700 Rp/ha) for farms at Cangkring. These farms utilize the traditional "empang parit" model with an 8:2 ratio of mangrove to water channels. Therefore, a reasonable expectation of annual net income from this model type would be the average of the above two sites which is US$328/ha/yr (804,600 Rp/ha/yr). Approximately 50% of the farmers' income was attributed to "empang parit" with the balance from agricultural or other sources of income. The difference in net income between the two sites was mainly attributed to the species cultured. Blanakan farms mainly produced tilapia while the Cangkring produced mainly milkfish. Milkfish had a market value approximately 33% higher than tilapia.

A similar financial analysis was made by the Forest Management Division (Bagian Kesatuan Pemangkuan Hutan) of Perum Pertuhani (Table 2). The mangrove crab, seabass (*Lates calcarifer*), tilapia-chicken and milkfish-shrimp production data are from Cikiong silvofisheries operation. The milkfish monoculture (for food and bait) is from silvofisheries in Cibuaya (Karawang District, West Java). On a per unit production basis, the mangrove crab culture out-performed all other species by a substantial margin. This would justify increased research on the various aspects of mangrove crab culture (e.g., larval culture, grow-out, optimized cost-effective feed conversion, species differentiation and hybridization, among others). As in the financial analysis reported above, all costs were not included; however, the results are useful to point out the magnitude of difference in the potential economic return among the species considered. This assists in designing a production strategy for an "empang parit" system that improves the economic returns of farmers.

Table 2. **Value of production from "empang parit" systems in Cikiong and Cibuaya, West Java** (US$1=2,450 Rp) (Anon. 1994, 1995)

	[1]Mangrove crab	[2]Seabass	[2]Tilapia and chicken coop	[2]Milkfish and shrimp	[2, 3]Milkfish
Annual net profit (ha/yr)	US$1,367 Rp 3,350,000	$1,347 3,300,000	$2,601 6,372,000	$2,508 6,144,000	$1,322 3,240,000
Net profit per unit area (m^2/yr)	US$22.79 Rp 55,833	$0.13 330	$0.26 637	$0.25 614	$0.13 324

[1]Cultured in 60 m^2 cage
[2]Cultured in "empang parit" system with an 8:2 (mangrove:water) ratio
[3]Monoculture for food and bait

An abbreviated interview of farmers involved in the *Mangrove Rehabilitation and Management Project* in Sulawesi (FitzGerald & Sutika 1997) at both Blanakan and Cikiong showed an average gross income of US$580/ha/yr (1,419,859 Rp/ha/yr) (range: US$313-946/ha/yr or 766,200-2,318,200 Rp/ha/yr).

The net profit was an average US$476/ha/yr (921,632 Rp/ha/yr). The variation in net income per farm was less, an average US$1,283/farm/yr (3,143,4154 Rp/farm/yr) (range: US$943-1,558/farm/yr or 2,310,400-3,816,400 Rp/farm/yr). The individual farmer operated between 1.5 to 10 ha of silvofisheries ponds. This may indicate a greater production effort per unit area by farmers with smaller farms. In addition, the individual with 1.5 ha supplemented his income (approximately 40%) from rice fields. The individual with 10 ha obtained 100% of his income from silvofishery. This assessment of production and costs at least provides a more reasonable evaluation of silvofisheries' potential. However, more research is needed to gather a fuller assessment of the silvofishery models.

Recommendations

Considerations in silvofisheries models

Silvofisheries should be approached with reasonable caution as with any development in environmentally sensitive areas such as the mangrove ecosystem. The basic principles of sustainability must be considered prior to development. For example, the availability and impact on the natural population of species cultured must be assessed including the availability and impact on seedstock recruitment and survival.

The overall development strategy should integrate environmental, conservation, social, and economic issues. Development is a dynamic, evolving process that changes over time with expanding activities, research, and emerging technology. These changes should be reflected in the comprehensive coastal plan which can be periodically revised. Baseline information on the environmental characteristics of specific areas, in particular, carrying capacity and potential uses, must be considered.

Development should be diverse in nature and serve the fundamental needs of the community while providing an economic base for expansion within an environmentally sensitivity framework. The integrated approach will allow for both sustained economic activities while implementing a conservation and rehabilitation program for the mangroves.

Comparative economic assessment

From a strictly economic perspective, it is useful to evaluate the capital costs and the potential value of products in silvofisheries, and compare them to brackishwater extensive culture. This is of value in decision making for the community or individual entrepreneur, and to planning/policy organizations. It can also provide a measure of the level of incentives that may be necessary to make silvofisheries a comparable economic activity for private land owners or entrepreneurs.

Both silvofisheries and brackishwater extensive culture ponds are essentially the same in construction. The exception is the central platform area; in extensive aquaculture, the area is cleared of all vegetation. The cost associated with perimeter dike construction would usually be less in silvofisheries because of the cost efficiency in reduced perimeter length associated with the adoption of a square design. The construction costs associated with the clearing of the central platform would be zero for a silvofishery pond except when cross channels are constructed through the platform. Therefore, from a construction cost perspective in comparing a silvofishery and an extensive brackishwater aquaculture pond, these costs can be represented as follows:

Silvofisheries pond = X (D_s) + Y (CA_s)

Brackishwater extensive aquaculture pond = X (D_a) + Y (CA_a)

where:
- X = cost per linear meter of perimeter dike
- D = linear length of perimeter dike
- Y = clearing/construction cost per square meter of central platform
- CA = area of central platform cleared
- subscripts a, s = indicate brackishwater extensive aquaculture or silvofisheries ponds, respectively

If the difference in annual net operating value of products between the silvofisheries and extensive pond (ΔV_{s-a}) minus the difference in the annual depreciated cost of construction between the silvofishery and extensive aquaculture pond (ΔC_{s-a}) is equal to or greater than zero ($\Delta V_{s-a} - \Delta C_{s-a} \geq 0$), then, from an economic perspective, the silvofisheries pond would at least be equal to or have an advantage to an extensive aquaculture pond system. This economic assessment can be further refined in a benefit/cost analysis that takes into account the tangible and intangible values associated with environmental benefits of maintaining the mangrove vegetation in silvofisheries.

Ownership

Mangroves and tidal wetlands are traditionally common property resources with rather low perceived value in developing countries. The use or optimum yield from any common property resources must be carefully executed and must consider a mix of benefits, including those of environmental, social and economic significance. In coastal aquaculture, the competition is usually between the traditional users of previously open-access resources and those who are encroaching on and expropriating these resources. This competition impacts on the social, economic, cultural, and environmental status of the area. Therefore, it is critical that the interactions among these factors are fully integrated into the assessment and planning process to increase the level of success in meeting the goals and objectives of land use and development plans, and to reduce potential user conflicts.

Land ownership is an important decision criterion in the use of the mangrove area. The "no associated land cost" or relatively low cost is a significant incentive for development. Therefore, the use of the mangroves allows the rural, low-income, and landless to enter land ownership through a lower entry barrier regardless of the long-term development costs (mainly in labor) and environmental costs. This is important from a social perspective in that land ownership brings a higher status in the community, which potentially raises the individual's influence in the community. Land ownership not only benefits the individual, but also bestows long-term benefit to his family and heirs.

Silvofisheries has been successful in situations where community property or government land is conditionally leased to community projects or individual/family operations (e.g., Blanakan and Cikiong). However, in areas that are under private ownership, the owner normally would have little incentive to reforest cleared property because forests are perceived as being of lower value. This emphasizes the importance of maintaining government ownership and control of mangrove areas. This will allow more controlled utilization through conditional leases in an integrated and environmentally sensitive manner under a land use plan.

In the case of private ownership of mangroves, capital cost related to pond construction seems to be inadequately considered. The cost of dike and gate construction is about the same for silvofishery pond and for aquaculture brackishwater pond. The revenue generation from silvofishery would have to justify this type of investment on private property with private capital as opposed to an activity with a greater rate of return on investment (e.g., semi-intensive or intensive aquaculture operation). Underwriting silvofishery demonstration projects that are not carefully designed within basic economic realities can create a misleading model that is not viable on privately owned land without substantial government subsidy. Therefore, demonstration projects have to be realistically designed to fulfill its long-term objectives. If the mangrove forest is privately owned, and the environment-friendly development is in the public good, the government can consider providing incentives to private landowners to use silvofisheries, and rehabilitate or reforest former mangrove areas. This incentive system should be designed to provide a reasonable economic return within an enforceable regulatory framework. Some incentive options could include the following:

- *Tax rebate or abatement on property tax.* This could be based on a formula that essentially defrays some of the economic loss the private landowner would incur through reduced production and land value.

- *Higher property tax on brackishwater ponds in former mangrove areas that are abandoned or low in production.* This negative incentive approach would place an increased economic cost to the owner to leave the property unproductive. Therefore, he would have the incentive to reforest the property or utilize silvofisheries to increase production (or improved brackishwater pond condition) and relieve the increased tax expenses of the property.

- *Land exchange with government property in a non-critical habitat area of equivalent economic value.*

Incentives and disincentives can be used in implementing policies that have been determined to be desirable (national and local level). The “green tax” has been advocated as a means of addressing environmental externalities. “Green tax” is cheaper to administer, does not distort economic activity, and is fair (Anon. 1996).

Systems model

Silvofishery is a labor-intensive technology appropriate for an individual, family or community operation and can be a viable alternative to brackishwater pond culture. It diversifies products from the land and aquatic production within an environmentally benign framework and is integrated into the mangrove forest ecosystem. But it is not suited to commercial large-scale aquaculture activity on privately owned land.

The cost of pond construction makes “empang parit” not economically attractive without fuller integrated utilization of resources. However, “empang parit” and other silvofishery models can be a useful alternative activity within the mangrove intertidal zone as a subsistence and conservation type of activity. Silvofishery models can also be viable forms of aquaculture in converting abandoned brackishwater ponds into an integrated reforestation and utilization program especially where the cost of pond construction is not included. Government subsidy in the form of low-cost lease and a package of technical and capital assistance should make it an attractive option to meeting the needs of the rural poor within a program of mangrove rehabilitation.

The selection of the most appropriate silvofishery model will be site-dependent and influenced by the status of the mangrove ecosystem. Therefore, no single model is the best. Silvofisheries should be integrated into an area-wide integrated approach to coastal zone management. This allows for maintaining a relatively high level of integrity in the mangroves while capitalizing on the economic benefits of brackishwater aquaculture.

The silvofishery model preferred in most applications is the integrated mangrove-crab culture systems. Its advantages include: (1) no permanent alteration of mangrove forest, (2) low capital investment, low labor requirement, low technology, and small unit size; (3) incremental ability for expansion; and (4) production of a high value product.

For areas under private ownership, the alternating brackishwater pond/mangrove model would be the most appropriate (Figure 4). It has a number of advantages and disadvantages that are site dependent. It maintains the same maximum ratio of mangrove to pond culture area as high as any of the other models while providing superior management and production. Variations in the ratios can be made based on environmental, conservation, development, and policy considerations. It is recommended that units of 2- or 4-ha ponds be standardized as the model units. This would mean that for every 2-ha pond, there would be an 8-ha mangroves maintained around it. Advantages of this model are: (1) the mangroves outside the pond are structurally unaltered; and (2) the tidal and ground water movement are not constrained. But the model is susceptible to violation - by encroachment or non-compliance — where regulations are not rigorously enforced.

Mangrove research

Studies on how to increase production from various silvofishery models should be conducted. This is particularly important for reforesting private lands. The different silvofishery models, specifically the two main types (mangroves integrated within the pond area and mangroves integrated around or outside pond area), should be evaluated. This should include optimizing the use of inputs and stocking strategies for different species within a polyculture system.

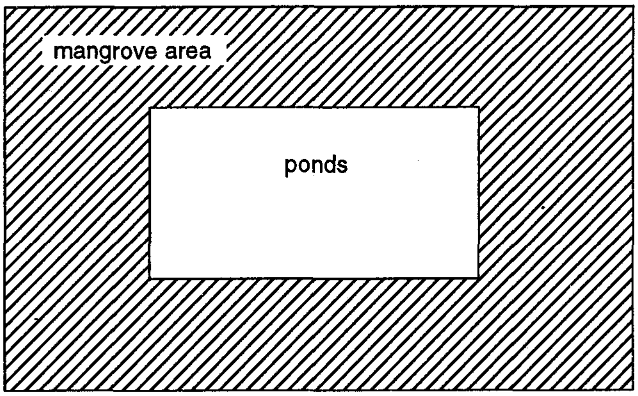

Figure 4. **A 10-ha silvofisheries site (with 8:2 mangrove to brackishwater pond ratio) alternating brackishwater pond and mangrove (not to scale)**

Density of trees and silviculture management (e.g., trimming, selective cutting, etc.) to maximize the production of litter has to be evaluated. The species of mangrove trees that can be used for specific pond conditions should be determined as well. Analyses should be made on the type and amount of vegetation cover, rate of litter production of different trees, and decomposition rates of different tree litters. These are important factors in the food web supporting pond productivity. The food web itself -- from mangrove vegetation litter to ponds -- should be studied so that appropriate management practices can be developed.

Evaluating trophic production and food web dynamics is of major importance. It is necessary to include all forms of macrophytes and algae to evaluate the different autotrophic compartments in total primary production, and then to study the energy flow and its utilization in the mangrove ecosystem. It will be equally important to determine and document the differences in food items ingested from those that are actually assimilated. This will assist in selecting the most appropriate aquaculture species for silvofisheries.

A thorough study of macro- and microalgae in mangroves to understand their growth dynamics and growth parameters within the mangrove forest is essential to the aquaculture component. Changes in the balance of autotrophs in nutrient cycles can maximize the energy available to the food web supporting the aquaculture species. It will also be important to determine how to best balance mangrove growth (density, height, canopy cover, species, etc.) with production of algae, since excessive shading from dense macrophytic vegetation would impair production of algae within the platform area. These are all part of a requirement to best enhance the quality and quantity of the food web.

Silvofisheries has the potential of capturing some of the economic benefits of the mangrove areas within an environmentally sensitive framework and a sustainable activity. Improvement in the economic return from this system will be a key factor in its widespread acceptance. Silvofisheries can also provide alternative income to the rural poor and reduce development pressure on the mangrove forests. Therefore, it should be considered in an overall development and management strategy for the coastal zone and could serve a role in the transition that shifts more intensive aquaculture to areas outside the mangroves.

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country efforts

Wild juveniles of mudcrabs *Scylla olivacea* and *S. tranquebarica* for stocking in aquasilviculture pond in the Philippines

Japan: Mangrove areas and their utilization

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Abstract

Although Japan has large-scale aquaculture, there is no aquaculture development in mangrove areas because the total area is small (553 ha) and strictly protected. Mangroves are preserved in comparatively good condition. Future development of aquaculture in mangrove areas is considered small-scale. Rather than aquaculture, Japan practices enhancement and management of wild fisheries. Tourism is another industry that would have an important role in mangrove utilization. But basic research on mangrove ecosystems is essential prior to determining policies for utilization of mangrove areas. International cooperative research work is important to encourage mangrove-friendly aquaculture and protect the environment.

Introduction

Research on mangroves has been conducted for several decades. In Japan, several books concerning mangroves were published recently (Tsujii *et al.* 1994; Odaki 1997; Nakamura & Nakasuga 1998). However, information on mangrove ecosystems and its utilization for fisheries are limited to several fish and crustacean species (Shokita 1988). This paper reports the present status of aquaculture in Japan and the utilization of mangrove areas, and discusses strategy for the sustainable utilization of mangrove areas.

Brief overview of aquaculture

The total fishery and aquaculture production has been decreasing after its peak of 12.8 million tons in 1984 (Figure 1). This trend is mainly due to decreasing landings of sardine and walleye pollock. But aquaculture production has been stable for the last 10 years (1987-1996), ranging from 1.2-1.4 million tons which is valued at 6-7 hundred billion yen.

The ratio of aquaculture production against that of total fisheries has been increasing, due to the decrease of total fishery production. In 1996, aquaculture accounts for 18% in weight and 30% in value. Marine aquaculture is dominant, accounting for more than 90% of total.

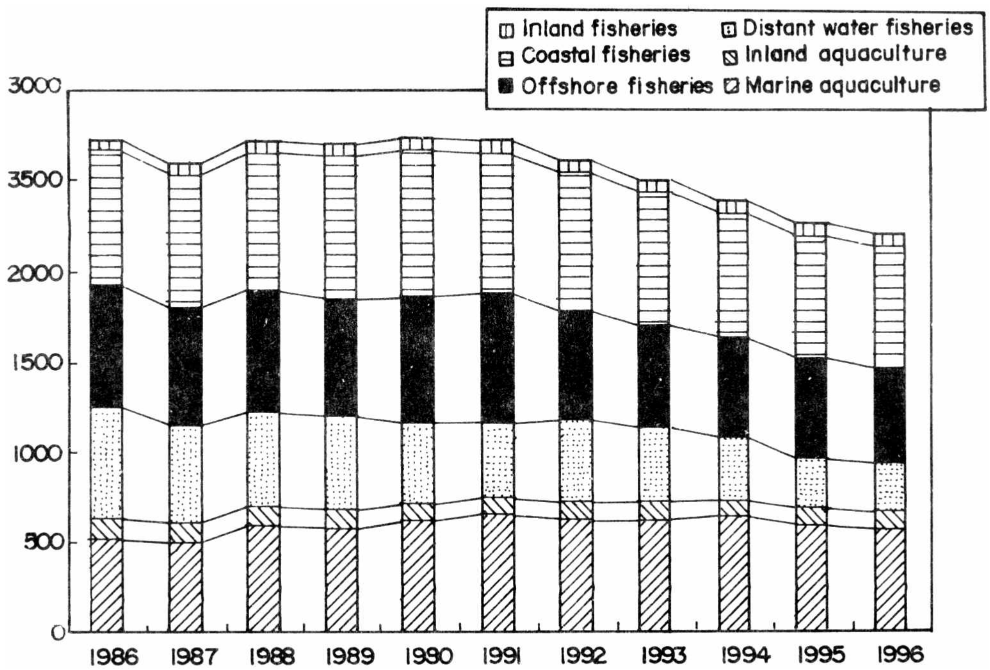

Figure 1. **Catch and yield in fisheries and aquaculture in Japan,** 1986-1996

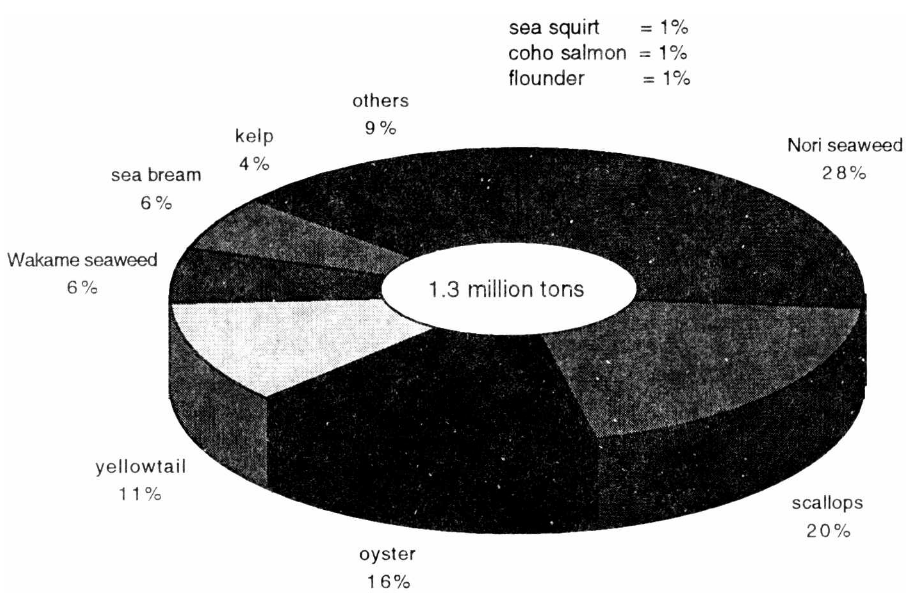

Figure 2. **Aquaculture production in Japan, 1996**

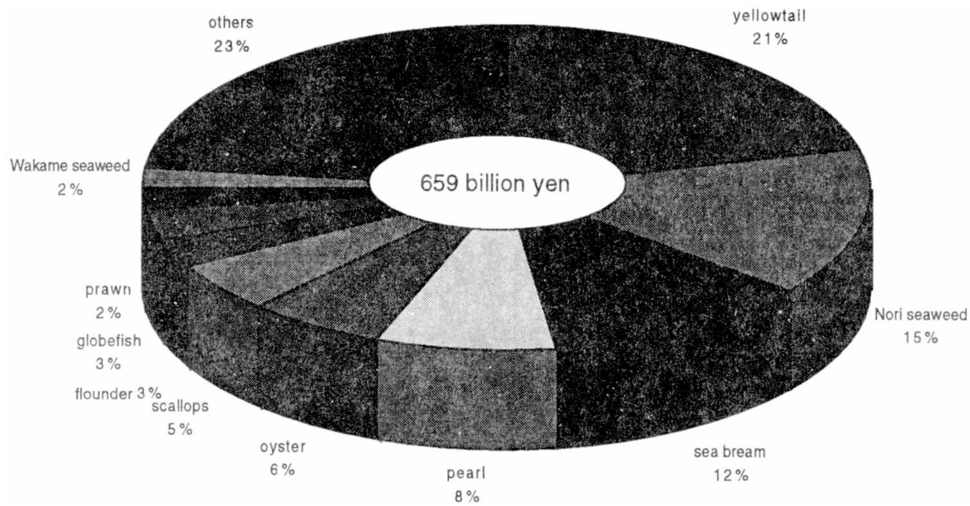

Figure 3. **Value of aquaculture products in Japan, 1996**

The top five aquaculture species in 1996 are: nori (seaweed), scallop, oyster, yellowtail and wakame (seaweed) in quantity (Figure 2) and yellowtail, nori, sea bream, pearl and oysters in value (Figure 3). Aquaculture in mangrove areas is nil because the area is small and legally well-protected.

Exploitation and protection of mangrove areas

History and utilization

Mangroves grow from Kagoshima to Okinawa (Figure 4) with more than 80 mangrove communities. The northern limit of mangroves is located in Kiire, a town in Kagoshima (31'20'N), where a *Kandelia candel* community is designated as a natural monument. The total mangrove area in Japan is only 553 ha and the mangroves in Iriomote Island accounts for 80% of the total. There are seven typical constituent species (Table 1), although mangrove areas have 7 to 19 species. Mangroves can be used as timber, firewood, dyeing materials, antiseptic and so on. At present, however, they are seldom utilized as raw materials in primary industries except for their use as textile dyes.

Fisheries in mangrove areas are limited to several fishes, crustaceans and molluscs. These are the shellfish *Terebralia palustris*, mud crab *Scylla oceanica,* shrimps *Penaeus monodon, Metapenaeus moebi*, *Macrobrachium* spp; and the black porgy *Acanthopagrus sivicolus*, mullets (Mugilidae) and snappers (Lutjanidae) and so on. Total landings of these species are so small that no statistics are kept, except for *A. sivicolus* of which annual landings are approximately 20-45 tons. *A. sivicolus* inhabit brackishwater areas in young and adolescent ages, later moving to coastal waters. Therefore, catches in mangrove and coastal waters are included in statistics of *A. sivicolus.*

Mangrove areas are very important as nurseries for many aquatic animals including target species in capture fisheries. At present, there is no aquaculture in mangrove areas, except for mud crab which have been experimentally reared in a pond constructed near the tidal flat in Iriomote Island.

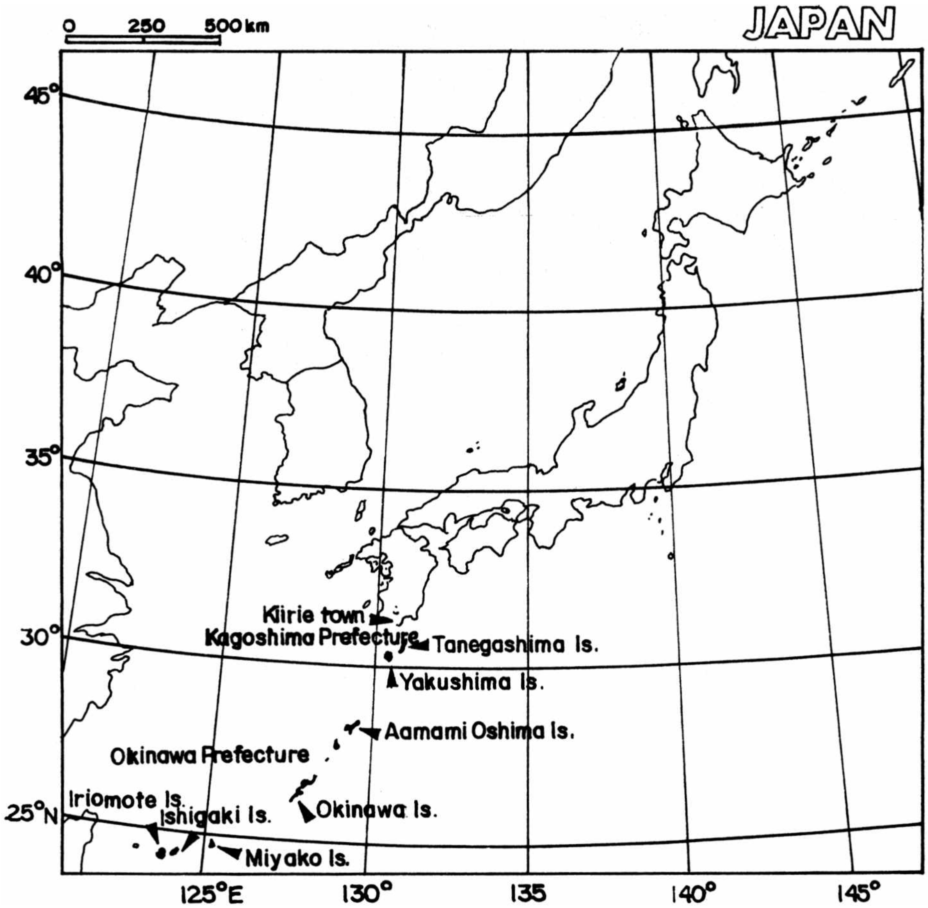

Figure 4. **Areas in Japan where mangroves grow** (arrow)

Table 1. **Typical mangrove species found in Japan**

Family	Species	English name	Japanese name
Sonneratiaceae	*Sonneratia alba*		Mayapushiki
Rhizophoraceae	*Bruguiera gymnorrhiza*	Black mangrove	Ohirugi
	Kandelia candel		Mehirugi
	Rhizophora stylosa	Spider mangrove	Yaeyamahirugi
Combretaceae	*Lumnitzera racemosa*		Hirugimodoki
Verbenaceae	*Avicennia marina*	Grey mangrove	Hirugidamasi
Arecaceae	*Nipa fruticans*		Nippayashi

The protection of mangroves

Some mangrove areas are protected as a natural monument or by various laws. Deforestation is not permitted except in some cases such as research.

Pressures on mangrove forest by human activity come from direct destruction like construction of ponds and ports, and from indirect effects of these works. Although the mangrove areas have not been changed on a large-scale, influence of regional small-scale destruction to the ecosystem is considered substantial. Recently, ecotourism is gaining popularity. Large motorboats run at high speed in mangrove areas and, as a result, mud near the roots of mangrove is washed away by waves made by boats. This is considered to be one probable cause of mangroves falling down and decaying.

There is a mangrove area that was planted by the government. This was at a construction site of a fish port. The purpose was to maintain the stability of the beach and to protect the environment. Non-profit organizations and several corporations have planted mangrove seedlings, too. Some of these corporations even investigated methods of planting seedlings.

Mangrove research related to fisheries

International cooperative research has been conducted on several themes related to mangrove areas. One is a program that seeks to establish the status of marine fisheries and stock management. This was started in 1995 between Malaysia and Japan. Another is a research to develop techniques of diagnosing and controlling viral diseases in prawn, conducted between SEAFDEC and Japan.

The Japan International Research Center for Agricultural Sciences and other national fisheries research institutes under the Ministry of Agriculture, Forestry and Fisheries play principal roles in mangrove projects. Domestic research on productivity in mangrove areas and ecology of the mud crab is proceeding in Ishigaki Island. Research objectives are focused on the process of organic matter supply, the role of benthos to dissolve organic matter, and actual state and ecology of zooplankton, crustaceans and fishes. For mud crab, the ecology at settlement, especially characteristics of the juvenile habitat, are being investigated. Techniques of mass seed production and releasing seedstock in sea ranching have been developed for mud crab and black porgy. The Japanese Government subsidizes the development of sea ranching techniques.

Strategies for utilization, protection and improvement of mangrove areas

Mangrove ecosystems have six main values and functions:

(1) maintaining the stability of coast, estuary and beach areas
(2) protecting the land behind the mangrove areas from tide and river
(3) trapping substances derived from land
(4) maintaining biodiversity
(5) providing habitat for animals including important species in fisheries at various stages of their life cycles
(6) providing nursery of juveniles of target species in capture fisheries

These values and functions can not exist unless the mangrove ecosystem is maintained. For fisheries and aquaculture, themes 4-6 should be resolved first. The understanding of mangrove ecosystems, in a broad sense, is necessary before or during the process of determining policies to enhance value and preserve mangrove areas. Towards this goal, research priorities must be on:

- understanding the functions of and relationships within mangrove ecosystems
- developing enhancement techniques for fishery resources
- establishing a scheme for the sustainable utilization and management of fishery resources

In terms of aquaculture, there is little possibility that mangrove areas will be utilized for aquaculture in Japan. The reasons are (1) the suitable area for aquaculture is so small that large-scale aquaculture in mangrove areas can not occur; (2) cutting and destroying mangroves are strictly restricted, therefore making ponds by cutting mangrove is legally not possible; and (3) tourism is a more beneficial industry than aquaculture.

Instead of aquaculture, the enhancement and management of natural fishery resources are expected. Sea ranching is a prospect for mangrove areas and sustainable farming can be done within the natural ecosystem. Target species of the sea ranching in mangrove areas are the mud crab and the black porgy. Other than fishery production, tourism is an important industry in mangrove areas. Protection and restriction for human activity in mangrove areas are essential for the sustainable utilization as resources for tourism. Usage of mangrove areas for education regarding the environment will increase. On the contrary, the situation in Southeast Asia is very different from that of Japan.

Mangrove areas are important fishing grounds and utilized in a wide variety of ways. The Japanese government has supported the solution of controversial issues on the sustainable utilization of mangrove areas in Southeast Asia based on research in domestic waters. For example, international cooperative research has been progressing on extensive polyculture techniques and the development of techniques of diagnosis and control of shrimp viral diseases. In terms of mangrove-friendly aquaculture, the Japanese government has began a five-year project this year to support SEAFDEC activities. International research cooperation must be promoted further.

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Philippines: Mangrove-friendly aquaculture

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Abstract

Mangrove areas in the Philippines were once considered vast tracts of wasteland that can be developed into other land uses. The economic "advantages" associated with such exploitation were considered socially "valuable" to human communities. Such advantages and exploitation, however, are now questioned, with the cost to society reevaluated. This paper discusses the factors causing mangrove deforestation with emphasis on aquaculture. Existing and future programs like the government's Coastal Resource Management project for the implementation of mangrove-friendly aquaculture are presented. Research needs and problems affecting mangrove management are likewise discussed.

Brief overview of aquaculture

Aquaculture is a major contributor to overall fish production. It is the only sector where continuous growth has been attained when compared to the municipal and commercial fisheries sectors. Aquaculture production of 392,348 tons in 1982 rose to 957,390 tons in 1997. This is about 35% of total fish production (2,766,507 tons) in 1997, a big contribution inspite of the many problems confronting the industry.

In 1996, there were 239,323 ha of brackishwater ponds although production varied according to fishpond management. Milkfish and tiger shrimp are still the major commodities reared and produced through aquaculture.

Table 1. **Estimates of mangrove forest area and depletion rates, 1920-1988**

Year	Estimated mangrove forest (ha)	Average depletion (ha/yr)
1920	450,000[a]	
1950	375,020[b]	2,499
1972	227,947[c]	6,685
1988	139,100[d]	5,553
1988	149,400[e]	4,572*
1988	141,713[f]	

[a] Brown and Fisher. 1920. Minor forest products of the Philippines. Bureau of Printing, Manila
[b] Aerial photographs taken in late 1940s and early 1950s by NAMRIA
[c] Digital analysis of 1972 LANDSAT data (NRMC)
[d] DENR. 1988. Philippine-German Forest Resources Inventory Project
[e] Swedish Space Corporation. 1988. Final report on mapping of the natural conditions in the Philippines (SPOT satellite images)
[f] NAMRIA's manual interpretation of 1987 SPOT satellite data
*1920-1988

Table 2. **Remaining mangrove areas in the Philippines in 1988,** by region and province (NAMRIA 1990)

Region	Province (area in ha)	Area (ha)	% of total
1	Pangasinan (200)	200	0.14
II	Cagayan (3,000), Isabela (400)	3,400	2.43
III	Pampanga (300), Zambales (200)	500	0.36
IV	Aurora (300), Marinduque (1,100), Occ. Mindoro (900) Or. Mindoro (1,500), Palawan (42,300), Quezon (4,000) Romblon (700)	51,000	36.50
V	Albay (400), Camarines Norte (2,500), Camarines Sur (2,500), Catanduanes (1,200), Masbate (1,500)	9,900	7.09
VI	Aklan (0), Antique (100), Capiz (1,700), Iloilo (300) Negros Occ. (725)	2,825	2.02
VII	Cebu (400), Bohol (8,700), Negros Or. (550)	9,650	6.91
VIII	Eastern Samar (6,000), Northern Samar (5,500), Western Samar (10,450), Leyte (2,900)	24,850	17.79
IX	Basilan (3,600), Sulu (*), Tawi-Tawi (*), Zamboanga Norte (300), Zamboanga Sur (15,400)	19,300	13.81
X	Agusan Norte (1,100), Agusan Sur (*), Misamis Occ. (1,200), Misamis Or. (*), Surigao Norte (6,300)	8,600	6.15
XI	Davao Norte (*), Davao Sur (*), Davao Or. (800), South Cotabato (*), Surigao Sur (6,300)	7,100	5.08
XII	Lanao Norte (1,300), Maguindanao (300) Sultan Kudarat (800)	2,400	1.72
Total		139,725	100.00

*not available

Table 3. **Mangrove area converted to fishponds** (ha)

Year	BFAR[1]	Change In area	BFAR[2]	NAMRIA[3]
1970	168,118	3,704		
1971	171,446	3,328		
1972	174,101	2,655		
1973	176,032	1,931	530	
1974	176,032	0	3,401	
1975	176,032	0	3,913	
1976	176,032	0	5,391	
1977	176,032	0	5,847	
1978	176,230	198	3,818	2,764
1979	176,230	0	5,717	3,348
1980	176,230	0	6,727	29,805
1981	195,831	19,601	5,932	12,992
1982	195,831	0	3,850	13,516
1983	196,269	438	3,985	9,676
1984	206,252	10,256	3,700	17,396
1985	205,000	(1,525)	3,159	1,891
1986	210,319	5,319	2,580	8,653
1987	210,458	139	3,213	27,598
1988	210,681	223	1,977	860
1989	210,681	0	514	70

[1]Data from the Philippine Fishery Statistics, 1970-1985, and NEDA Statistics Yearbook, 1986-1989. The annual area reported is cumulative

[2]Data from the list FLAs issued by BFAR Licensing Division as of 1973

[3]Data from the list released by DENR to BFAR on suitable areas for fishponds

Aquaculture development and mangrove area conservation

For many years, mangrove areas were considered vast tracts of wasteland that can be developed into other land uses. Vegetations were cleared to give way to development or when its presence was considered unsightly. The then Bureau of Forest Development (BFD) reported in 1967 that mangrove areas covered 418,990 ha; 15 years later, only 239,387 ha existed (Table 1); and to date, only 139,735 ha remained (NAMRIA 1990). Table 2 presents the distribution of remaining mangroves in the country. NAMRIA noted that 95% of presently existing ponds are former mangrove areas developed between 1952 to 1987. In 1952, there were 89,000 ha of fishponds which expanded to 210,681 ha in 1989 (Table 3).

Causes of mangrove destruction

There are many. On top of the list is utilization for charcoal/firewood. Other factors are expansion of agricultural areas including fishponds, urban and industrial development, harbor and channel construction, mining, and community housing projects.

Policies, legislation and regulations

The depletion of mangrove resources prompted the Philippine government to formulate policies and legislation for its protection. Some of these legislations were general in nature, some are more specific laws. In 1989, the government adopted the Philippine Strategy for Sustainable Development (PSSD) to resolve and reconcile the conflicting issues from different sectors. Among the PSSD implementing policies are:

Administrative jurisdiction: DENR is authorized to control and administer mangrove resources (Executive Order 192); protect and maintain buffer zones (DENR Administrative Order 76); protect, develop and manage mangrove areas (AO 15). DA-BFAR, on the other hand, is authorized to manage fishponds.

Legislation: Presidential Decree 159 provided for silvicultural and harvesting scheme for mangroves; PD 704 (1975) provided for buffer zones along shorelines facing seas and lakes and the general protection of mangrove areas; and PD 2151 and 2152 (1981) declared 74,268 ha of mangroves as wilderness areas and forests reservoirs. Letter of Intent 917 provided for the protection of mangrove forests; Memorandum Circulars (s. 1989, 1992, 1993) declared *Oplan Sagip-Gubat* as a banner program of DENR and provided for the participation of local people in reforestation. Lastly, the Fisheries Code of 1998 promotes conservation and management of mangrove resources.

Existing programs on appropriate utilization of mangrove areas

Programs for the preservation, development and rehabilitation of mangroves are being implemented jointly by DENR and DA through the National Mangrove Committee (NMC), and concerned non-government organizations. NMC was created in 1976, and was tasked to formulate a comprehensive national mangrove plan and to review fishpond and timber license applications. The result of NMC's inventory was used in PD 2151 and 2152.

Another approach was the reforestation of degraded areas. Mangrove rehabilitation started as small scale community-based projects in the provinces of Bohol, Cebu and Negros Oriental. In recent years, however, contract reforestration, agreement or stewardship or 25-year leases were undertaken. As of 1990, there were 8,705 ha planted to mangroves (Table 4).

The programs undertaken by DENR and NGOs include: (1) Central Visayas Regional Project I (CVRP-1), Rural Rainfed and Development Program (RRDP), Palawan Integrated Area Development Program (PIADP), Organization for Industrial, Spiritual and Cultural Advancement (OISCA), National Reforestation Program (NFP), Fisheries Sector Program (FSP), and Coastal Environment Program (CEP).

On fishpond development, the existing Joint DA-DENR General Memorandum Order No. 3 s. 1991 promotes the rational utilization of mangrove forest lands, previously released for fishpond development. Some provisions:

- Undeveloped ponds (no dikes and no water control structures; water in pond can not be changed by tidal action), and abandoned or unproductive ponds shall be reverted to mangrove forests

Table 4. **Mangrove areas reforested**
(as of December 1990)

Region	Area (ha)
I	575
II	252
m	1,292
IV	1293
V	741
VI	519
VII	820
VIII	939
IX	1,280
X	598
XI	396
XII	-
Total	8,705

Source: Planning Division, DENR, Quezon City

- Areas no longer covered by fishpond leases or found vegetated with mangroves shall revert to DENR

The Fisheries Code of 1998 strengthened the above Order, having pro-environment provisions such as: (1) reforestation of river banks, bays, streams and seashore fronting reservoirs, settling ponds, and other pond facilities; (2) granting of incentives and non-incentives for sustainable aquaculture practices; (3) reversion of all abandoned, undeveloped, or underutilized fishponds to mangrove state; and (4) provision for a *Code of Practice for Aquaculture* based on FAO's Responsible Fisheries Code.

The Fisheries Resource Management Project, a component of the Coastal Resource Management Program (CRMP) which supports mariculture development and generation of non-fishing employment for municipal fisherfolk is probably one of the most important programs of DA-BFAR. FRMP will diversify the source of income of fisherfolk, and reduce their reliance on fishing, thus facilitating implementation of mangrove resource conservation and protection.

Lastly, the promotion of the technology on marine cage culture can divert the attention from fishpond to mariculture.

Model areas of mangrove-friendly aquaculture

Under BFAR's CRMP, the culture of mudcrab, some fishes and molluscs are considered for aquaculture in the mangroves. But since the participation of local communities is very much required, community organization and training is first implemented. In the process, pilot testing of the technologies known to be successful in other countries will follow.

Aquasilviculture in Ubay, Bohol

In 1987, DA started aquasilviculture in its Ubay Brackishwater Research Station in Bohol. The idea came from a cross-country visit to Indonesia by one of DA's regional directors. The station's farm area is divided into 4.94 ha of aquasilvi pond, 4.22 ha of open ponds, 1.0 ha of experimental ponds, and 0.08 ha infrastructure (Figure 1).

The developmental scheme of this project is something to reckon with. In 1987, mangrove propagules were planted in rows inside the 2.63 ha (MP#4) and 2.32 ha (RP2 and MP2) fishponds, taking into consideration that sufficient spaces between the dikes and the newly planted trees is left. 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 1,000-3,000/hectare. There was no feed given, but production was observed to be good, producing as much as 1 ton/ha/yr. To date, the trees are on its 15th year, but no harvest of mangrove trees is done. There are as many as 20,000 fully grown trees at the center of the pond. There are still spaces between the dikes and trees where aquaculture is undertaken, but the area is no longer stocked with milkfish fingerlings. It is used as a free entry area for various marine fish species coming from the sea through the main supply canal.

To maintain ample spaces between trees, regular thinning or removal of small old branches is undertaken every 3 months. This further avoids total shading of the pond which can lead to anaerobic condition in the bottom.

Mangrove trees are also planted inside the milkfish ponds, along the periphery of the main dike, and outside the pond along the water supply canal. The trees not only protect dike from erosion, but also make the soil compact and firm. The litter or fallen leaves that decay outside or in the pond provides organic fertilizer which enhances the growth of natural food. The fully grown mangrove trees are now luxuriantly growing.

After the beneficial impact of mangrove trees was noted, another pond compartment (1.6 ha) was planted with mangrove trees in 1995 with 20:80 ratio of pond space to mangrove. The trees are now five years old, but the area is still used for growing milkfish fingerlings to marketable sizes.

Fish production

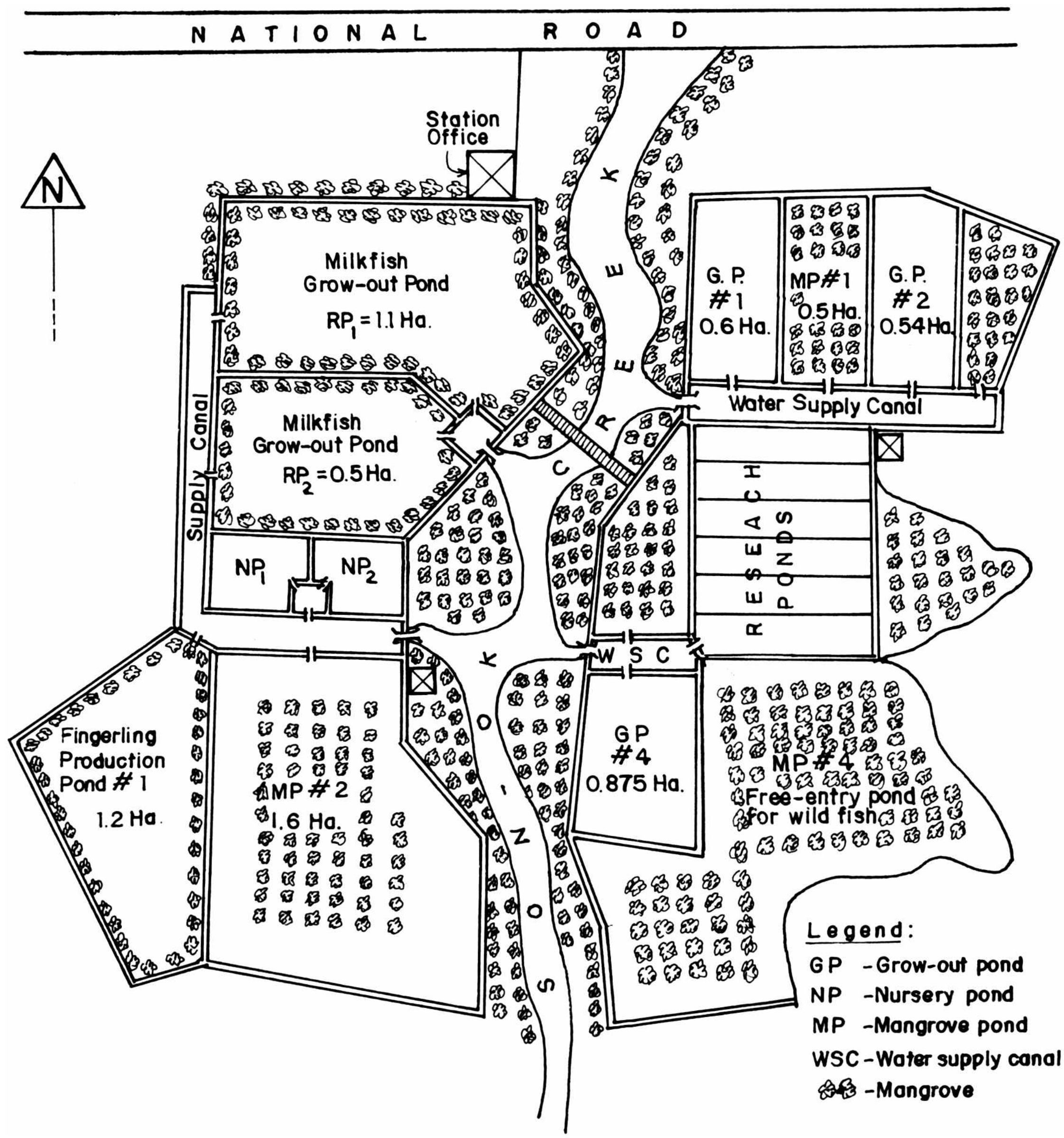
Fish production in the mangrove-aquaculture ponds may not be too high, but it consisted of several species of high commercial value. Although there was no recording made by the station staff, they reported that about 500 kg of several fish species were recovered in 1998 from the 2.27 ha pond. The fishes were caught at the entrance of the pond, including: siganids, tilapia, groupers, shrimps, mullets, barracudas, caravalle, slipmouth, whiting, milkfish, ten pounder, tarpons, scats, goby, snappers and sea bass. Crustaceans (blue crabs, shrimps) and molluscs (oysters, clams, snails) were also collected.

It was noticeable that big-sized carnivorous species like groupers, snappers and barracudas were collected. Few planktonic and herbivorous feeders were caught. Fishes collected were big, some were over 1 kg each (grouper barracuda, snapper, others).

Other observations and problems encountered

Wild birds. The area serves as a refuge/sanctuary for wild birds and ducks, too. These are commonly

Figure 1. **Layout of Ubay Brackishwater Demonstration Farm** (not drawn to scale)



observed in the morning. Birds usually found only in the forests are seen among the trees.

Fish monitoring and harvest. The presence of mangrove roots and watered depressions in the mangrove forests posed a problem in assessing the fish stocks. Total fish harvest was also a problem particularly when the stock was grouper. They took refuge in tree roots or got buried in mud when water receded. The fish were found weak and some died when recovered. This affected marketing since live groupers are preferred.

Death of mangroves. Some species of mangroves are not resistant to prolonged submersion of its aerial roots, leading to their death.

Thick growth of filamentous algae. Mangrove-aquaculture ponds were observed to have an overgrowth of filamentous green algae, covering the entire pond surface. Such condition is not very favorable to fish stock as it could lead to oxygen depletion at night and may result in fish kills.

Agri-nipa-aquaculture farm in Puerto Galera, Mindoro

The agri-nipa-aquaculture (ANA) project in Tabinay, Puerto Galera started in March 1989. Productivity of the area prior to ANA establishment was very low since the site was mostly covered with tall reed grass. An area measuring 1,400 m^2, located in the central part was already planted to nipa while rice (5,000 m^2) was planted in the southern part. Rice production was very poor according to the farmer because of its proximity to the sea and salt sprays carried by winds.

Protection of existing mangrove stands
At the start of the project, the second growth mangrove stand fringing the site was protected from wood gatherers. The mangrove area is about 3.68 ha consisting of six species. The mangrove stand protect the site from strong waves, typhoons and strong winds. Some open areas and skips were planted to *Rhizophora* species.

Fishponds
It took three months to plan and construct the nipa-aquaculture ponds. Two fishponds were constructed (Figures 2 and 3). One was around the newly established nipa plantation (Pond I), and the other was around the established mature nipa stands (>2 years) (Pond II). Tilapia and milkfish fry were stocked in each pond. Mixed stocking was also done.

Nipa plantation
Nipa accounted for 80% of the central portion of ponds I and II. Nipa seedlings about 4-5 months old were used to plant Pond I. The seedlings were spaced either 1 or 2 m apart Nipa was used instead of mangrove trees because of its higher economic potential in the area. It can be compared with coconut in terms of economic value. Its ecological role includes erosion control, coastal protection and stabilization, and provision of sanctuaries for some marine species. Its leaves are used in making nipa shingles, native bags, coarse baskets, hats, mats, brooms and raincoats. Nipa sap can also be extracted and processed into alcohol, wine, sugar and vinegar.

Fruit and vegetable crops
Agricultural crops were planted on the dikes and available open spaces within the site to maximize use of the area. This is to provide immediate and added source of food and income since it takes 3-4 years before nipa can be utilized for income generation. Crops found to adapt to saline conditions

Figure 2.
Layout of the agri-nipa-aquaculture scheme

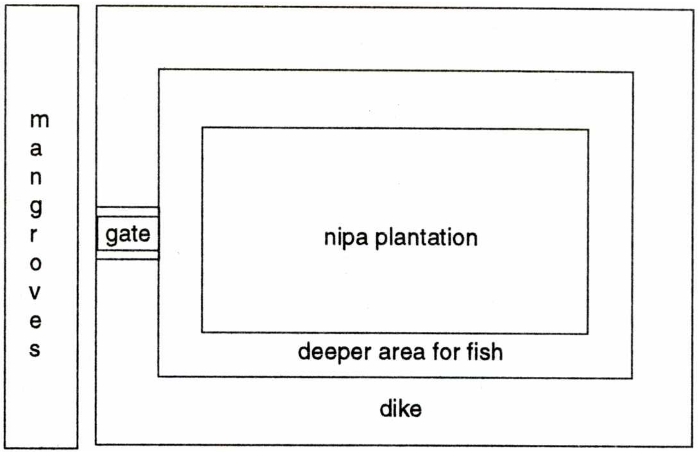
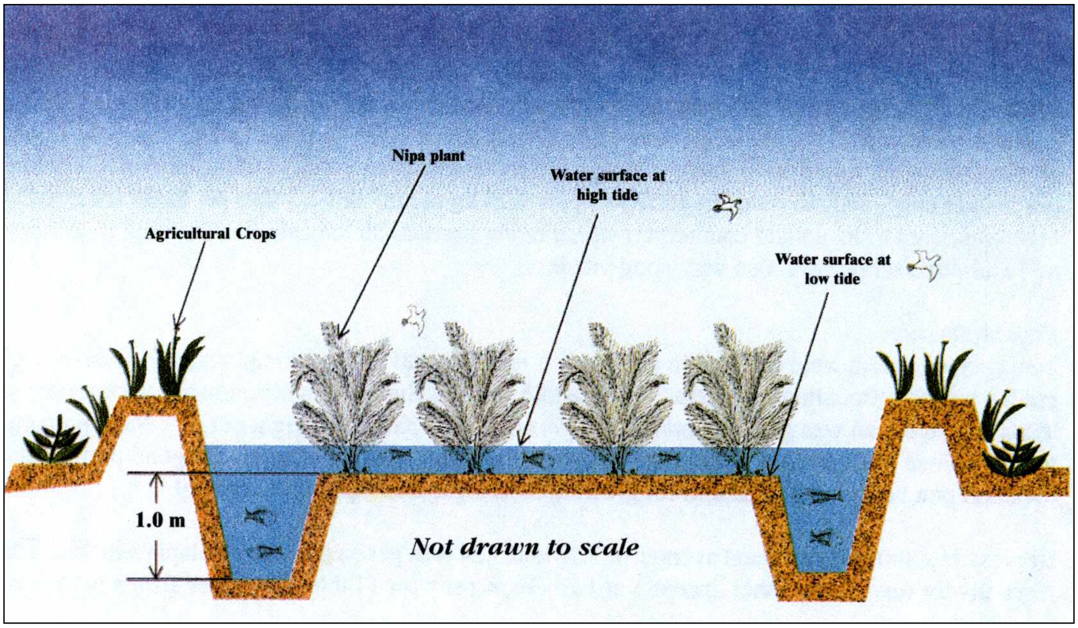


Figure 3. **Cross section of agri-nipa-aquaculture pond** (water level during low and high tides indicated)



of the pilot site were banana, tomato (*marikit* variety), pole *sitao*, bush *sitao*, eggplant, *upo*, *okra*, pineapple, passion-fruit, peanuts, corn, *patola*, and jackfruit.

Mangrove litter and other coastal debris that were washed ashore were collected and used as organic fertilizer and soil conditioner. Laboratory analysis showed that mangrove litter has adequate nutrient contents to support good crop production, as follows: pH, 6.2; organic matter, 15.27%; nitrogen, 0.76%; phosphorus, 10.35%; potassium, 0.81%; calcium, 43.91%; magnesium, 24.21%; sodium, 7.74%; cation exchange capacity, 55.51 meq/100 mg soil.

Table 5. **Fish production in the agri-nipa-aquaculture system, Mindoro** (tons/ha/crop)

Cropping cycle	Pond I (newly established nipa)			Pond II (w/ mature nipa stand)		
	Tilapia	Shrimps[1]	Others[2]	Milkfish	Shrimps[1]	Others[2]
1st crop	1.62[a]	0.05	0.17	d	d	d
2nd crop	1.58[b]	0.10	0.06	1.71[e]	0.08	0.03
3rd crop	1.55[c]	0.07	0.06	1.40[f]	0.06	0.05
4th crop	1.57[b]	0.02	0.03	1.68	0.07	0.01
5th crop	1.60[b]	0.03	0.10	1.66	0.06	0.04
6th crop	1.65[a]	0.01	0.03	1.70	0.03	0.03
7th crop	1.54[b]	0.01	0.05	1.58	0.02	0.01
Average	1.59*	0.04	0.07	1.62**	0.05	0.03

[1]majority are freshwater shrimps; [2]mullet, mudfish, tarpon, sea bass, etc.
[a]sex reversed tilapia; [b]mixed sex tilapia; [c]golden hybrid tilapia; [d]construction stage; [e]milkfish only; [f]mixed milkfish and tilapia
*approx. 3.18 tons per ha per year; **approx. 3.24 tons per ha per year

From the data generated, the best variety of bush *sitao* under the prevailing condition is UPLB-3 with a yield of 2.77 kg per m^2 per crop. There were seven other varieties tested. For pole *sitao*, all three varieties tested were high yielding. On top is *sandigan* variety with a yield of 11.29 kg per m^2 per crop. Tomato (*marikit* variety) yields 9.75 kg per m^2 or 97.5 tons per ha which is very high compared to its upland counterpart which rarely exceeds 30 tons per ha. Com (32 pieces per m^2) and other crops have also very good yields.

Fish production

Two species of fish were cultured in the ponds -- milkfish and tilapia (mixed sex, sex-reversed and golden hybrid). Stocking rates were 2-3 fingerlings per m^2. Supplemental feeding with commercial feeds and rice bran was given amounting to 5% of the fish biomass weight per day. Pond preparation was done prior to each crop. Two crops were stocked yearly. Activities for pond preparation included pond drying, fertilization for growing food algae and water management.

Harvest data showed an annual average of 3.18 and 3.24 tons per ha per year of tilapia and milkfish, respectively (excluding other species) at two crops per year (Table 5). Other fishes were also harvested.

Nipa production

The first harvest of fronds from the newly established nipa at 3 years old (Pond I) is shown below:

Spacing of nipa	*Production (no. of fronds)	*Length (cm)
1 m apart	125.67	155.01
2 m apart	234.00	180.05

Note:
**Average of three replicates. Area for each replicate is 120 m^2. Each replicate has either 99 plants (for nipa spaced 1 m apart) or 20 plants (nipa spaced 2 m apart)*

For nipa planted 1 m apart, it took 2.75 fronds to produce one shingle; while two fronds from nipa planted 2 m apart were needed. Harvest from Pond II was about 4 fronds per nipa palm (now >5 years old). About 1.5 fronds made up a shingle. Harvesting was done every 4 months.

At the project's end in December 1996, the cooperator-farmer had a net income of ₱81.00 from nipa planted 1 m apart in a 120 m^2 plot or about ₱20,250 per ha per year. From nipa planted 2 m apart, the annual net income is ₱52,500 per ha per year.

Soil quality
There was soil degradation at the site. The new nipa plantation had loam type of soil, becoming sandy loam three years later. The mature existing nipa area was sandy loam, later becoming silt loam.

Costs-and-returns
Tables 6 and 7 show the projected income of a backyard nipa-aquaculture farm in the first few years of operation.

Other projects

BFAR has started last August 1998 a small-scale mudcrab project in one of the mangrove areas adjacent to its research center in Pagbilao, Quezon. The project consists of 6 units of 10 x 20 m net pens.

DENR's Ecosystem Research and Development Bureau, on the other hand, had a 0.8 ha project started in 1994. The project utilized a 60:40 combination of mangrove plantation and fishpond as pilot areas in Catanauan, Quezon and a 0.25 ha area in Sta. Elena, Camarines Norte. Projects had been completed and turned over to the local mangrove association.

Also, SEAFDEC/AQD has a model area of mudcrab culture in pens in mangroves since June 1997 in Palawan province. It is a joint project with the Puerto Princesa City government and the Manalo Multi-Purpose Cooperative Inc. The cooperative provided the area and technician that manages the project; the City government acted as coordinator and provided crablets and feeds for one cropping; AQD provided the design, technical assistance and technology packaging.

There are may other similar projects operated by academe, NGOs and other interested private individuals but these have not been reported.

Recommendations

Establishing a national plan
With BFAR becoming a line bureau effective January 1999, a national plan for the improvement of mangrove areas integrating aquasilviculture will be prepared. Consultative meetings with DENR, DA Regional Offices, NGOs, other agencies and community organizations will be conducted to determine issues and problems that need to be addressed. Implementation will be a joint undertaking by the government and these organizations. The plan will be in consonance with the provisions of the Fisheries Code of 1998 and other related laws.

Table 6 **Projected income from fish and nipa of a 1,000 m² backyard nipa aquaculture farm for the first three years of operation (pesos)**

Activities	Unit cost	Year I	Year II	Year III
Aquaculture				
Digging 20% of the area (20 man-days)	120.00	2,400.00	-	-
Tilapia fingerlings, sex-reversed	0.30	450.00	450.00	450.00
Feeds, manure, fertilizers		2,000.00	2,000.00	2,000.00
Repair and maintenance		-	400.00	400.00
Nipa plantation				
Clearing for nipa planting (1 man-day)		80.00	-	-
Hole digging (2 man-days)		160.00	-	-
Planting (1 man-day)		80.00		
4-5 month old nipa seedlings	5.00	1,250.00	-	-
Maintenance (4 man-days per year)		320.00	320.00	320.00
Nipa harvest				
Tie	0.10	-	-	280.00
Bamboo sticks, 1.5 m	0.10	-	-	260.00
Labor, per 50 shingles	50.00	-	-	2,808.00
Shingle assembling and sewing		-	-	2,808.00
Gross income / sales				
2 harvests with 80% survival, (5 pcs fish per kilo)	30.00	14,000.00	14,000.00	14,000.00
Nipa shingles, 1.5 m long / double		-	-	11,232.00
Net income (before tax)		7,660.00	11,230.00	16,284.40

Table 7 **Projected income from banana and vegetables of a 1,000 m² backyard agri-nipa-aquaculture farm for the first five years of operation (pesos)**

	No. of plants	*Price per bundle*	*Year I*	*Year II*	*Year III*	*Year IV*	*Year V*
Banana							
Saba	100	60	-	6,000	6,900	7,935	9,125
Lakatan	20	85	-	1,700	1,955	2,248	2,585
Poot	50	42	-	2,100	2,415	2,777	3,194
Total			**-**	**9,800**	**11,270**	**12,960**	**14,904**

Basic assumptions: (1) yearly increase of 15% on price of bananas and (2) yearly production of banana is 1 bundle per plant

	Harvest	*Price*	*Year I*	*Year II*	*Year III*	*Year IV*	*Year V*
Vegetables							
Pole *sitao*	188 kg	12/kg	2,256	2,594	2,983	3,430	3,945
Bush *sitao*	100 kg	12/kg	1,200	1,380	1,587	1,825	2,099
Tomato (*marikit*)	100 kg	5/kg	500	575	661	760	874
Corn	375 pc	2/pc	750	862	991	1,140	1,311
Upo (cooking variety)	200 pc	3/pc	600	690	794	913	1,050
Total			**5,306**	**6,101**	**7,016**	**8,068**	**9,279**

The rational and sustainable management of the mangrove resource would not be an easy task since many government forestry programs (mangrove included) in the region are polarized with two or three agencies having opposing mandates. Activities must be balanced, otherwise, irreversible damage will occur. Sustainable management should ensure that the ecological integrity of the ecosystem and its closely associated resources are intact.

Population and economic development pressures must be minimized. As much as possible, conversion should be restricted to areas that will not adversely affect other resources. Traditional rights of the coastal communities must be given due consideration (e.g., provide a tenurial system to make use of mangrove areas on a sustainable basis).

Information, education and training

The private sector and other stakeholders will be kept informed of the status of aquaculture in the mangrove areas and the plans of the government. Information campaigns through meetings, printed media, among others, is necessary.

Education campaigns will be an integral part of the national program. Likewise, training of local fisherfolk in resource management and development will be conducted.

The need for baseline information

Since important data on mangrove and other resources would be needed in the national plan, the research and academic community may be invited to undertake studies on some critical areas.

Baseline information on mangrove ecosystems is still insufficient, especially its relationship with other ecosystems and resources within the coastal zone. There is a need to assess the extent of mangrove use, and quantify their socio-economic benefits. Creating multi-disciplinary research committees on various aspects of the mangrove ecosystem may be necessary. There are, however, many tools that can provide better baseline information today like remote sensing, geographic information system (GIS), and environmental impact assessment techniques (Umali *et al.* 1986; Untawale 1986).

Applied research needs

Economic valuation of mangroves is not easy. On the whole, there is a need for researchers to determine the impact of mangrove conversion on fisheries resources, its socio-economic repercussions and the other resources associated with mangroves (Untawale 1986).

The impact of mangrove conversion varies, depending on prevailing local conditions. In typhoon prone areas, the destruction of the mangroves increases the risk of coastal erosion from storm surges and winds. Along estuaries, denudation accelerates the erosion of riverbanks. When large areas of mangroves have been converted to shrimp ponds, it results in the exposure of acid sulfate soils, leading to poor production, mass mortality of stocks, and the discharge of toxic substances into nearby waters (Paw & Chua 1991). Conversion to salt ponds also alters soil structure and increases salt content, making the area difficult to reclaim especially for agriculture or silviculture. These conditions are sometimes irreversible or costly to mitigate. Hence, an economic analysis of mangrove conversion should take all these into consideration.

Intensive aquaculture production systems are likely to have greater impact in terms of pollution and employment potential. The cost of waste treatment can be considered and its damage to the aquatic environment valued. Semi-intensive culture system is recommended for adoption.

The present rate of wood cutting appears to be unsustainable and degradation of mangrove is apparent in many areas. With the degradation of mangrove areas, fisheries areas are showing signs of overexploitation or diminishing population (Aquaculture Asia 1996).

Socioeconomic studies

It is generally accepted that for sustainable management to succeed, local communities must be involved in the planning, implementing and monitoring stages. Without this early involvement, such programs can not work. Along with the anticipated involvement of local communities, new and rather experimental technology on aquasilviculture should be introduced as livelihood. Aquasilviculture involves traditional non-destructive aquaculture techniques combined with sustainable forestry techniques, including limited harvest of mangrove products.

Socio-economic studies which could be replicated have been piloted with success by DA, SEAFDEC/AQD and DENR in some areas. Culture of other fishery resources like mollusc and seaweeds should also be piloted to give additional income to fisherfolk.

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Thailand: Mangrove-friendly shrimp farming

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Status of aquaculture

Fisheries production mainly comes from marine fisheries (>75% of total) (Figure 1). However, the highest value comes from the culture of black tiger shrimp (*Penaeus monodon*) which is over 72% (260,200 tons) of coastal aquaculture production in 1995. Thailand's long coastline -- 2,600 km -- means that there are many areas suitable for shrimp culture.

Status of mangroves

Area and distribution
Mangrove forests are found along muddy coastlines and in estuaries. Within the Gulf of Thailand, mangroves occur from Trat province in the eastern region to Prachuuab Kirikhan in the central zone. On the east coast of the southern region, they occur from Chmphon province to Pattani, and on the west coast, from Satun province to Ranong (Table 1, Figure 2).

Biodiversity
The mangrove vegetation in Thailand has a rich, well-developed flora: 55 genera and 77 species belonging to 36 families of trees and shrubs (Santisuk *et al.* 1988). However, human activities have directly contributed to their degradation.

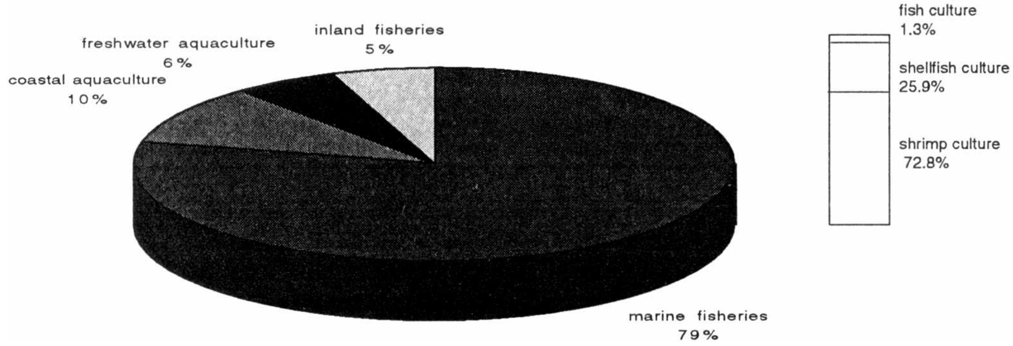

Figure 1. **Fisheries production in Thailand by sector, 1995** (Kongsangchai 1995)

Table 1. **Existing mangrove forests in Thailand, 1993**

Region	Provinces	Mangrove forest areas	
		Area (ha)	% of total
1	Trat	7,668	4.55
	Chantaburi	4,072	2.42
	Rayong	680	0.40
	Chonburi	92	0.06
		12,512	7.42
2	Chachoengsoa	536	0.32
	Samut Prakan	312	0.19
	Bangkok	200	0.12
	Samut Sakhon	1,819	1.08
	Samut Songkram	924	0.55
	Phetchaburi	2,068	1.23
	Prachuab Kiri Khan	40	0.02
		5,899	3.50
3	Chumpphon	3,293	1.95
	Surat Thani	3,164	1.88
	Nakhon Si thammarat	7,996	4.74
	Pattalung	128	0.08
	Songkhla	548	0.33
	Pattani	1,295	0.77
		16,424	9.74
4	Ranong	19,308	11.45
	Phangnga	30,716	18.21
	Phuket	1,548	0.92
	Krabi	28,527	16.91
	Trang	24,328	14.42
	Satun	29,420	17.44
		133,847	79.35
	TOTAL	168,682	100.00

Causes of mangrove destruction
The existing mangrove forest area in Thailand has decreased by more than 50% in the past 32 years (1961-1993). The rate of deterioration is approximately 6,200 ha per year. The major causes include shrimp farming, mining, and other human activities (Table 2).

Utilization of mangrove areas
Because large mangrove areas have been converted into shrimp farms and residential areas, there is conflict between the government and the people who occupied the mangrove areas. In order to resolve the conflict, the government decided to classify the mangrove areas as follows:

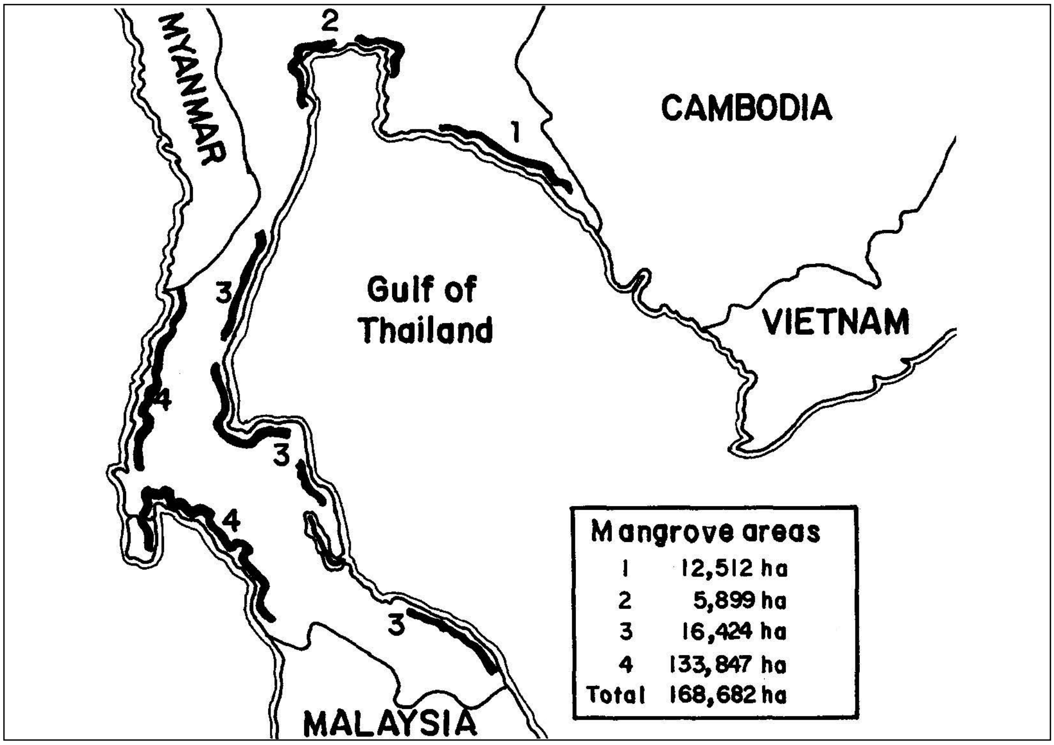

Figure 2. **Mangrove areas of Thailand**

Table 2. **Conversion of mangrove areas by various human activities** (Kongsangchai 1995)

Activities	Change in area (ha)	
	Before 1980	1980-1986
Shrimp farming	26,036	84,223
Mining	926	4,526
Others (urbanization, salt production, agriculture, etc)	53,630	2,132
Total	80,592	90,880

Preservation zone -- 36,278 ha - this is mangrove forest areas with no allowance for development activities.

Economic zone A -- 199,689 ha -- this is mangrove forest areas that can be used only for sustainable forest activities, for example, community forest, mangrove forest plantation for forest production.

Economic zone B -- 130,081 ha -- this is mangrove forest areas where development and other activities are allowed provided some caution is exercised as these activities could affect the environment. These include areas that are agricultural, industrial, and commercial in nature.

Mangrove-friendly shrimp farms

Impact of shrimp farming

Shrimp farming has the greatest impact on mangroves in Thailand. From 1980 to 1986, shrimp farms were established by clear-cutting mangroves. Many problems have since arisen, as follows:

Physio-chemical:

- Acid-sulphate soils due to exposure of the cleared land to oxygen
- Water-logging and rise in water salinity and temperature, affecting the growth of living organisms
- Increased coastal erosion and sediment and waste deposits from land to sea

Biological:

- Changing species diversity and population density

Ecological:

- Discharge of wastes from shrimp ponds leads to change in natural water equilibrium. It leads to eutrophication in shrimp farm areas

Constraints in shrimp farming

Most of Thailand's shrimp culture have developed into intensive culture. The "open system" is a common technique used by shrimp farmers where they take in and discharge water from/to the surrounding waterway. However, success of the farm would depend on the environment outside the farm. Shrimp farms could easily become corrupted like what happened in the upper part of the Gulf of Thailand in 1984-1990. Shrimp died because of eutrophication and diseases when the water supply became contaminated with pollutants such as organic matter, plankton bloom, pesticides, etc. The pollutants came from land (residential, agriculture, industrial) and/or effluents from shrimp ponds themselves. Moreover, the destruction of the mangroves around the farms aggravated the problem. Mangroves could have helped absorb some of these wastes (Figure 3).

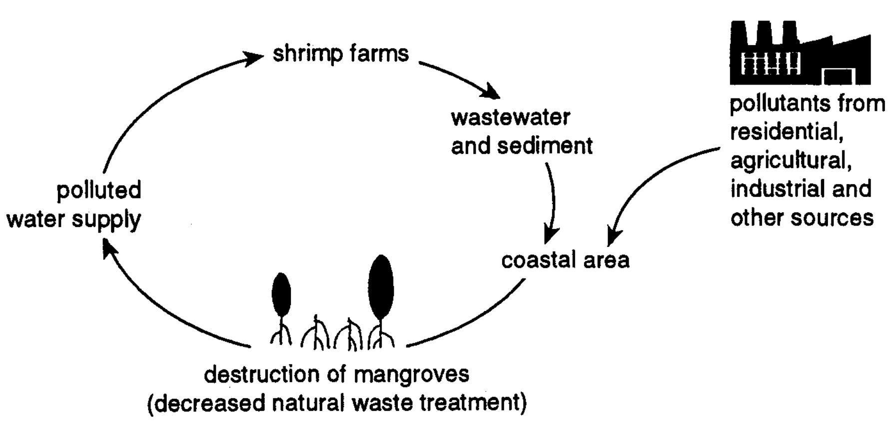

Figure 3. **Corruption of shrimp culture operations in the upper Gulf of Thailand**

Studies on closed and recirculating water system for tiger shrimp
The Phetchaburi Coastal Aquaculture Station in Laam Pakbia, Banleam District was initially operated to conduct studies on *Anemia* culture. But with the problems of shrimp farms, the station started research work on closed and recirculating water system. This work is made under the project "Recovery of shrimp culture in the upper part of the Gulf of Thailand" beginning 1995.

The project mainly emphasized the use of biological treatment of waste products in shrimp culture and the ecological management of the culture system (Figure 4). The following are the conditions:

- Shrimp culture should be carried out in areas which have been affected by pollution for some time
- Shrimp culture must be harmless to the environment outside the farms, with minimal waste discharge as much as possible

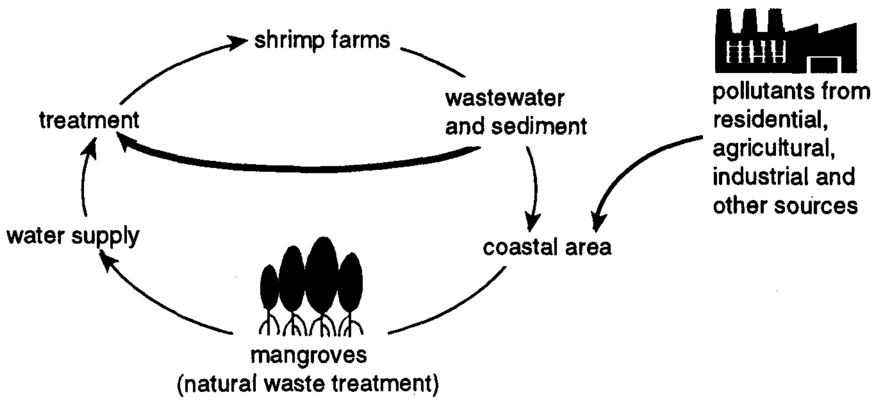

Figure 4. **Shrimp culture with waste treatment**

The studies on closed system shrimp culture mainly relate to waste management inside the farms since the most important waste products from shrimp ponds are culture water and waste sediment. Initial results are discussed below:

Biological control of water quality in closed and recirculating water system
Water quality parameters -- oxygen, ammonia, BOD, etc -- usually fluctuate, stressing the shrimp and causing the culture to be discontinued in some instances. Biological water controls may be applied to improve water quality. Examples of these are food web management and the use of treatment ponds.

- Food web management in shrimp ponds (Figure 5)
  Most private shrimp farms attempt to kill unwanted fishes which compete with shrimp for food and space by using tea seed powder or other chemical products. However, this practice disconnects the food web in shrimp ponds.

  There is an indirect relationship between water quality and the food web. In ponds that do not have plankton feeders, zooplankton (rotifers, copepods) sometimes increase in number rapidly by consuming phytoplankton. But most of them die after all the phytoplankton are consumed. When this occurs, water in the ponds become clear, accompanied by the reduction of oxygen and a rise in ammonia caused by the decomposition of plankton cells by bacteria. These conditions stress shrimp and reduce their resistance to diseases.

Shrimp farmers can release fishes that are plankton feeders to prevent all these from happening. This can be done on the first month of culture. The suitable fish species must be small so they do not interrupt shrimp behavior and can adapt and reproduce in seawater (0-30 ppt) easily. Guppy, platy and sail fin (all are aquarium fishes) are suitable.

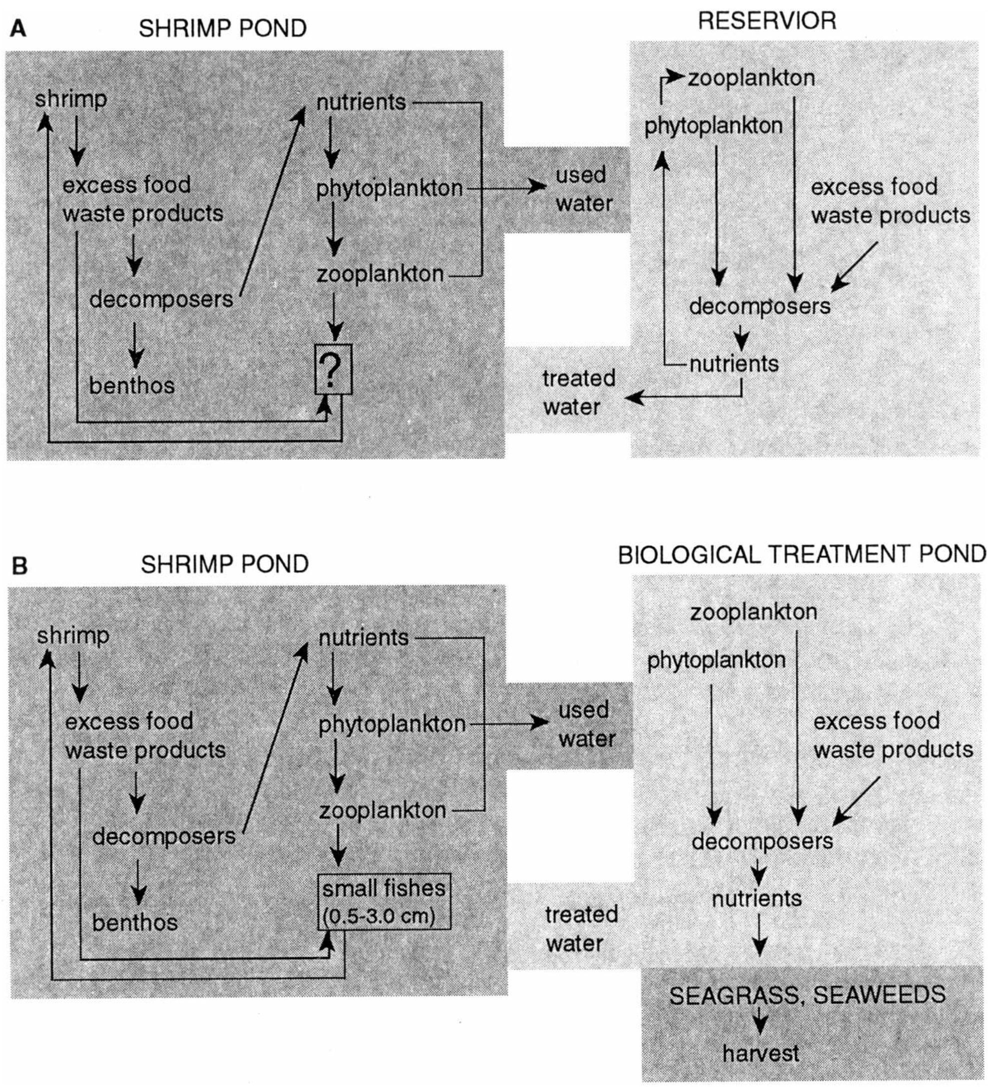

Figure 5. **The use of reservoir (A) vs. the use of biological controls (B)** that include food web management in shrimp ponds and use of treatment ponds

- Biological treatment ponds or polyculture ponds

  Treatment ponds are of two purposes: (1) purification of used water from shrimp ponds and recirculation of treated water back to shrimp ponds; and (2) purification of raw sea water (sometimes contaminated by pollutants). With regards to modification of reservoirs to become biological treatment ponds, here are some disadvantages of reservoirs (Figure 5):

  No aeration for increased degradation of organic substances.

  Most shrimp waste product is converted into phytoplankton biomass, and this is impossible to remove from the water. This means that plankton and nutrients may still cause eutrophication in shrimp ponds afterwards.

  But there are methods to increase the efficiency of water treatment in reservoirs such as:

  Installation of aerators so that organic substances can be degraded faster.

  Growing of macrophyte on the reservoir's bottom to absorb excess nutrients, for example: seaweeds (*Gracilaria*, *Caulerpa*) and sea grass (*Ruppia*). Let the nutrients be converted into plant biomass which can be removed or harvested out of the system.

  Release of carnivorous fish in the reservoirs to prey on or control the population of herbivores that graze on seaweeds and seagrasses.

  Frequent harvest of seaweeds and/or seagrasses as an indirect way of removing nutrients out of the system. Moreover, the plant biomass may be utilized for other purposes such as agar extraction (*Gracilaria*) and livestock feed.

Sediment treatment

Waste sediment affects the environment the most. It settles on the pond bottom and is easy to see after shrimp harvest. The sediment consists of organic matter, ammonia, hydrogen sulfide, and other kinds of waste products from shrimp. Although sediment discharge is inhibited by the law of environment protection, the best way to treat or handle it has not been established. In Thailand, there are many trials being done, for instance, the use of waste sediment as fertilizer.

The Phetchaburi Coastal Aquaculture Station is testing a mechanical approach. A device that is normally used to plow paddy fields is modified to turn over and aerate the sediment. The purpose is two-fold:

(1) Some gases released from bacterial activity during degradation of organic substances are accumulated in waste sediment such as ammonia, hydrogensulfide, methane, etc. By plowing or turning over the sediment, these gases can evaporate so that organic degradation by bacteria is increased.

(2) Plowing can increase oxygen penetration into the sediment, so that (aerobic) bacterial activity is enhanced.

Sediment treatment can be done once a week, at least three times. The pond bottom will be improved and shrimp farmers will be able to culture shrimp in the next crop without discharging waste sediment.

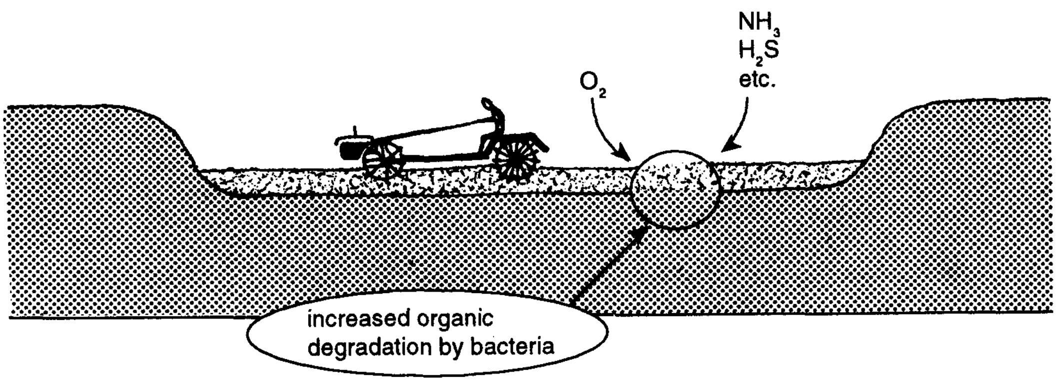

Figure 6. **Sediment treatment of shrimp ponds**

Silvofisheries or aquaculture in mangroves

The Phetchaburi Coastal Aquaculture Station is studying silvofisheries or aquaculture in artificial mangroves (=modified ponds) (Figure 6). The dikes are built in order to get a longer line for growing mangroves. The culture of shrimp or fish can be done intensively or extensively in the waterways. Mangrove and aquaculture can be interdependent -- mangroves absorb nutrients and waste products from aquaculture, and the cultured shrimp/fish can use natural food made abundant by mangroves. Theoretically, the supplementary food requirement of cultured species will decrease.

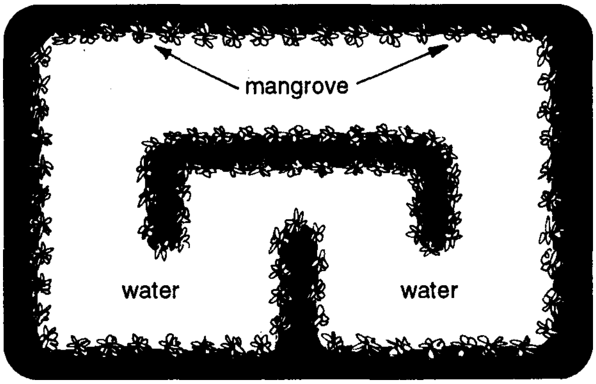

Figure 7. **Thailand's silvofisheries model**

Conclusion

Studies on “mangrove-friendly shrimp culture” in Thailand are on-going, and there are some evidence that the new method of managing shrimp culture has lower environmental impact. It is clear that shrimp farms in the future need to have some kind of water and sediment treatment system. Besides lower impact to the environment, the use of mangrove treatment may be the new approach to increase the mangrove area in Thailand.

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Viet Nam: Mangrove-friendly aquaculture

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Overview of aquaculture

In 1995, the Ministry of Fisheries and the Institute for Fishery Economic and Planning estimated that aquaculture covers 590,000 ha, of which 250,000 ha are brackishwater shrimp ponds and 325,000 ha are freshwater fishfarms (lakes, reservoirs, garden ditches, paddies, ponds). Aquaculture contributed about 415,280 tons or more than 30% of total fishery production. Molluscs including clams, blood cockle, abalone, and other gastropods contributed about 100,000 tons. The export earning from aquaculture in 1995 was US$260 million, accounting for 47% of total fisheries export.

Viet Nam's aquaculture systems can be described as extensive and/or improved extensive. The strategy is to quickly increase production of shrimp, fish and other commodities to serve the local and export markets. The average yield of a traditional extensive shrimp farm is low - 70-80 kg/ha -- which is attributed to the decline in natural shrimp seed supply. For improved extensive farming, it is higher, 200-300 kg/ha in the northern part of Vietnam and 400-500 kg/ha in the south.

Aquaculture in tidal areas and brackishwaters

High-value shrimps (*Penaeus indicus, P. merguiensis* and *P. monodon*) are cultured in brackishwater ponds. There is also integrated farming of *P. monodon* with one rice crop or *Macrobrachium rosenbergii* with one rice crop. Culture of other species including mud crab (*Scylla serrata*), seaweed, marine fishes and special products are highly developed.

Annual shrimp production is about 50,000 tons, mainly from the four provinces of Ca Mau, Bac Lieu, Soc Trang and Tra Vinh in the Mekong Delta. This is about 84% of total shrimp production. The common practice of stocking ponds is through the natural influx of shrimp seed at flood tide during full and new moon.

In the early 1990s, a yearly yield of 350-400 kg/ha used to be possible for extensive and improved extensive farms (Luu 1991, 1993; Tuan & Phuong 1994). Recently, this has dropped to less than 100 kg/ha/year because the density of natural shrimp seed has decreased due to overexploitation of nearshore breeding grounds and inland water ways; the loss of nursing grounds in mangrove areas; environment deterioration created by too much organic matter available in ponds, alluvium deposition, blue-green algae booming; and disease outbreaks.

In the case of improved extensive shrimp farming, farmers depend on hatchery-produced seeds of *Penaeus monodon* and *P. indicus*, if they can afford it.

Apart from shrimp, mud crab, blood cockle (*Arca granosa*), and clam (*Meretrix meretrix*) are produced mainly in southern Vietnam.

From 1993 to 1995, 43 aquaculture projects with national investment of 149 billion VND were implemented by the Ministry of Fisheries under Decree 773 TTg (former 327 CT). The results included: (1) expansion of 15,790 ha of new farming areas, (2) settlement of 3,847 households, (3) creation of jobs for 9,449 persons, and (4) harvest of 18,991 tons of aquatic products of which shrimps make up 1,063 tons.

Mariculture
Some provinces carry out small-scale marine farming operations with the following species: lobster (*Panulirus ornatus*, *P. longipes*), red grouper (*Epinephelus akaara*), Dumeril's amberjack (*Seriola dumerili*), sea bass (*Lates calcarifer*), pearl oyster (*Pteria margaritifera*), clam, and abalone (*Haliotis diversicolor*).

Aquaculture in reservoirs, rivers and streams
The use of floating cages and pens was promoted in the country as a whole. Up until 1995, there were 16,000 cages and pens used for fish farming. The main species cultured are grass carp (*Ctenopharyngodon idellus*) and marble sleepy goby (*Oxyleotris marmoratus*). Other species farmed in cages and pens include: hybrid walking catfish (*Clarias* spp), snakehead (*Ophicephalus micropeltes*, *O. striatus*), common carp (*Cyprinus carpio*), giant gouramy (*Osphronemus gorami*), and river catfish (*Pangasius bocourti*).

Viet Nam has a long tradition of culturing special species such as trionychid turtle (*Palea steindachnen*), swamp eel (*Fluta alba*), and tiger frog (*Rana tigrina*) based on semi-intensive and intensive farming systems in small ponds.

Fish and shrimp hatcheries
By 1995, a total of 840 hatcheries (559 shrimp and 281 fish hatcheries) produced more than 1 billion juveniles of *P. monodon*, *P. indicus*, *M. rosenbergii* and 6 billion fish fry. The country's central coast is by far the largest producer of postlarval shrimp where over 76% of the country's hatcheries are located. In 1994, approximately 1.7 billion shrimp postlarvae were produced from 570 hatcheries.

Mangrove areas

Existing mangrove area
Viet Nam had about 400,000 ha of mangrove forests in the 1940s (Mauran 1943) which was mainly distributed in the southern part of the country (250,000 ha). By the 1950s, this forest was reduced to 290,000 (Rollet 1956) because of overexploitation for wood, charcoal and firewood. By 1962, this was further reduced to 286,000 ha (Ross 1975). The 1962-1971 war with the US further destroyed 104,939 ha, of which 52% are located in Ca Mau Cape (Hong 1993). After the war, the reduction of of mangrove areas was caused by its conversion to agriculture and shrimp farming. Up to the end of 1991, the area of mangrove forest in Minh Hai province had decreased to 47,840 ha (Hong 1993).

Distribution of mangrove forest
More than 50 mangrove trees have been identified (Hong 1993a,b; 1995; 1997) with the following distribution (Figure 1):

Region 1 *The northeast coastal region from Mong Cai (Quang Ninh province) to Do Son (Hai Phong City):* Mangrove forest expanded because a shelter island existed outside of the mangrove forest band. The main mangrove trees are *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, *Aegiceras comiclatum*, *Kandlia candel*, *Avicennia marina*. The height of mangrove trees is limited at 1.5-7.0 m due to the cold weather/ winter season.

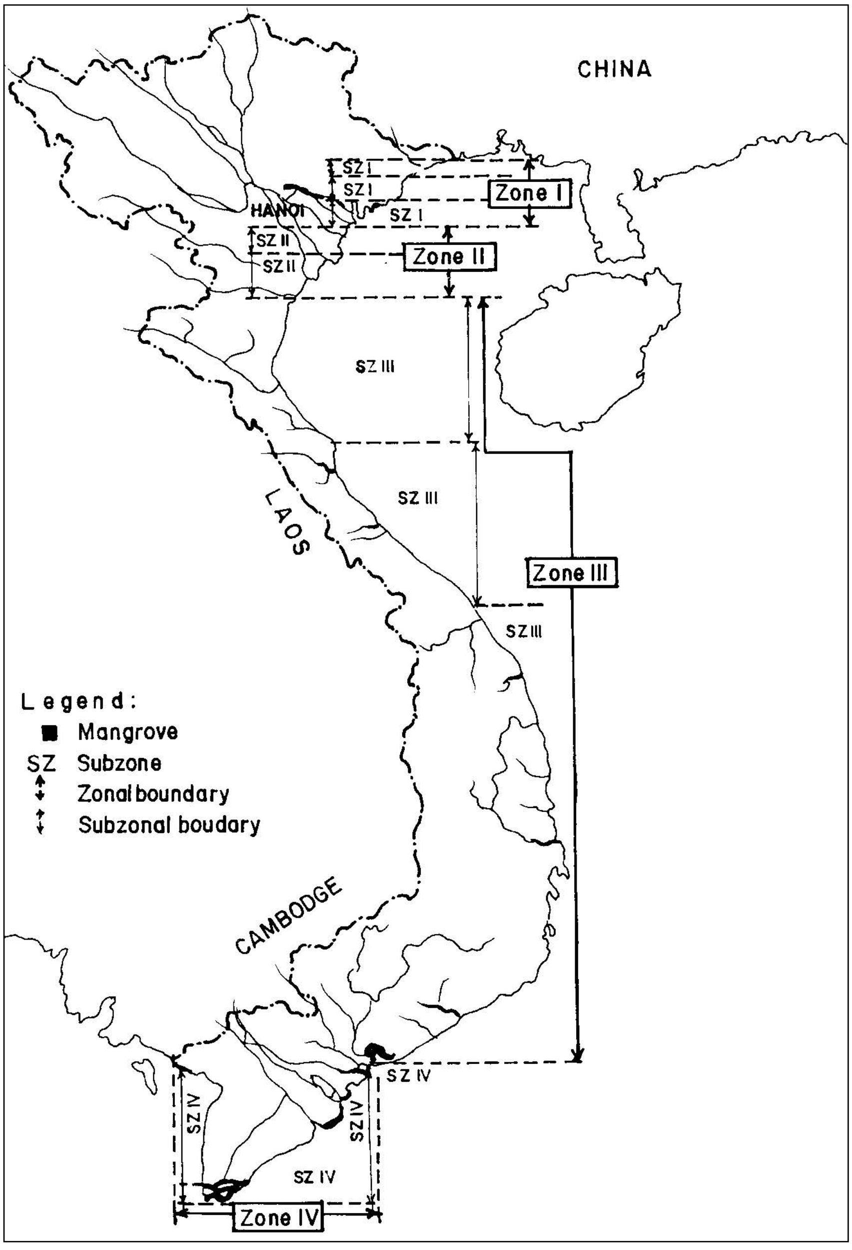


Figure 1. **Distribution of mangrove forest in Vietnam** (Hong 1993)

Region II *Coastal region from Do Son to Lach Truong river mouth (Thanh Hoa province):* Due to the lack of shelter islands, the mangrove forest is not so developed as other typical brackishwater trees such as *Sonneratia caseolaric, Kandelia candel, Aegiceras comculatum*, and *Acanthus ilicifolius.*

Region III *Central coastal region from Lach Truong river mouth to Vung Tau:* Because of the narrow tidal flat, slope coast and typhoons, mangrove trees consisting of *Rhizophora apiculata*, *R. stylosa, Aegiceras comiculatum, Bruguiera gymnorrhiza, Avicennia alba* are located at the river mouth.

Region IV *Southern coastal region from Vung Tau to Ha Tien:* Due to suitable conditions -- wide tidal flat, rich alluvia from Dong Nai and Mekong rivers, rare typhoon -- the mangrove forest is highly developed with many trees such as *Rhizophora apiculata, R. mucronata, Bruguiera sexangula, B. parviflora, Avicennia alba, A. officinalis, Nypa fruticans, Ceriops decandra,* and *C. tagal.*

Value of mangrove resource

Generally speaking, mangrove forests play a very important role in coastal protection and land reclamation. Along the coast, they buffer the impact of wave action and slow down erosion. They also provide natural protection of sea dikes. Along those stretches of the coast where accretion takes place, mangroves colonize the newly formed mud flats, and trap and stabilize sediment.

Mangrove trees provide a variety of valuable products such as timber, fuelwood, charcoal, tanin, among others. The leaves of the *Nypa* palm are highly valued as roofing material. The total biomass of mature *Rhizophora apiculata* in Viet Nam's forests was measured to be 276,829 kg/ha of which 57% or 158,034.02 kg are timber (Tri 1986).

The high amount of leaf litter produced by the mangrove trees provides the base of natural food chains in the estuarine and coastal waters. During decomposition, the leaves are enriched by proteins from microorganisms that break down the leaves. This protein-enriched plant detritus provide the main food for juveniles of commercially important penaeid shrimps that spend part of their life cycle in brackish tidal swamps. Plant detritus are transported by the current seaward and the nutrients released from the mineralization process support primarily productivity in estuarine and coastal waters. Besides, many estuarine organisms feed directly on detritus.

Mangrove swamps are nursery areas for a large number of marine species (eg., penaeid shrimps, mud crab, fish and molluscs).

Zonation and succession

The following description of mangrove species zonation and distribution is mainly based on data provided by Dr. Phan Nguyen Hong (Hong *et al.* 1993; Hong 1997). The main factors determining zonation are salinity and soil properties. Along the coastline, on newly accreted land with a substrate of deep, soft mud affected by low tide, pure stands of *Avicennia alba* are found. Scattered stands of A *officinalis* and *Bruguiera sexangula* also occur. Mixed communities of *Rhizophora apiculata - B. parviflora* or *A. alba - R. apiculata* occupy areas flooded by the tide.

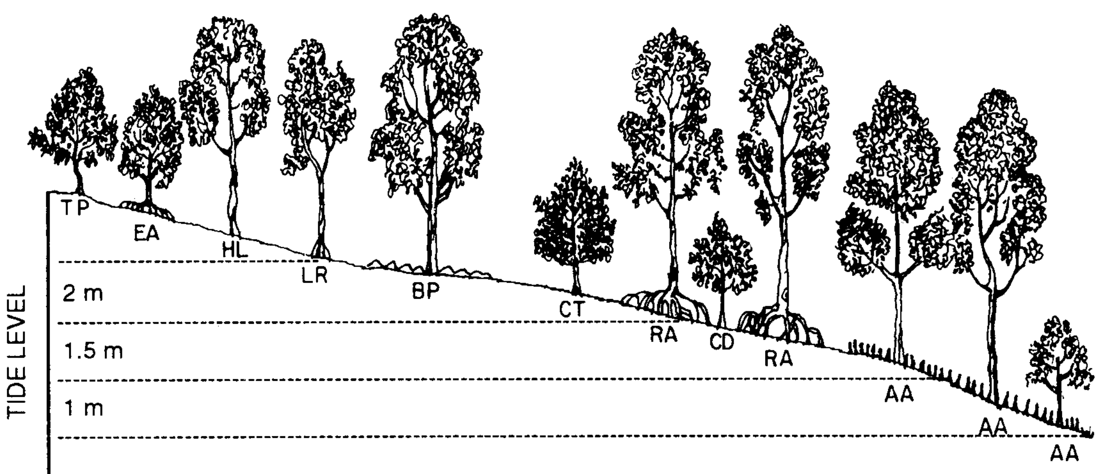
On high land flooded only during spring tide and with loamy substrate, a community of *Lumnitzera racemosa-Ceriop tagal* is found. On high land near the sea, a pure community of *Exoecaria agallocha* is anchored on firm mud and a secondary forest of the palm *Phoenix paludosa* can be found.

The rhizomatous palm *Nypa fruticas* is characteristic of areas which are slightly brackish though regularly flooded. In parts of the mangrove forest that are rarely flooded and where trees have been cut, the giant fern *Acroostichum auereum* can be seen. On the severely eroded sandy flats of the east coast of Ca Mau peninsular, from Bo De to Dat Mui, an almost pure stand of *Avicennia manina* is found. In rapidly accreting areas, *Avicennia alba* has not been replaced by *Rhizophora apiculata,* but instead the mangrove has developed into a mixed community of *A. alba* - *A. officinalis.*

The zonation and succession of mangrove vegetation at Ca Mau Cape is illustrated on Figure 2.

Wildlife

Reptiles, birds and mammals originally made up the terrestrial wildlife fauna of the southern mangrove forests (Hong & San 1993). Some surveys on wildlife trade have been carried out, showing a huge number of reptiles and amphibians traded on the local market for consumption or for export. Tigers, deers, wild pigs and crocodiles existed in mangrove forests long ago, but have disappeared because of overhunting and destruction of mangrove areas. Rehabilitation of mangrove forests can increase population of such animals as wild pigs, crocodiles, monkeys, water birds, fishes and shrimps like in the case of Can Gio District, Ho Chi Minh City when 20,000 ha of new mangrove trees were replanted.



SUCCESSIVE STAGES			
Luminitzera racemosa *Excoecaria agallocha* *Thespesia populnea* *Cerbera manghas* *Heritiera littoralis*	*Rhizophora apiculata* (dominant) *Bruguiera parviflora* *Ceriops tagal* *Ceriops decandra*	*Avicennia alba* *Rhizophora apiculata* *Ceriops tagal* *A. officinalis* (mixed community)	*Avicennia alba* (pioneer)

Figure 2. **Zonation and succession of mangrove vegetation at Ca Mau Cape**
(Hong & San 1993)

The mangrove forest is a good habitat for some stages of the life of fishes, shrimps, crabs, clams, oysters and so on. Humus is a very important food source.

Mangroves in Vietnam have very abundant aquatic life. For example, 80 species of crustaceans, 160 species of molluscs and 250 fish species were identified by Vietnamese scientists. Recently, 106 species of algae, 102 of zooplankton, 113 of zoobenthos, 50 of marine and brackish fishes and 17 of shrimps were recorded in an area of 4,000 ha mangrove forest located in Ben Tre province (Xuan *et al.* 1998).

Some causes of mangrove destruction

Chemical war carried out by the US
About 159,000 ha mangrove area in southern Vietnam were destroyed by defoliant sprays during the American-Vietnam war, with loss of timber calculated at 21,928,611 m^3 (Hong 1997).

Overexploitation
The mangrove forest has been overexploited by local communities for poles, charcoal/fuelwood, woodchips, medicines, and food in times of famine.

Conversion to shrimp ponds, agricultural land
Thousands of hectares of mangrove forest have been converted into shrimp ponds in the last decade. But yields of shrimp and crab are low even after 2-3 years of operation because of the degradation of the pond environment. Pond design is part of the problem, as it allows very limited water exchange (pond is either too big or too small, and there's only one sluice gate). The locals usually abandon the old ponds, and clear cut the mangroves to build new ones. Thousands of hectares of protected coastal mangroves from Quang Ninh to Ninh Binh provinces have been destroyed in this manner. From 1983 to 1995 alone, about 66,253 ha of mangrove forest in Minh Hai province have been converted into shrimp ponds (Cuong 1996).

Due to the lack of agriculture land, some mangrove forest areas have been destroyed and converted into ricefields and subsidiary land although these lands are not suitable for agriculture. Crop yield is very low because of freshwater shortage and acidification. In the case of Quang Ninh and Hai Phong provinces, about 50,000 ha coastal areas have been fallowed (Hong *et al.* 1995).

Other causes
Some mangrove areas have been destroyed to build residential areas, industrial areas, roads, fishing and coal ports. Mangrove forests near industrial areas could not regenerate normally due to waste waters with high concentration of toxicants.

Consequences of mangrove destruction

Decline of biological resources
Mangrove destruction not only decreased timber sources but also lowered species composition and population of aquatic organisms and other animals (eg., mammals, birds, reptiles and amphibians). For example, the densities of wild shrimps *Penaeus indicus* and *Metapenaeus* spp in the Mekong Delta decreased to only 1 shrimp/260 m^3 and 1 shrimp/45 m^3, respectively (RMFP 1998).

Increasing fallowed land and CO_2 concentration
Mangrove soils have chemical (salt and acid) and physical features unsuitable for agriculture. Insufficient freshwater causes soil degradation as had happened so often in the past. Besides, a huge amount of organic matter from the mangrove is decomposed; hence, adding to higher atmospheric carbon dioxide (CO_2) concentrations and contributing to global warming.

Salinity intrusion, silt accumulation, soil and water pollution
Shrimp ponds significantly decrease the areas for receiving marine and brackishwaters. So, during the dry season, seawater goes further inland through the canal and river systems, affecting rice fields and eroding the banks of canals and rivers.

Silt can not be transported but builds up because shrimp dikes and rice paddies bisect some small rivers and tributaries. Some of these tributaries may also become eroded.

The concentration of toxicants such as H_2S, FeO, NH_4, chemical fertilizes, pesticides, and oils tends to increase in some mangrove areas which have been converted into shrimp ponds and agriculture lands.

Legislation, policies and regulations

Legislation and policies
The government has issued in 1991 a law protecting and developing forestry in which mangrove forest preservation in national coastal areas are included. The government has also developed a number of policy measures.

To attract local people to take part in mangrove preservation and reforestation, an area of 5-10 ha is allocated to households based on Government Decision No. 202 dated 2 May 1994. A Contract of Leased Forest Land which is signed by the Director of SFE and household head and registered at the People's Committee of Commune defines the rights and obligations of contracting parties.

The forestry policy towards the year 2010 aims to:

- conserve natural resources (e.g., watersheds, biodiversity)
- make forest development and land use ecologically and socially sustainable
- give long-term benefits to rural population and country economy (i.e., improve living standards, develop the mountainous and coastal areas)

Viet Nam also became a contracting party to the RAMSAR Convention on January 20, 1989 and had designated the mangrove islands of Xuan Thuy district in Nam Ha province for inclusion in the RAMSAR list (Duc 1990).

Regulations
Some regulations have been issued and implemented, as follows: (1) densities of planted mangrove must be 10,000-20,000 trees/ha; (2) the first to be thinned will be stands 9-10 years old, next will be stands 18-20 years old; and (3) for shrimp farming, 70% of the farm area must be reserved for mangrove planting.

Under Decision 327 dated 15 September 1992, some Provincial Forest Development Plans were prepared. The objectives of these plans are reforestation and rehabilitation of coastal and estuarine mangrove ecosystems; specifically, protection of coast against erosion, reclamation and stabilization of newly accreted mud flats, rehabilitation of nursing areas for economically important fish and shrimp species, sustainable forest production, improvement of income levels and the standard of living of local people.

At regional level, the Mekong Delta Master Plan has identified 10 forestry projects since 1993. Four of these projects are located in the coastal zone and much emphasis was put on re-establishing mangrove protection belt, protection of nature reserves, and creating new ones in mangrove areas.

Between 1965-1974 after liberation, about 2,783 ha of mangrove trees were replanted in Minh Hai province to protect guerrillas, and from 1975 to 1990s about 63,323 ha have been replanted to mangrove trees (Hong 1997)

Organizations to support mangrove-friendly aquaculture

National level
The Ministry of Agriculture and Rural Development (MARD) has assigned the tasks of mangrove preservation and mangroves development to the Department of Forest Management and Control (DFMC) and Department of Forest Development (DFD), respectively.

Provincial level
Under the leadership of MARD and the Provincial People's Committee (PPC), a Sub-Department of Forest Management and Control (SDFMC) has been established in all coastal provinces. The SDFMC manages the Boards of Mangrove/Melaleuca Special Use Forest or Mangrove Forest Reserve. The Sub-Department of Forest Development (SDFD) belonging to the Provincial Department of Agriculture and Rural Development (PDARD) supplies concrete guidance in mangrove rehabilitation and protection to local Forestry-Fishery Enterprises (FFE).

Land-use options in mangrove areas

Ecological considerations
Shrimp culture can be considered destructive to mangroves, however, it is the best way to increase the value of the mangrove ecosystem to support the poor. The problem is building mangrove-friendly aquaculture models to ensure sustainable development. The coastal areas of the Mekong Delta practice these models:

- **Mixed shrimp farming-mangrove forest**
  About 3 ha (300 x 1,000 m) are reallocated to each household for mangrove planting and for canal excavation to culture shrimp. FFE gives capital for the household to plant *Rhizophora* at a rate of 1,000-2,000 trees/ha. The household invests money and labor in excavating canals and in building embankments that are 5 m wide with one outlet and one inlet sluice gate. The ratios of pond size including embankments and mangrove forest are 32% and 68%, respectively (Binh 1994). At neap tide, the seawater just wets the ground, so the trees grow well. The low tree density prevents too

much shading in canals and gives enough light for phytoplankton and enough surface and dissolved oxygen for aquatic organisms. The farming method is traditional extensive without additional supply of food and shrimp seed, and the highest yield is estimated at 200-250 kg/ha/year. The soil in this model is not degenerated due to good water exchange; it is also usable for a long time (about 7 years now).

- **Mixed mangrove forest-shrimp farming**

FFE invests in felling miscellaneous trees, replants mangrove, divides the area into 5-ha squares on an average, and allocates it to households for forest protection and shrimp farming. The household invests in digging canals and building embankments on 30% of allocated land. Besides a surrounding canal system in the *Rhizophora* planting area, there are 2 canals of the same size separated by a 6-m bank in order to increase the area of unshaded water surface suitable for primary production by phytoplankton. *Rhizophora* are planted at a density of 10,000 trees/ha.

Socioeconomic considerations

In principle, no economic activities such as aquaculture, farming, and settlement are permitted in the Protection Belt and Full Protection Zone (FPZ) except controlled thinning, collection of dead forest products and protection of breeding and nursing grounds. But in practice, relocation and resettlement of all existing farms and people living in these zones would be costly and could lead to social problems.

To wisely use the inland mangrove forest and to reduce the pressure from the human population on the FPZ or Core Area, some conditional human activities — e.g., traditional extensive shrimp farming mixed with mangrove forest, cage and pen aquaculture — in the BP are allowed, aimed at sustainable use of natural resources, creation of jobs and increasing income of the poor.

In the Economic Zone, human activities are concentrated on settlement, development of a long-term mangrove forest (main product) in combination with short-term aquaculture (additional product for daily life).

Other farming models may be explored to diversify products, reduce risks from one crop (shrimp), increase household income, and provide locally produced food. This could include culture of crabs and fishes in ponds and subsidiary crop production such as vegetables, banana, cassava, cherry in the raised beds and land near the house.

Existing programs on sound utilization of mangrove areas

In the Mekong Delta, some projects and studies relating to aquaculture in mangrove areas are being done:

MILIEV - Rehabilitation of Mangrove Forest Project

This Netherlands Government 3-year technical assistance project started in March 1996. It aims to achieve three main goals: providing natural protection of the coast, contribution to sustainable aquaculture, and restoring biodiversity. It has an aquaculture component which includes some experimental farming systems such as improved extensive shrimp farming, sea bass cage culture, mud crab cage culture, and fish-and-pig farming carried out in 184 FFE, Tam Giang I FEE and Dam Doi FFE (Ngoc Hien District, Ca Mau province).

Semi-Intensive Shrimp Culture Project

Under the Mekong Delta Master Plan, a feasibility study was undertaken for shrimp culture-cum-mangrove reforestation on two pilot areas nearly 3,000 ha located at Ba Tri (Ben Tre province) and Ganh Hao (Ca Mau province).

Mixed Shrimp Farming-Mangrove Forest Models in the Mekong Delta

A pilot program to improve extensive shrimp farming mixed with mangrove forest was carried out in 1995-1998 by the Ministry of Fisheries/RA2-ACIAR/AIMS in cooperation with The Centre for Mangrove Forest Research. The pilot farm was on 12,000 ha located at Tam Giang III FFE and 184 FFE, Ngoc Hien District, Ca Mau province. Specific objectives of the project were to investigate factors controlling shrimp yields and wood production from existing shrimp farming-mangrove forest systems and to evaluate different culture options for shrimp and mangrove forest management. During the first phase, recommendations with respect to pond design, management, water quality and shrimp/crab seeds supply were detailed.

Integrated Management of Coastal Resources in the Mekong Delta

The project is jointly proposed by Can Tho University and Wageningen Agricultural University (Netherlands). The 3-year project has strong training and research components that focus on socio-economic aspects of water management in coastal farming systems, remote sensing, land use planning, ecology and environmental impact assessment. The study site (about 10,000 ha) will be located in Vinh Loi District, Bac Lieu province.

Strategic plans for improving mangrove areas

Strategic plans

- Zoning of coastal mangrove areas (Protection Belt, Full Protection Zone, Buffer Zone, Economic Zone, Protected Area, Core Areas, Conservation Areas, Bird Sanctuaries)
- Establishment of management measures for each zone and area
- Community development (extension and education, transfer of technology, upgrading of infrastructure)
- Economic policy (land allocation and making contract with farmers to protect mangrove forest for long periods)
- Improvement of credit system serving the poor (low interest and long borrowing period)
- Controlling human population in mangrove forest areas (limitation of human habitation)
- Management of mangrove areas (based on a combination of some sectors such as agriculture, forestry, fisheries and aquaculture, environment, and land management)

Development programs

- **Integrated Provincial Master Plans/Projects**

  A feasibility study was undertaken for the South Mang Thit Integrated Irrigation and Drainage Project under the MDMP study. This area includes Tra Vinh province. Project interventions are water control and regulatory works, mangrove forestry, fisheries and aquaculture, drinking water supply, and public health and sanitation

- **Coastal Wetlands Protection and Development, Southern Mekong Delta**

  This Euroconsult-supported technical assistance project was carried in the coastal areas belonging to the provinces of Minh Hai, Soc Trang and Tra Vinh in 1995 to 1996.

One of the main objectives is providing of nurturing functions for fisheries and provision of support services for the mangrove forestry and aquaculture in protected wetlands and key surroundings areas

- **Mangrove/wetland management project in Thanh Phu, Ben Tre Province**
  This 3-year project (1998-2000) is supported by the Mekong River Commission for the purposes of mangrove forest resources inventory and management strategy for coastal mangrove wetland reserve

- **National project of planting 5 million ha of forestry up to the year 2010**

Recommendations (national and regional levels)

Creating awareness through education and training
To ensure sustainable development of mangrove ecosystems and resources, the awareness of local people should be increased through education and training courses. Likewise, the participation of the local community in the protection and conservation of mangroves should be encouraged.

Topics that discuss the value of mangrove forest, mangrove forest planting and management, sustainable mixed aquaculture farming-mangrove forests systems can be taught to farmers, women, children and FFE management staff.

Promoting research on critical areas, sustainable management plans
Research on mangrove ecosystems and biodiversity in some zones such as Accreting Areas, Protection Belt, Full Protection Zone, Core Areas, Special-Use Mangrove Forest should be carried out. It could cover classification of mangrove functions and mangrove valuation, zoning and management, strategies of economy and occupations which mitigate the devastation brought by people, and improvement of mixed aquaculture-mangrove forest farming systems.

Some specific studies are suggested:

Assessment studies
- determining the value of mangrove resources including natural shrimp seed stock
- possibility of natural mangrove regeneration in different areas located on high land or fallow land
- pollution levels in mangrove and river mouth areas created by oil, fertilizers, pesticides and heavy metals

Impact research
- on agriculture and aquaculture development in mangrove forest along the coast of the Mekong Delta and vice versa

Socio-economic studies
- on mixed aquaculture farming-mangrove forest systems which provide households with reasonable income and benefit

Mangrove-related fisheries
- quantitative study on the processes of energy flow, nutrient exchange and exchange of aquatic organisms between mangrove swamps, estuaries and coastal waters

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Malaysia: Mangrove-friendly aquaculture

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Abstract

The paper describes some mangrove-friendly aquaculture activities that are practiced in Malaysia. Among these are the culture of cockle and oyster, semi-intensive culture of tiger prawn, fish cage culture, and pen culture of mud crab. Policies, regulations, future directions and priority areas in research and development that can contribute to sustainable mangrove utilization are discussed.

Brief overview of aquaculture

Aquaculture is not indigenous to Malaysia but was introduced during the late 19th and early 20th century. Species cultured include fishes, molluscs and crustaceans. Presently, aquaculture contributes about 10% to total fish production, while mariculture comprises more than 80%. The 1997 National Agriculture Policy describes Malaysia's strategies for food sufficiency and places great emphasis on fish production through aquaculture. By the year 2010, a production of 600,000 tons has been targeted from the aquaculture sector.

The first known brackishwater culture was introduced in the state of Johor in early 1900s, when Chinese immigrants brought with them the technique of penaeid prawn culture in trapping ponds located in the mangroves. Penaeid prawn farming has grown in importance and intensity over the years. Prawn (mainly the giant tiger *Penaeus monodon*) fry are presently produced from hatcheries, and semi-intensive or intensive farming is normally practiced. From a production of about 60 tons in 1984, it has expanded over a hundred-fold to 7,407 tons in 1995 (Annual Fisheries Statistics 1984, 1995).

The most important brackishwater species in terms of total production is cockle (*Anadara granosa*). Malaysia is the world's top producer of cockles with production estimated at more than 100,276 tons in 1995. Cockle culture also contributes 88% to Malaysia's mariculture production (Annual Fisheries Statistics 1995). However, it relies solely on seeds collected from the wild.

Other species cultured include the sea bass *Lates calcarifer*, snapper *Lutjanus* sp., grouper *Epinephelus* sp., mussel *Perna viridis*, oysters *Crassostrea belcheri* and *C. iredalei*, and mud crab *Scylla* spp. The culture of mussel, oyster and mudcrab contributes only 1% to total mariculture production. Fish cage culture contributes 5% to total mariculture though it was introduced only in 1974. Off-shore cage culture is presently initiated, and its success may herald the expansion of cage culture from the sheltered coastal waters to the open and less polluted seas.

Mangrove management and conservation

Management of mangrove areas has been implemented beginning the turn of the 20th century with the conservation of forests for wood production (firewood, charcoal and poles). Although mangrove forests have been set aside as reserves, intense pressure for their conversion to other uses are frequently encountered. Outside the forest reserves, stateland forests that are unalienated and under the jurisdiction of the states are under even greater pressure for conversion.

In Peninsular Malaysia, protected mangrove areas account for only 0.3% of the total area; in Sarawak, 0.2% and Sabah, 1.3% (Table 1).

Existing mangrove areas
Mangroves form only about 2% (641, 172 ha) of Malaysia's total land area (Figure 1). Despite the recent greater awareness of their ecological role, these habitats are still lost at an estimated 1% yearly (Ong 1995). This rapid loss has resulted in the imposition of a moratorium by the Malaysian Government in 1996 disallowing new clearing of mangrove areas.

Table 1. **Gazetted mangrove conservation areas in Malaysia**

State	Locality	Classification	Area (ha)
Johor	Pulau Kukup FR, Compt. 6	Virgin jungle reserve	26
Pahang	Sg. Miang FR, Compt. 1	Virgin jungle reserve	56
Perak	Pulau Kecil	Virgin jungle reserve	42
Sabah	Batumapun	Virgin jungle reserve	164
	Umas-Umas	Virgin jungle reserve	830
	Elopura	Virgin jungle reserve	1,093
	Kota Belud	Bird sanctuary	1,518
	Sepilok	Virgin jungle reserve	1,235
Sarawak	Samunsam	Wildlife sanctuary	220
	Bako	National park	166
Selangor	Kuala Selangor	National park	320
TOTAL			5,670

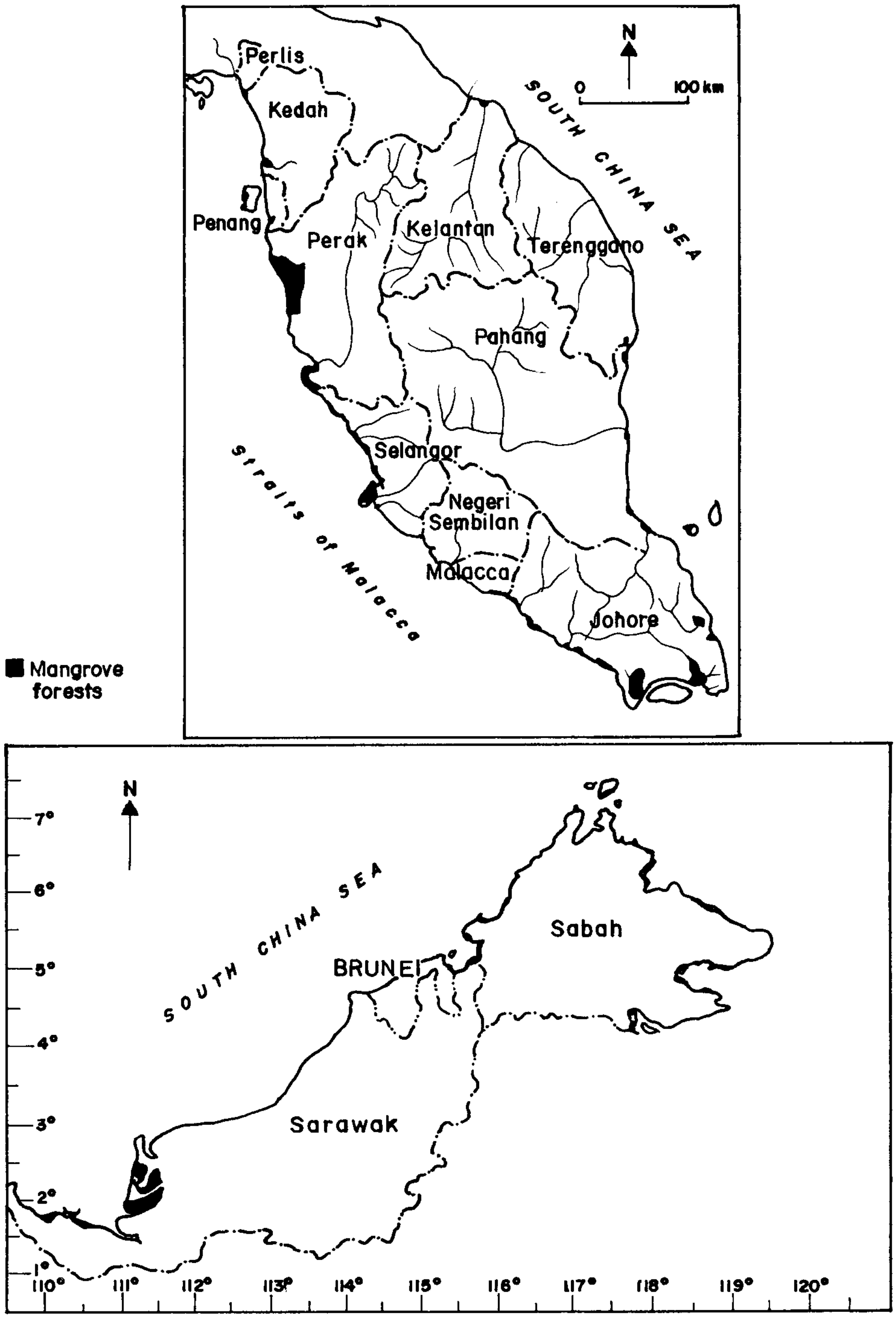

Figure 1. **Distribution of mangrove areas in Malaysia**

A total of 641,194 ha of mangrove forests remain in Malaysia, of which 57% are found in Sabah, 26% in Sarawak and 17% in Peninsular Malaysia, mainly along the west coast (Figure 1). Out of the total area, 440,400 ha are mangrove forest reserves, and 200,794 ha are stateland mangroves (Table 2).

Value of mangrove resource

Mangrove habitats are known to be important spawning, breeding and nursery grounds for many fishes and prawns. Sasekumar *et al.* (1992) recorded 119 fish species and 9 prawn species from the mangroves in Selangor, while 117 fish species were reported from Matang (Sasekumar *et al.* 1994). Mangroves play a significant role in sustaining the fisheries resources through tidal flushing of detritus and nutrients that form the food base for microorganisms, which in turn support the coastal and near-shore fisheries. Prawn resources especially, have been closely correlated with the presence of mangroves (Sasekumar & Chong 1987; Chong 1996). Mangroves also contribute to the livelihood of coastal communities dependent on wood products harvested from mangrove forests, and of artisanal fishers dependent on fisheries resources for a living.

Mangroves play a role in maintaining the water quality in coastal areas and act as a buffer against soil erosion. Studies have shown that unprotected coastlines have an erosion rate of about 20 times greater than shoreline protected with mangroves (Salleh & Chan 1988). Mangrove areas are also important foraging and stop-over sites for local and migratory shorebirds. About 115 species of birds have been recorded from mangrove areas (Nisbet 1968). Many species of terrestrial animals reside permanently or enter the mangrove areas as visitors. Visitors include the wild pig (*Sus scrofa*) and the mouse deer (*Tragulus* sp.) which visit the landward edge at low tide, and the otters which are commonly found in estuaries (Sasekumar 1980). Monkeys recorded include the leaf monkey (*Presbytis cristata*), the

Table 2. **Mangrove forest reserves and stateland mangrove areas (ha) in Malaysia**

State	Forest reserves	Stateland	Total
Johor	16,659	8,050	24,709
Kedah	8,034	-	8,034
Kelantan	-	-	-
Malacca	238	100	338
Negeri Sembilan	233	727	960
Pahang	2,483	8,990	11,473
Penang	451	-	451
Perak	43,502	-	43,502
Perlis	-	-	-
Sabah	317,423	49,927	367,350
Sarawak	34,992	133,000	167,992
Selangor	15,090	-	15,090
Terengganu	1,295	-	1,295
Total	440,400	200,794	641,194

Source: Department of Forestry Peninsular Malaysia, Sabah and Sarawak long-tailed macaque (*Macaca fascicularis*) and the proboscis monkey (*Nasalis larvatus*) which are endemic to Kalimantan. They feed on the leaves of *Avicennia* and *Sonneratia.* The flying foxes (*Pteropus vampyrus* and *Macroglossus lagochilus*) and the fruit bats (*Econycteris spelaea*, *Macroglossus minimus*, *Cynopterus brachyotis* and *C. horsfieldii*) are commonly found along the landward edge. The fruit bats are known to feed on the nectar and pollinate the flowers of durian (*Durio zibeehinus*), and survive on the nectar of *Sonneratia* flowers when durian are not flowering. Reptiles reported include the crocodile (*Crocodilus porosus*), the pit vipers (*Trimeresurus pupureomaculatu* and *T. wagleri*), the clouded monitor lizard (*Varamus bengalensis*), the monitor lizard (*V. salvator*), the reticulated python (*Python reticulatus*), the black cobra (*Naja naja*), the king cobra (*Ophiophagus hannah*) and the common snake (*Cerebrus rhynchops*) (Sasekumar 1980; Gan 1995).

Causes of mangrove destruction/conversion

Threats to mangroves include: (1) human settlement development, (2) aquaculture development, (3) wood-chips operation, and (4) land reclamation. Ong & Gong (1991) estimated that 20% of the mangroves have been lost to various development purposes in the last two decades. Mangrove forest reserve has decreased from 505,345 ha in 1980 to 445,802 ha in 1990, a 12% loss in ten years (Table 3). The rate of decrease in stateland mangroves is not known, but is believed to be significantly greater than 12%.

The brackishwater pond area in operation for 1995 constitutes less than 1% of total mangrove area compared with 30% being utilized for other purposes (Table 4). Despite the small hectarage converted to prawn farms, its conversion has taken the brunt of the criticism on mangrove destruction. This is due perhaps to some of the spectacular reports on the collapse of unsustainable farms all over the world (Choo 1996).

Mangrove habitats are commonly utilized for various purposes such as for human settlements, ports, jetties, airports, tourist resorts, industries, agriculture and aquaculture. If development does not follow guidelines for sustainable utilization, these habitats will face widespread destruction which in turn will impact on the sustainability of fisheries and wildlife resources. Impacts include coastal erosion and deterioration of coastal water quality. Saenger *et al.* (1983) estimated that 15 fauna and 17 flora species in Asia and Oceania are at risk of extinction as a result of mangrove forest degradation. Loss of mangrove habitats will also have economic implications since some of the coastal inhabitants rely on wood products and fisheries resources for a living.

The mangrove forest is normally exploited for its firewood, charcoal and poles. There is, however, declining demand for firewood utilization due to competition from cleaner and more efficient fuel. In the present Matang Mangrove Management Plan (The Second Ten-Year Period, 1990-1999), no allocation of forest areas were given to firewood production (Gan 1995).

Charcoal production is the mainstay of the economy and management of mangrove forests. But it is facing stiff competition from other fuels like gas, kerosene and electricity. Mangroves are also harvested for poles which are sought after in the building industry. Pole production is the second most important objective in managing mangrove forests. Poles are used in river dressing, embankment construction and scaffolding. In Sabah and Sarawak, mangroves have been harvested unsustainably for wood-chips which are used for manufacturing rayon (Ong 1995).

Table 3. **Area (ha) of mangrove forest reserves in Malaysia in 1980 and 1990** (NAIMANCOM 1996)

State	1980	1990	Loss/increase	%
Johor	25,619	16,697	-8,922	-34.8
Kedah	9,037	8,034	-1,003	-11.1
Malacca	77	314	237	75.5
Negeri Sembilan	1,352	1,061	-291	-21.5
Pahang	2,496	2,032	-464	-18.6
Penang	406	406	-	-
Perak	40,869	40,869	-	-
Sabah	349,773	316,460	-33,313	-9.5
Sarawak	44,491	36,992	-7,499	-16.9
Selangor	28,243	21,983	-6,260	-22.2
Terengganu	2,982	954	-2,028	-6 8.0
Total	505,345	445,802	-59,543	-11.8

Table 4. **Area of brackishwater ponds in operation in 1995** (Annual Fisheries Statistics 1995)

State	Area (ha)
Johor	587.84
Kedah	389.30
Kelantan	67.85
Melaka	20.24
Negeri Sembilan	30.50
Pahang	171.82
Penang	86.72
Perak	356.47
Perlis	7.75
Selangor	297.72
Terengganu	48.48
Sabah	544.59
Sarawak	14.16
Total	2623.44

Organization and systems related to mangrove preservation (including government regulations)

Policies and plans that are relevant to the conservation and management of mangrove forests include the following:

National Policy on the Environment
This proposed policy is based on seven principles that harmonize economic development goals with environmental imperatives. These principles are:

- Steward of the environment - exercise respect and care for the environment in accordance with the highest moral and ethical standards

- Conservation of nature's vitality and diversity - conserve natural ecosystem to ensure integrity of biodiversity and life support systems

- Continuous improvement in the quality of the environment - ensure continuous improvement in productivity and quality of the environment while pursuing economic growth and human development objectives

- Wise use of natural resources - manage natural resource utilization in order to protect the resource base and prevent degradation of the environment

- Integration of sustainability in all decision-making - ensure that the policies, objectives and mandates of all sectors take into consideration their impact on the environment

- Commitment and accountability - ensure the highest commitment to environmental protection and accountability by all decision-makers, resource users, non-governmental organizations, and the general public in formulating, planning and implementing their activities

- Active participation in the community of nations - participate actively and constructively as a responsible member of the world community, in regional and global efforts towards environmental conservation and enhancement

National Coastal Resource Management Policy
This policy proposes to "provide the framework for related policies, strategies and management guidelines on coastal resources with a view to facilitating the attainment of Vision 2020 through complementary macro and sectoral policies to achieve the national objective of balanced development."

Seventh Malaysia Plan (1996-2000)
This plan aims to balance growth objectives with environmental concerns. Environment and resource management will be guided by the proposed National Policy of the Environment which will be made operational. Focus will be given on the establishment of a strengthened institution framework, enactment of relevant legislation and regulations and creation of an efficient and effective enforcement and monitoring machinery.

Presently, no specific legislation and regulations singularly address the ecological dimension of mangrove management, probably because the laws for forest management were established at the time when the environmental functions of mangroves were not well-understood (MCRST 1992). The mangroves are currently managed as forest reserves which are regulated by the National Forestly Act 1984 (amended 1993). Other relevant legislation in include:

- National Parks Act 1980
- National Land Code 1965
- Land Conservation Act 1960
- Woodbase Industries Act 1985
- Protection of Wildlife Act 1972
- Fisheries Act 1993
- Environmental Quality Act 1987

Model areas/projects where mangroves are used for aquaculture

Cockle culture
The culture of cockles in the mangrove mudflats of Peninsular Malaysia (especially in Perak, Selangor and Penang) is regarded as mangrove-friendly, and is the mainstay of the mariculture production, contributing over 90% of the production. Around 4,700 ha of mudflats are utilized for culture and the production from 1983 to 1995 is shown in Table 5.

Natural cockle spat are abundantly found in Perak, Selangor and Penang, and are collected for culture. The collection is regulated by Fisheries Regulations 1964 (Conservation and Culture of Cockle). The method and time of collection, as well as the permitted spat size for collection and

Table 5. **Total cockle production in Malaysia from 1983-1995** (Data compiled from Annual Fisheries Statistics)

Year	Production (tons)
1983	38,530
1984	63,581
1985	44,761
1986	45,664
1987	40,794
1988	34,867
1989	39,346
1990	35,932
1991	46,625
1992	55,587
1993	77,755
1994	82,335
1995	100,276

harvest size are stipulated. The biggest threat to the sustainability of this industry is widespread coastal reclamation that may decimate Spatfall and culture areas.

Oyster culture

The culture of mangrove oysters (*Crassostrea iredalei* and *C. belcheri*) is practiced in the estuaries of Batu Lintang, Kedah, Telaga Nanas, Perak and in Sabah. The raft, long-line or rack methods are commonly used. Oyster spat (5-10 mm size) are collected from the wild using collectors made of netlon, oyster or coconut shells, or old motorcycle tires suspended from rafts or long-lines. When the spat reach 10 mm in size, they are culled from the collectors and transferred to racks, netlon bags or plastic baskets where they are grown as single oysters. After thinning, the collectors with the remaining spat are resuspended from the rafts or long-lines for grow-out. The grow-out phase takes 12-14 months for oysters to reach a marketable size of 9-11 cm. Total production in 1995 was about 26 tons with a wholesale value of RM 260,000 (Annual Fisheries Statistics 1995). Although mollusc culture has been reported to cause sedimentation of coastal waters (Chua *et al.* 1989), the activities carried out in mangrove estuaries in Malaysia are not intensive and are very unlikely to be detrimental to the environment.

Pen culture of mud crab

In 1992, the Inland Fisheries Division of the Department of Agriculture, Sarawak initiated the pen culture of mud crab (*Scylla* spp.) in logged mangrove areas in Sematan. Mud crab are reared in areas where the vegetation is left intact so that the crab can grow and reproduce in the natural environment. Mud crab are able to breed freely and there are now over 100 crab pens in Sematan. A large number of berried females are caught from the pens. Recent studies reported a high proportion of young crab (< 100 g) in the area and the increase in the recruitment has been attributed to pen culture (Chang 1997). Fishers are also reforesting the bare areas to provide more shade for mud crab.

Penaeid prawn culture

Prawn farms that are developed recently are sited on higher ground in back swamps more than 100 m behind the coast, and are therefore more mangrove-friendly. Semi-intensive cultures (stocking density, 10-20 postlarvae/m^2) are practiced and waste treatment facilities are available (Choo 1996a). Draining of wastewater, especially during harvest and pond cleaning, into sedimentation ponds prevent nutrient-rich water from reaching coastal waters thus preventing hypernutrification or eutrophication. Guidelines for sustainable prawn farming recommended by NATMANCOM (1986) are shown below:

Choice of site is prioritized as follows:

- Mangrove areas already reclaimed for agriculture purposes, unused or abandoned due to poor soil conditions or production
- “Hutan darat” or the landward side of the mangrove forests where forestry output is poor and where impact on coastal fisheries is least
- Stateland forests which are outside the forest reserves and are usually unproductive for forestry

On farm size and location:

- The pond site should be at least 100 m from the high tide level
- Not more than 20% of forests in a given area can be cleared for pond construction
- The next farm/project should be constructed at a distance more than four times the length of the coast occupied by the first farm/project

On culture techniques:
- The pond should be constructed without excavation to avoid problems associated with acid sulfate soils;
- The water regimes should be managed by pumping rather than tidal fluctuations
- Pellet feeds should be used rather than raw trash fish

The Department of Fisheries (DOF) together with the Food and Agriculture Organization (FAO) has prepared a document “Code of conduct for shrimp farming” to guide farmers in the practice of sustainable shrimp farming.

Coastal cage culture
The species cultured in cages in coasts and estuaries include sea bass (*Lates calcarifer*), grouper (*Epinephelus* sp.), and red snapper (*Lutjanus argentimaculatus*). Although feeding is still largely dependent on trash fish, some progressive farmers (less than 5% of total) have converted to the use of formulated fish pellets that are less polluting and more nutritious. The use of chemicals and antibiotics are also discouraged, and are confined to those that are approved. Other guidelines for sustainable cage culture practices can be found in the document “Proposed code of practice for marine finfish farming in floating cages” prepared by DOF and FAO. In 1995, a total of 4,800 tons of fishes were produced from cage culture, with a wholesale value of RM 76 million (Annual Fisheries Statistics 1995).

Integrated seaweed-penaeid prawn culture
A pilot project involving the integrated culture of tiger prawn and seaweed was initialed in October 1998 in Pantai Merdeka in Kedah. This project is a collaborative effort between the Fisheries Research Institute and the Fisheries Development Authority, Malaysia (Ramli Saad, pers. comm.). Four ponds with an average size of 0.25 ha were stocked with tiger prawn fry at 20/m^2. The seaweed *Gracilaria changii* was cultured in racks. A total of 12 racks were spread over 10 m^2 of the pond area, and the seaweed was planted at a density of 1 kg/m^2. The tiger prawn are expected to reach market size in four months, while the first harvest of the seaweed will take place two months after its planting with subsequent crops harvested a month later.

Strategic plan for improving mangrove areas

Future directions, policies, and regulations
Some legal issues pertaining to the utilization of mangrove land can be further improved. One critical issue is the designation of permanent forest reserves which can be changed by the states. The National Forestry Act (1984) gives the right to states to reclassify lands for activities that have “higher economic value.” This clause have dire implications in states that opt for short-term benefits against the wider and sustainable ecological role that mangrove ecosystems provide. The administration of stateland forests often poses a problem since state governments very often regard mangrove land as wasteland that could be delineated for all sorts of purposes. Ideally, stateland mangrove should also have a management plan where the areas could be zoned for the complementary and sustainable use of all stakeholders.

The Mangrove Management Plans were initiated in the early 20th century when the key activities were centered around wood products. A sustainable plan will have to take into consideration the management of other activities in the area, for example, aquaculture. The reforestation of abandoned prawn ponds and other mangrove areas left bare from clearing should be attempted. Attempts have been made in Thailand, Indonesia and Malaysia to replant mangroves (Choo 1996b), and collaboration between ASEAN countries to learn from each other's experiences will benefit the whole region.

DOF together with FAO had formulated regulations and code of practice for aquaculture in Malaysia. The document includes site, design and management considerations for fish and shrimp culture, and is designed to set professional standards and guidelines for producing shrimp and fishes. The regulations will be enforced after the document is endorsed by the federal and state governments.

Recommended approaches

While it is recognized that the mangrove ecosystem plays an important role in sustaining aquatic resources, it may not be pragmatic to advocate a no-use policy in order to prevent the loss of this very important habitat.

The Mangrove Policy should be one that allows for the use of the ecosystem without damage to ecological processes and biodiversity (Robadue 1995). It may not be realistic to put a total ban on some aquaculture activities, for example, penaeid prawn farming. What is more realistic is advocating sustainable practices. Prawn farming has been practiced close to a century in Malaysia, and the initial extensive culture system has never been regarded as environmentally damaging. However, the extensive system practiced in the 1900s may not be economically viable nowadays. What is needed now is a semi-intensive culture system that can balance sustainability with economic viability.

Folke & Kautsky (1992) contended that intensive one-species aquaculture, for example shrimp farming, could be made sustainable if culture systems are integrated with the ecosystem processes and functions. The development of a sustainable aquaculture industry implies that culture has to be carefully weighed against the capacity of the ecosystem to support aquaculture, and that aquaculture should not exacerbate environmental degradation (Folke & Kautsky 1989). What is urgently needed are management plans that encompass all activities including those of non-mangrove users like agriculture, aquaculture and artisanal fisheries. This coastal zone management plan can indicate areas where various activities are permitted, and can contain guidelines and regulations to ensure sustainable use.

The proposed National Coastal Resources Management Policy has recognized the importance of managing the coastal resources sustainably. All parties concerned must see to it that this policy together with the implementation strategies be adopted and implemented with full commitment.

The Seventh Malaysia Plan also gives great emphasis on environmental awareness and education programs, and a sum of RM 15 million has been allocated for this purpose. Government and non-government agencies can work together to achieve this objective.

NATMANCOM (1996) states that while basic and long-term research on the functioning of the ecosystem should continue to provide baseline information for resource managers, applied research should be accorded greater priority. The areas identified for fisheries are as follows:

- Guidelines on the use of mangrove ecosystems for brackishwater aquaculture
- Site selection criteria for brackishwater aquaculture
- Quantification of impacts of current capture and culture fisheries on mangrove ecosystems

- Development of improved aquaculture techniques in mangrove area

Apart from these R&D areas, NATMANCOM (1996) also deems applied research in the following areas important:

Forestry aspects
- Silvicultural techniques for restoration of mangrove along eroding shores
- Development of working plans for mangroves in Kedah, Perak, Selangor and Johor
- Quantification of environmental impacts of current logging practices on mangrove ecosystems
- EIA guidelines for logging of mangrove forests
- Development of criteria and indicators for sustainable management of mangrove forests
- Development of cost-effective means of afforestration of degraded sites

Environmental aspects
- EIA guidelines for development projects involving mangroves
- Identification of suitable forest areas for conservation purposes
- Quantification of environmental impacts of pollution vis-a-vis oil spills, industrial effluents and other waste discharge on mangrove ecosystems
- Geomorphological and hydrological features of accreting and eroding mangrove shores
- Cost-effective coastal protection of eroding mangrove shores
- Environmental impacts of man-made nearshore islands on mangrove ecosystems
- Effectiveness of establishing mangrove buffers through development setbacks
- Impacts of anticipated sea level rise on mangrove ecosystems
- Development of mangrove management plans as an integral part of coastal zone management
- Impacts of bunding on mangrove and coastal ecosystem

Socio-economic aspects
- Socio-economic values of mangrove to local communities
- Socio-economic impacts of development on mangrove communities
- Traditional uses of mangroves by local communities

Legal and institutional aspects
- Reviewing the adequacy and effectiveness of existing framework of legal and institutional arrangements governing mangroves and other coastal habitats
- Recommendations for eliminating inconsistences and weaknesses in the existing arrangements both at the federal and state levels

Ecological aspects encompassing the role of mangrove-related fisheries
- Evaluation of the ecological functions of mangroves
- Inventories of terrestrial and aquatic biodiversity associated with mangrove ecosystems
- Ecological relationships between mangroves, seagrass beds and coral reefs
- Hydrodynamics and productivity of mangrove ecosystems
- Comparisons of undisturbed and disturbed mangrove ecosystems

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Brunei Darussalam: Mangrove-friendly aquaculture

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Abstract

Aquaculture in Brunei Darussalam is quite recent compared to other countries. Cage culture of marine fishes and pond culture of marine shrimp are popular. Mangrove area utilized for aquaculture (shrimp ponds) is very minimal, 190 ha of the total 18,418 ha. This report describes the status of mangroves and practices of aquaculture in Brunei Darussalam.

Introduction

Brunei Darussalam is a coastal state located in the north-western portion of Borneo island within latitudes 5° 05'N and 4° 00'N and longitudes 114° 04'E and 115° 22'E. The country has a land area of 5,765 km^2 (576,400 ha) divided administratively into four districts -- Brunei-Muara, Tutong, Belait, and Temburong. Its coastline is roughly 130 km long, fronting the South China Sea. The country shares a common border with the east Malaysian State of Sarawak. The main population centers are in the coastal zone, accounting for over 85% of the population (305,100 in 1996). Brunei Darussalam is a Malay Islamic Monarchy and has a stable economy largely dependent on the exploitation of petroleum products.

Status of aquaculture

Since 1965, the government has implemented a series of National Development Plans to veer its economy away from the traditional oil and gas industry. Aquaculture has been identified as one of the priority areas for development because of the availability of potential sites and the high demand for quality fish products in local and export markets.

At the early stages of aquaculture development, steps have been taken to promote freshwater fish culture in inland waters and a considerable number of small-scale farms and backyard type ponds have been developed in all districts. However, the emphasis shifted to coastal aquaculture in the late 1980s, particularly marine fish culture in floating cages and prawn culture in brackishwater ponds.

The shift is due to the industry's high profitability and improved technology which is touted to be sustainable. The Department of Fisheries (DOF) in the Ministry of Industry and Primary Resources has identified four sites for marine fish culture in the Brunei-Muara district and about 390 ha for brackishwater ponds mainly for commercial shrimp culture (DOF-MIPR 1992). The ponds are located in Telisai and Tunggulin in Tutong District (290 ha) and in Pengkalan Sibabau in Brunei-Muara district (100 ha). Most of these areas are sparsely vegetated with some fringes of mangroves, except Pengkalan Sibabau, which is entirely mangrove forest.

Aquaculture in Brunei Darussalam is still in its infancy, and its development is well-regulated. Currently, there are 18 floating cage culture farms which produced 130 tons of fish in 1997. Brackishwater shrimp pond area totals 33 ha - 16 ha in Pengkalan Sibabau (four farms), 15 ha in Telisai (six farms) and 2 ha in Serasa (a pilot project) - which produced 73.7 tons of shrimp in 1997. All shrimp farms have been developed as clusters for easy and efficient management. They follow semi-intensive culture practices with a stocking density of 15-30 postlarvae/m^2. Average production ranges 1.5-4.0 tons/ha/year.

The DOF has targeted a production of 233.5 tons of marine fishes and 732.9 tons of shrimp at the end of year 2000. A total of 56 ha of cage culture farms and 93 ha of shrimp farms is targeted to be developed. Further, the DOF anticipates conversion of some of these farms (plus some new farms) to follow intensive culture with stocking densities ranging from 50 to 100 postlarvae/m^2. The target production is 15-20 tons/ha/year. The main reason for intensification is limited land, however, intensive farms will have their own water reservoirs, bio-ponds, and silting ponds to mitigate adverse impact to the environment.

The DOF runs its own shrimp hatchery (the only in the country) to cater to the fry requirement of the industry. About 10% of shrimp fry requirement are still imported from the neighboring countries.

Status of mangrove forests

The mangrove forests in Brunei Darussalam cover 18,418 ha, representing 3.2% of the country's total land area. These occur largely in the northern part of Temburong district, along the lower reaches of Belait, Tutong and Brunei rivers and around Muara (Figure 1). Mangrove areas in the four districts are given in Table 1.

Majority of these mangrove areas are dense primary forests. Sparsely vegetated, isolated patches can be seen only in few areas. Brunei's mangroves appear to have exceedingly high regenerative capacity (Zamora 1992). Studies have shown that 78% of plants are replacement pools in some areas.

Value of mangrove resources

From an ecological standpoint, mangroves are known to:

- export detritus and nutrients into nearby systems which form the food base of a complex of marine organisms, which in turn support valuable estuarine and nearshore fisheries
- act as nursery and breeding grounds for many economically important fishes and crustaceans
- reduce surges and strong winds associated with storms
- help prevent erosion of riverbanks which in turn protect adjacent properties

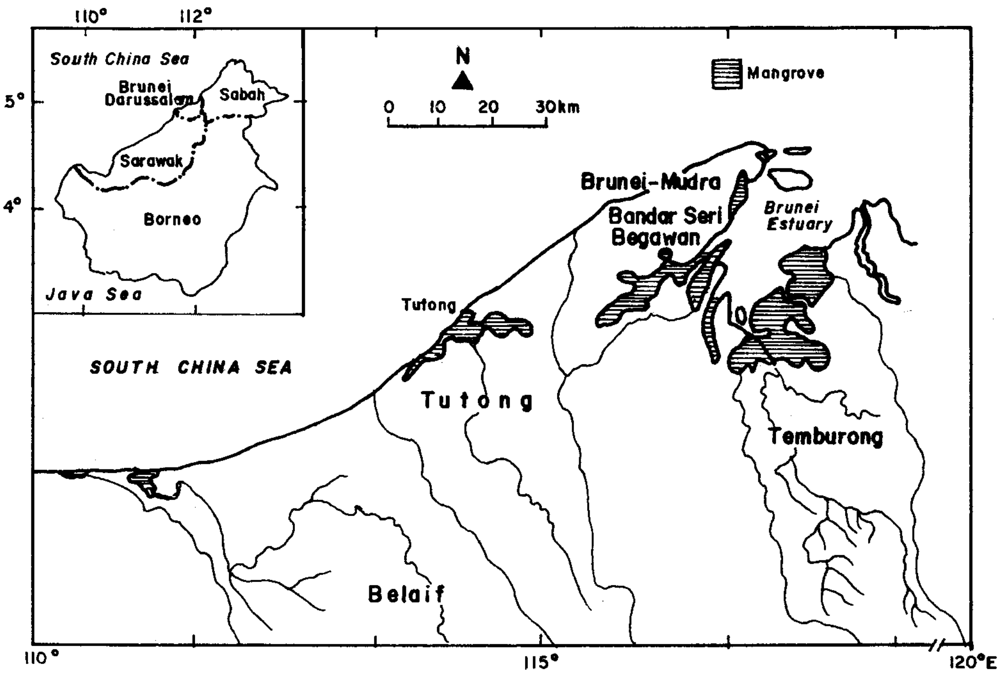

Figure 1. **Distribution of mangrove forests in Brunei Darussalam**

Table 1. **Mangrove areas relative to total land area** (Zamora 1992)

District	Total land area	Mangrove area	% of total mangrove area
Temburong	116,600	12,164	66.0
Brunei-Muara	57,000	3,937	21.4
Tutong	130,300	1,784	9.7
Belait	272,500	533	2.9
Total	576,400	18,418	100.0

- harbor unusual wildlife which provides valuable opportunities for education, scientific studies and tourism

Therefore, mangroves can be considered as one of the most valuable ecosystems in the country.

Mangrove resource utilization

In the past, mangrove forests of Brunei Darussalam were a major source of wood and/or firewood (Lim & Sharifuddin 1975). It had also been a source of dye for the tanning industry. At present, mangrove forests continue to be exploited for charcoal and for poles for use in construction. Charcoal production, however, is declining because of the increasing use of natural gas (Stewart

1986). On the other hand, the demand for mangrove poles has increased markedly in recent years as a result of the substantial development of the construction industry. But even a 15-30% annual increase in demand will not deplete the country's mangrove resources (projected over a 20-year period) (Zamora 1992).

Some mangrove areas are being developed as residential, industrial, and coastal aquaculture sites in Brunei-Muara district. These include 154 ha resettlement project and 10 ha shrimp farm in Pengkalan Sibabau, and 33 ha industrial site in Kg. Lumut. Two other sites in Temburong district have been developed as mangrove forests reserves (the 2,566 ha Silirong Forest Reserve and the 14,348 ha Labu Forest Reserve) for protection of genetic resources and biological diversity, and to enhance ecotourism.

Biodiversity

Mangrove forests in Brunei are among the best preserved in the region, rich with different types of flora and fauna. Zamora (1987) listed 81 species of vascular plants in the mangrove swamps. These consist of 47 flowering plants, 1 gymnosperm, and 33 ferns and fern allies. The most dominant species are *Rhizophora apiculata* (bakau minyak) and *Nypa fruticans* (nipha) while *Kandelia candel* (aleh-aleh), *Bruguiera cylindrica* (berus ngayong), *B. parviflora* (berus linggadai) and *B. sexanguila* (berus pulut) are rare. The country's mangroves are home to several unique and endangered wild-life including the proboscis monkey (*Narsalis larvatus*), crab eating macaque (*Macaca facicularis*), silver leaf monkey (*Presbytis cristata)* and large fruit bat *(Pteropus vampyrus).* Mangrove and associated mud flats are also used by migratory birds as wintering habitats.

Preservation of mangroves

The DOF implemented a mangrove management program in 1992 (DOF-MIPR 1992) to promote sustainable development of Brunei's mangrove resources and optimize benefits to the present and future generations. The program pursues the following specific objectives:

- Preserve mangrove systems needed for the protection of genetic resources and biological diversity and as sources for restoring areas where management has failed or accidents have occurred

- Conserve mangrove resources (plants, animals, physical space or land) for maximum benefit of the people

- Minimize or avoid conversion (e.g., housing, aquaculture, and agriculture) that eliminate mangrove resources

To achieve these objectives, a mangrove use zonation scheme (Zamora 1992) has been proposed to allocate the country's 18,418 ha mangrove area, as follows:

- 58% (10,686 ha) for conservation and environment protection
- 41% (7,533 ha) for wood production (poles, charcoal) on a sustainable basis
- 1% (199 ha) for conversion into brackishwater aquaculture and human occupancy

Distribution by district of this proposed zonation is given in Table 2. A high proportion of mangrove resources (58%) is earmarked for preservation or conservation in the belief that it is more ecologically and economically beneficial to the country over the long term. However, with the increased need for land, more mangrove areas might need to be sacrificed for development projects.

Table 2. **Proposed zonation of mangrove areas** (Zamora 1992)

District	Total mangrove (ha)	Zoned area (ha)	Land use
Temburong	12,164	393	Preservation
		4,238	Conservation
		7,533	Environmental protection; timber production
Brunei-Muara	3,937	3,738	Preservation
		187	Conservation
		12	Human occupancy; brackishwater aquaculture
Tutong	1,784	1,774	Environmental protection
		10	Brackishwater aquaculture
Belait	533	533	Protected area
Total	18,418	18,418	

Silirong and Labu forest reserves have been developed under this scheme and some areas in the Labu reserve is allowed for wood production on a sustainable basis. A limited number of licenses has been issued each year for the harvest of wood for pole and charcoal production. A reforestation scheme has been proposed under this program particularly for wood production areas.

Sound utilization of mangrove areas for aquaculture

Intensive brackishwater shrimp farming has been blamed for the massive destruction of mangrove forests in many parts of the world. The estimated world-wide loss of primary mangrove forests due to shrimp farming in the last two decades is about one million ha (Greenpeace 1997). The industry has been highly criticized by environmentalists for massive clearance of mangroves, releasing chemicals and wastes, and inadvertently releasing genetically altered species into the marine environment. The industry has also been blamed for heavy siltation and destruction of important habitats such as seagrass beds and coral reefs.

Intensive shrimp culture is one of the major causes of mangrove destruction. In Asia, an average intensive farm has been reported to survive only 4 to 6 years before serious pollution and disease problems compel shutdowns. Generally, these farms shift their operations to new areas with crop failures but not after vital habitats have been permanently lost for fishes, molluscs, and crustaceans, as well as numerous birds, migratory species, and endangered species.

With understanding of the consequences faced by other countries with mangrove destruction, Brunei Darussalam is taking necessary steps to develop a sustainable aquaculture industry without or minimal destruction to mangrove forests or the environment as a whole. To achieve this, the government is implementing a well-managed program with the participation of the private sector.

The objectives of the program are:

- prevent uncontrolled expansion of the aquaculture industry
- assess environmental impacts before proceeding with any particular method or site-specific development. Where negative impacts are possible or likely, such projects will be stopped or modified
- ensure the protection of mangrove forests, wetlands, and other ecologically sensitive areas
- ensure that aquaculture development does not limit access to coastal resources by coastal communities and artisanal fishers
- ensure the implementation of regulations and continuous monitoring of operations
- ensure that abandoned or degraded aquaculture sites are ecologically rehabilitated
- ensure that aquaculture is integrated in a compatible manner with the social, cultural, and economic interests of the country

DOF is solely responsible for the aquaculture industry, and the persons or organizations that plan to develop aquaculture farms are required to register with DOF and obtain a permit. The farms are required to strictly follow the instructions of the DOF on site selection, pond construction and subsequent operations.

Mangrove-friendly aquaculture

The aquaculture practices in Brunei Darussalam are generally mangrove-friendly, as follows:

- **Zonation of area for aquaculture**

  DOF controls aquaculture development by identifying suitable areas and allowing farms only in identified or zoned area. Development of areas other than the identified is not allowed and a license is mandatory for anyone who will go into aquaculture. The identified area has a master plan of development, i.e., the area is subdivided into farm lots. The access road, main water supply and discharge canal and electricity are provided by the government. Initially, a successful applicant is granted 4 ha. After a year or two, the farm operator may apply for expansion. Additional area is given subject to the operator's performance. At the moment, there are two areas developed under this scheme, located in Pengkalan Sibabau, Brunei-Muara District (100 hectares) and in Telisai, Tutong District (90 hectares).

  This zonation system seems to be successful in preventing indiscriminate exploitation of mangrove areas for aquaculture. Moreover, in these two areas zoned for aquaculture, mangrove buffer zones of at least 50 meters from the river bank are maintained. Other areas planned for aquaculture development are located in non-mangrove areas.

- **Use of bio-pond**

  Incorporation of a bio-pond in newly developed shrimp farm is required by DOF. A bio-pond will receive all the water discharged from ponds, contain and process (oxidize, settle sediments) the water for few days, and discharge it back to the main canal. This will minimize the loading of the surrounding area with polluted farm water.

  The effectivity of the bio-pond in minimizing pollution is not yet well-established. Water quality and other pertinent data will be gathered to evaluate and further improve the bio-pond system, if necessary.

Figure 2. **Crab culture farm at Kampung Serdang in Brunei-Muara**

The future development of shrimp farming industry in the country will not cause significant damage to mangrove forests. In fact, lands where mangroves have grown have proved less than ideal for shrimp farming. Mangrove soils are often acidic, so that ponds excavated in these soil have to be heavily and expensively limed to maintain suitable pH. Leaving the mangrove forests intact is now recognized as yielding positive benefits. Hence, future farms will be established in areas just inland from a mangrove forest with the effluent trickling down and being filtered. Mangrove forests are superb natural filters for organic matter and what reaches the sea is more-or-less pristine water. Further, DOF will be looking for barren lands near the coasts instead of mangrove lands for the new prawn farms.

- **Silvofisheries**

Fitzgerald (1997) reviewed the effectiveness of different silvofisheries models in Brunei Darussalam, in particular mangrove crab (*Scylla serrata*) culture. There is only 1 crab farm with 4 modules of crab pen. Each module is 30 x 30 m. The pen is made of palm tree locally known as "nibong." Inside the pen, small trenches 30-50 cm wide and 20-30 cm deep are provided to hold water. Trenches cover about 10% of the pen area. Mangrove crab juveniles are stocked in each pen at 30-50 kg per stocking. Stocking frequency is dependent on the estimated quantity of the harvested crab and on the availability of crab juveniles. The crabs are fed trashfish. Figure 2 shows the crab culture farm at Kampung Seralang in Brunei-Muara area.

Different silvofisheries techniques are being practiced in other countries. Indonesia's "empang parit model" and Hong Kong's "gei wai system" have been proven to be successful and mangrove-friendly (Fitzgerald 1997). However, these systems are labor-intensive and follow extensive culture methods which require larger areas for production. These might not be suitable for Brunei Darussalam because of limited mangrove areas and expensive labor. Instead, the modem "closed system" shrimp aquaculture will be more appropriate. It has been proven to be more applicable and environment-friendly for intensive shrimp farming.

Plan implementation

The agencies responsible for implementing plans on development, conservation and management of mangrove resources in the country are as follows:

Area	Implementing agency
Planning and management of mangrove forest production and protection	Department of Forestry
Fish production and development of aquaculture in mangrove areas	Department of Fisheries
Use of mangrove areas for agriculture	Department of Agriculture
Development of mangrove areas as sites for residential, industrial and commercial development	Department of Town and Country Planning
Land uses in mangrove areas	Land Department
Establishment of mangrove areas as reserves, conservation sites and wild life sanctuaries and for research	Museum Department

Problems affecting wise utilization of mangroves

The major problems observed on the implementation of a sound program for the proper utilization of mangroves in the country are (1) lack of awareness among the public on the importance of mangroves for the environment and the country's economy and (2) lack of clear understanding on the ecology of mangrove forests.

Unlike other countries in the region, Brunei Darussalam has no serious poaching or encroachment problems or uncontrollable illegal development of mangrove areas. Still, irresponsible activities of some public members and fishers that cause forest fires and pollution due to indiscriminate release of oil and garbage could cause significant damage to the mangrove environment. The damage could be prevented by creating awareness among the public on the value of mangrove ecosystems. This will further help obtain support for conservation and rehabilitation programs and reduce pressure on conversion uses. Public awareness programs can be carried out via publication of leaflets, TV programs and encouraging eco-tourism.

Lack of sound understanding on the ecology of mangrove forests is another set back. The best example for this is the recent excavation in the upper reaches of the Brunei estuary for a river widening and drainage project, without knowing that soil in the area contain high levels of pyrite. This created severe environmental problems due to the increase in water acidity, badly affecting capture and culture fisheries in the Brunei estuary. Understanding mangrove ecology needs implementation of research programs. Currently, DOF, in collaboration with University Brunei Darussalam

(UBD) is carrying out a research program for this purpose. More research programs are being planned.

It is expected that development projects including aquaculture will not cause significant damage to the mangrove resources in Brunei Darussalam and that those resources will be conserved for the benefit of future generations.

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Indonesia: Mangrove-friendly aquaculture

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Abstract

The paper describes the mangrove forests in Indonesia, the most extensive in the world. It also describes the causes for their destruction, and the government intervention for aquaculture development ("tambak") and mangrove area conservation ("tambak tumpangsari"). A strategic plan for improving the mangrove areas is presented, including a development program for coastal planning and land zoning process. The paper concludes that "tambak" will continue to be developed to expand fish production. The statement is based on Indonesia's rate of population increase vis-a-vis the certain decrease in natural resources on a per capita basis. Aquaculture would continue to expand while capture fishery declines. Thus, a socio-economic shift to other employment alternatives would be necessary.

Introduction

Indonesia stretches over 5,000 km from Sumatra in the west to Irian Jaya in the east. It is the largest archipelago state in the world with a land and marine territory of about 7.7 million km^2, consisting of some 17,508 islands with over 81,000 km of coastline. Approximately 75% of Indonesia is marine and coastal waters including 3.1 million km^2 of territorial seas and 2.7 million km^2 of Exclusive Economic Zones (EEZs).

Coastal and marine habitats include the most extensive mangrove forests in the world, seagrass beds and spectacular coral reefs which provide breeding and nursery grounds for a large number of commercially valuable fish species, crustaceans (crabs and prawns), bivalves (cockles and mussels), and gastropods (oysters); and a wide variety of endemic animals (e.g. *Nasalis larvatus*). The mangroves are presumably an important carbon dioxide reduction system. Moreover, a rich tradition of artisanal mariculture has evolved along the mangrove waterways, creeks and estuaries. Fish production from these areas constitute an important part of the people's protein supply.

Brief overview of aquaculture

The use of man-made ponds in rearing brackishwater animals has been practiced in Indonesia for hundreds of years. Today, aquaculture is still largely traditional and extensive, and is considered the most promising short- and long-term means of increasing fish supply and supplementing catch from the natural fishery. It has always been pointed out that the nation's fisheries resources is finite and can not keep up with the inevitable growth in human population.

Fisheries production was reported to have increased from 1.16 million tons in 1968 to 3.5 million tons in 1992, of which 0.34 million tons came from coastal aquaculture. Moreover, some 89,000 tons of shrimps valued at US$823.4 million were exported in 1992. In 1995, the total value of shrimp and fish export was US$851 million and US$1.5 million, respectively. As a result, more mangrove forests are being cleared and converted into "tambak" (brackishwater ponds) in the belief that their operation can be highly profitable or at least can yield a reasonable living.

Significant increases have been made in the volume and value of fish exports, especially shrimp. But over the past six years, the shrimp yield from "tambak" has decreased from a peak of 140,131 tons in 1991 to 79,494 tons in 1995 (Ditjn Perikanan 1996). This decrease is believed to be related to increased levels of pollutants entering the "tambak."

Mangroves

Mangrove areas have long been appreciated in Indonesia as sources of a wide variety of food, construction materials, fuel, dyes and drugs. Inhabitants of coastal zones have traditionally used mangroves for many purposes including wood and energy production.

The use of mangroves vary from site to site on each island, depending on the characteristics of the ethnic population as mangrove dwellers. Majority of indigenous people have access to and use of the mangroves. Such communities have a profound utilitarian knowledge and dependence on the direct and indirect benefits of the mangrove ecosystems.

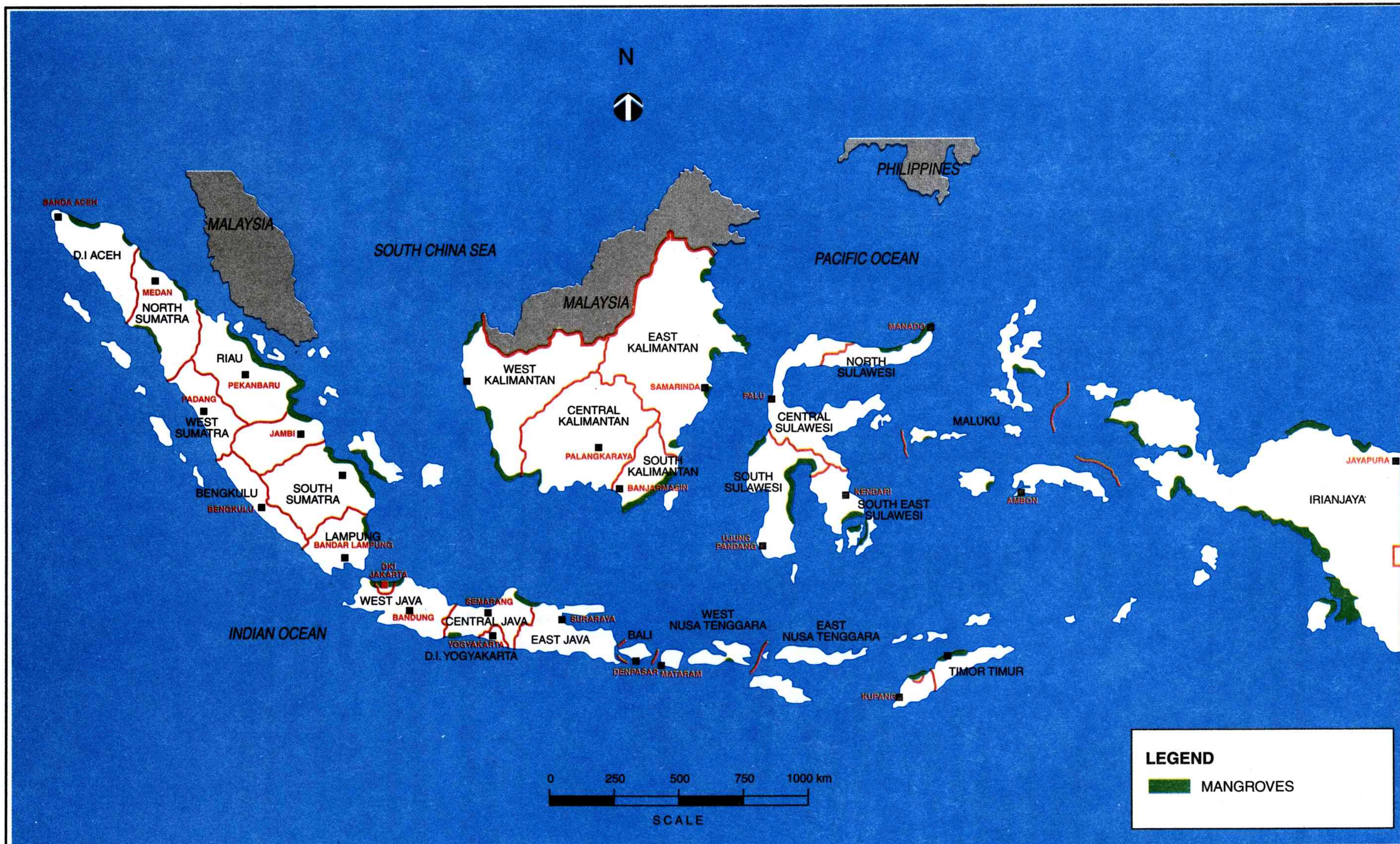
Along the extensive mangrove fringes of the island coasts, the development of human groups resulted in distinct patterns of cultural adaptation which can still be recognized today. In Sulawesi for example, converting mangroves to "tambak" appears to be part of the locally accepted means to legitimize ownership claims over mangrove areas.

With the advent of industrial and urban requirements for fuelwood among others, mangroves have been an important commodity recognized by both the colonial government and the Government of Indonesia (from 1945 to present). Commercial exploitation is within the purview of the Department of Forestry (DOF) which is responsible for licensing. A Spatial Land-Use Plan (Government Act No. 24/1992) has made the mangrove ecosystem an important element in the conservation and economic development of the coastal region.

Existing mangrove areas

Mangroves are found throughout the archipelago in 22 of the 27 provinces but are concentrated in Irian Jaya, East and South Kalimantan, Riau and South Sumatra (Figure 1). In Maluku, Nusa Tenggara (Lesser Sunda Islands) and other small islands, the ecological conditions are less favorable and the mangroves are small in extent and scattered.

Probably more than half of Indonesia's mangroves are found in Irian Jaya. Mangroves occupy a vast area in the low lying coastal zone, especially in the protected areas with muddy substrates, and in



Sumber: Koesoebiono et al., 1982, ODA 1993, ADB 1995

Figure 1. **Distribution of mangroves in Indonesia**

Table 1. **The mangrove forest areas in Indonesia, by province, from various sources (in ha)**

Province	BIPRAN (1982)	PHPA-AWB (1987)	NFI (1993)	RePPPRoT (1985-1989)	GIESEN (1993)
Aceh	54,335	55,000	102,970	59,400	20,000
North Sumatra	60,000	60,000	98,340	86,800	30,750
Jambi	65,000	50,000	13,450	18,000	4,050
Riau	276,000	470,000	221,050	239,900	184,400
South Sumatra	195,000	110,000	363,430	240,700	231,025
Bengkulu	0	20,000	2,610	2,100	2,000
West Sumatra	0	0	4,850	3,000	1,800
Lampung	17,000	3,000	49,440	31,800	11,000
West Kalimantan	40,000	60,000	194,300	205,400	40,000
Central Kalimantan	10,000	20,000	48,740	28,700	20,000
East Kalimantan	266,800	750,000	775,640	667,800	266,800
South Sulawesi	66,650	90,000	120,780	112,300	66,650
South Kalimantan	66,000	55,000	104,030	67,200	34,000
South East Sulawesi	29,000	25,000	70,840	100,900	29,000
North Sulawesi	4,833	10,000	38,150	27,300	4,833
Central Sulawesi	0	0	37,640	42,000	17,000
Maluku	100,000	46,500	148,710	212,100	100,000
West Java & DKI Jakarta	28,608	5,700	0	8,200	5,000
Central Java	13,576	1,000	0	18,700	13,577
East Java	7,750	500	0	6,900	500
Bali	1,950	500	0	500	500
West Nusa Tenggara	3,678	0	0	6,700	4,500
East Nusa Tenggara	1,830	21,500	10,780	20,700	20,700
East Timor	0	0	4,600	100	100
Irian Jaya	2,943,000	1,382,000	1,326,990	1,583,300	1,382,000
	4,251,010	3,235,700	3,737,340	3,790,500	2,490,185

Data sources

BIPRAN (Dit. Bina Program, Dep. Kehutanan together with FAO/UNDP). 1982. Data from the '70s

PHPA/AWB (Asian Wetland Bureau). 1990-1992. Sumatra Wetland Project

NFI (National Forest Inventory). INTAG, Dep. Kehutanan using Landsat data from early and mid-80s

RePPPRot. Ministry of Transmigration and the British Government. Landsat data from early to late 1980s plus aerial photography and radar imagery

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Table 2. **Mangrove forest category** (Department of Forestry 1995)

Category	Area (ha)	%
Protection forest	424,800	12
Nature reserves	674,600	19
Normal production forest	683,600	19
Limited production forest	372,400	11
Conversion forest	928,900	26
Forest converted	449,300	13
Total mangrove forest	3,533,600	100

There are several provinces with their mangrove areas still in debate, e.g., Bengkulu, West Sumatra, East Timor, Central Sulawesi

large estuaries. They always form an assemblage containing a few species and/or as a luxuriant forest with dense big trees (over 40 m tall and 40 cm diameter breast height) dominating the structure (Sukardjo *et al.* 1980).

The extent and exact limits of mangroves in Indonesia are continually changing. At the seaward side, accretion (deposition of silt and subsequent colonization by pioneer plant species) or erosion (reduction through changes in sea currents) may occur, while at the landward side, a progressive change to "hutan darat" or inland forests may take place.

In view of the constant natural advancement and reduction of mangrove forests, human reclamation of land use, and inadequacy of precise data, recent figures on the extent of mangroves in Indonesia vary (Table 1). Also, the total area of mangrove forest by provinces in Indonesia is uncertain although the general location is known. Various sources have put the total figure between 2.17 and 4.25 million hectares (Table 1) as methods of assessment and interpretation vary widely. The latest (1995) official Ministry of Forestry estimate of 3,533,600 ha is distributed among several categories (Table 2). The figure is still in debate, especially the extent of mangroves in Bengkulu, West Sumatra, Central Sulawesi, West Java and Jakarta, Central Java, East Java, Bali, Nusa Tenggara Barat (West Lesser Sunda Islands), and East Timor.

Value of mangrove resource

Very broadly, mangroves are trees and bushes that grow in tidal zones as littoral plant groups. Its importance is based on the products directly taken from mangrove forests, and on the amenities they provide within and beyond its boundaries. In this context, mangroves are valued more as an ecosystem than simply a group of plants. In modem society therefore, the value of mangrove resources can be classified into:

- direct-use value - products directly derived from mangrove such as firewood, nipa roofing, fishponds, and coastal fisheries
- indirect-use value - protective and support functions such as nutrient recycling, sediment, and erosion control

- option value - this is similar to an insurance payment reflecting the value of future use if options for the potential resource are exercised
- existence value - willingness to pay for conservation of environmental assets even when the resource is not in use

Biodiversity

Indonesia with its wide range of natural habitats, rich plant and animal resources, and high number of endemic species, is recognized as a major world center for biodiversity. Biodiversity is usually considered at three levels: genetic, species, and ecosystem diversity (Bappenas 1993). Many sectors of the nation's economy are dependent directly on the diversity of natural ecosystems.

An estimated 40 million people are directly dependent on natural ecosystems for subsistence. About 12 million people live in and around forests and many more are dependent upon coastal resources. It is the poorest rural people who are most dependent on natural habitats for their livelihood, and it is they who suffer first and most when those habitats are simplified, degraded or otherwise impoverished, but it is the whole nation and the future generations that suffer in the long term.

There are primary, secondary, and marginal mangroves in Indonesia. The primary mangroves constitute the mangrove forests *sensu stricto* as it comprises species in the intertidal zone that are always saline though not salt-demanding, called facultative halophytes. The most important species are *Rhizophora apiculata*, *R. mucronata*, *Avicennia alba*, *A. mama*, *A. officinalis*, *Sonneratia* spp.

The secondary mangroves consist of subsidiary species, such as *Lumnitzera* spp., *Excoecaria agallocha*, *Aegiceras* spp., *Heritiera littoralis*, and also ferns, palms, and herbs.

The marginal mangroves represent species commonly associated with mangroves in landward fringes and occur in seasonal freshwater swamps, beaches, swales, and other marginal mangrove sites. Although they are in mangrove areas, the species are not restricted to the littoral zone. Important species in these sites include *Glochidion litoralle*, *Scolopia macrophylla*, *Calamus erinaceus*, *Ficus retusa*, *Melaeuca leucodendron*, and species of sedges and grasses.

Causes of mangrove destruction

The mangrove forests of Indonesia come under increasing threat from a number of developments. In some isolated cases, such as the northern coast of Java, mangrove destruction has been almost total (Sukardjo 1990). The foremost cause of mangrove destruction has been the conversion to other uses such as aquaculture ("tambak"); coastal infrastructure including port, industrial, business and housing development; and agriculture.

Mangroves are also vulnerable to the impact of development activities that occur well beyond it. The most serious threat comes from non-sustainable management of watersheds and the increase in industrial and domestic pollutants that enter the water cycle. Crowded islands like Java have to contend with sediment deposition, alterations in water flow, drainage and pollution. For the islands like Sulawesi, the most serious direct threat is generally believed to be the unofficial clearing of mangroves for fish and prawn culture ("tambak"). Despite the fact that prawn production is beset by problems, small-scale entrepreneurs are still clearing significant areas of mangroves.

The extent of exploitation for wood products varies greatly throughout Indonesia, but overall, they do not appear to be significant when compared with other human activities. What is more alarming is the perception among the general public and many government officers that mangroves are worthless, that mangrove areas are land suited only as recipient of urban wastes or land that can be converted to other uses. The mangrove's ecological function is not perceived. If this erroneous perception is not corrected, the future of Indonesia's mangroves is bleak.

It can be generally concluded that mangrove destruction occurs through:

- misperception of some people in the country
- overlapping policy of resource use and development
- inefficient coordination among the agencies concerned with mangroves
- conversion of mangrove area to "tambak"
- clearing for new settlement, expansion of old ones, and other infrastructure in the coastal zone development
- forest exploitation by HPH holders
- cutting for fuelwood, others
- siltation from onshore soil erosion from development activities
- land fill, reclamation, use as dumping ground
- pressure from both population and resources extraction

Mangrove utilization

The increase in mangrove forest utilization is a consequence of the national commitment as articulated in GBHN (*Garis Besar Haluan Negara* or Outlines of State Policy) and Repelita (*Rencana Pembangunan Lim tahun* or the National Five-Year Development Plan) (see also later section on policies and legislation). Summaries of the traditional use of mangrove resources are given in Sukardjo & Toro (1989) and Sukardjo & Achmad (1982), and their functions and values are in Sukardjo (1994). Generally, mangroves are used for the following:

- **resettlement areas**

  About 60% of the country's population live along the coast. This is about 75% of townships. Mangrove land has been converted to housing development in Kandang Bay, North Sulawesi, and Jakarta, and other places

- **forest resources**

  Wood products -- timber, poles, panelling, roof shingles, charcoal, pulpwood -- are some of the commodities derived from mangrove forests. Where these are harvested sustainably, the damage to the ecosystem is negligible.

  Indonesia's forestry policy is based on the sustainable management concept. However, there is increasing occurence of large-scale felling of commercial-quality mangrove forests. By definition, this practice is not sustainable. Although logged-over areas may regenerate, the chances of regeneration usually decrease as the size of contiguous clear-cut area increases (Sukardjo 1987). Aggravating the problem is the conversion of clear-cut areas to other uses (e.g. human settlement, agriculture, "tambak") which effectively destroys the natural resource base. It is only through the acceptance and implementation of proper, non-exploitive silvicultural practices that mangrove resources, goods, and services can be perpetuated for the benefit of the nation and its people.

  Timber. Few species of mangroves produce high quality timber (as logs or wood planks) that can be traded on the international market. Although saw mills exist in some localities (e.g. in Muna

Island), the quantity of logs sawn into planks and pots is limited. Generally, however, Indonesia produces more timber from mangroves possibly because of the high stocking density. If the sampled sites represent all mangrove areas in Indonesia, this converts to an estimated volume of 124,745 to 199,646 m^3 of wood/ha. It is apparent that medium-sized trees (10-40 cm diameter) are predominant. If growth rate can be pegged at roughly 3% of the standing volume, Indonesia's mangroves might have a mean annual increment of 1.44-5.93 m^3/ha/year.

Poles. Mangrove forests in Indonesia were estimated to produce 170,000 poles/year in 1987. Poles are used mainly for foundation piling, scaffolding, and fish traps. The use of *Rhizophora* spp., *Ceriop* spp., *Sonneratia* spp., and *Oncosperma tigillaria* is extensive.

Wood chips. Indonesia today is the main producer of wood chips particularly in Kalimantan, Riau and Irian Jaya. The wood chips factory at Tarakan in East Kalimantan is the only one based solely on mangrove concession. The chips are exported to Japan as raw material in the production of rayon. The mangrove logs used are primarily less than 30 cm in diameter. In 1978, some 382,737 m^3 of mangrove logs (mainly *Rhizophora* spp.) worth US$2.6 million were exported from Indonesia, most of which came from Aceh and Riau provinces in Sumatra (FAO 1985). The wood-chipping operation that was clear-cutting mangrove areas in Bintuni Bay, Irian Jaya, was stopped by the government in 1990.

Pulpwood. The provinces of Riau and Aceh are the major producers of mangrove-derived pulpwood, producing 164,530 m^3 worth US$1,146,018. About 63,000 m^3 were exported to Taiwan and Japan in 1997-1998.

In the 1990s, the majority of Indonesian pulpwood was derived from natural mangrove forests which are primarily composed of *Avicennia* sp., *Bruguiera* sp., and *Camostemon* sp. Generally, however, mangroves do not produce high quality pulp. Pulp production has declined significantly in the past decade, and the pressure on mangrove forests for pulpwood was considered negligible by 1996.

Charcoal. Between 1978-1980, charcoal production was estimated to be about 52,000 tons/year. About 42,920 tons were exported in 1980, valued at US$3.6 million (Biro Statistik 1982). Export rose to 177,833 tons in 1994.

The 1985 Bina Program of the Department of Forestry estimated a potential production of 461,197 tons of mangrove charcoal a year from approximately 1 million ha of forest (excluding Irian Jaya). Charcoal is sourced from *R. apiculata* and *R. mucronata.* Both species have a very high calorific value, producing high quality charcoal for the local and export markets.

Firewood. The mangrove species most commonly used for firewood are *Ceriops, Xylocarpus*, *Avicennia*, *Bruguiera*, *Lumnitzera*, *Exoccaria agallocha* and *Heritiera littoralis.* Mangrove wood is still an important source of cooking fuel for coastal villagers in Indonesia and a source of subsistence income. In some localities such as Muna island, firewood collection pose a significant threat to the mangrove forest, but in other areas such as Riau, these products are managed sustainably using the traditional "panglong" system (Danhoff 1946). The wood is usually obtained from small-sized trees (usually less than 7 cm diameter) and is used mainly for daily cooking (called "kayu teki"), while a smaller quantity is burned as insect repellent. Subsistence and semi-commercial wood cutters use axes and canoes to extract wood, and splitting is sometimes done at home by women. Little is known about the level of firewood production from mangroves in Indonesia though Nurkin (1979) reported production of 26,339 m^3/year from South Sulawesi and annual export of 700-1,500 m^3 from Riau in 1973-1976.

Tannin. Tannin extraction remains a small-scale operation in Indonesia. Tannin is extracted from the bark (the best one is from *Ceriops*) and is used in the manufacture of ink, plastic and glue, a dye-cum-preservative for fishing nets, batik and in the tanning of leather.

Nipa. The nipa palm *Nypa fruticans* is one of the most versatile and useful trees commonly found in the mangrove ecosystem. Its collection plays an important role in many coastal villages. The Bugis, Bajau, and Javanese use mature nipa leaves for walls, mats, baskets, bags, hats and raincoats, while the young leaves are used as cigarette and food wrappers. The tough petioles are burned for food or chopped and boiled to obtain salt. The immature, tender kernels are eaten raw, boiled or made into sweet meat. The sweet sap from the beheaded flowering stalk is made into a fermented beverage and vinegar. In South Sumatra, nipa sap is used for making syrup liquor. The yield of pure alcohol from nipa is about 3,000 liters/ha and, with an estimated 1 million ha of nipa palm swampland in Indonesia, mainly in Kalimantan, Sumatra and Irian Jaya, the economic potential of pure alcohol production is considerable.

Others. Another traditional use of mangrove trees is as a source of medicine, and this is still being used in some coastal villages. Various medicinal and cosmetic uses are found for mangrove seeds, roots, bark and latex. Gates, fences, spoons and kitchen items are also fashioned from various mangrove species.

- **Agriculture**

The potential for conversion of mangrove forest *per se* to agricultural land is extremely limited because of the inhospitable physical and chemical environment in which mangroves thrive, namely daily inundation with salt water, very high levels of salinity in the soil and, in some places, the presence of acid sulfate soils. In addition, the soils are considered toxic to most crops because of extreme acidity and high levels of active iron and aluminum that are toxic and that make silicates, molybdenum and trace elements unavailable to crops. There are many examples in Indonesia of successful irrigation schemes in freshwater swamps, but there are probably an equal number of failures. Great care must be taken when attempting to develop swampland be it a marine, freshwater, or peat swamp. One agricultural use for mangrove forests that does not involve planting crops or even disturbing the forest is the collection of mangrove leaves for livestock fodder. Goats are particularly fond of the leaves of *Rhizophora,* and even the older leaves are palatable.

- **Ecotourism**

Tourism should be considered as a potentially non-destructive use of mangroves or, whether directly using mangroves or not, as a potential source of alternative incomes for mangroves residents. To this end, GOI tourism agencies at national, provincial and district levels should be asked to provide input into regional coastal resource management strategies, management plans and the execution of management plans. Because tourism is largely private sector driven, major commercial operators may also have important contributions to make.

Aquaculture development and mangrove area conservation

Aquaculture in the coastal zone offers particular advantages in Indonesia. This, in turn, has led to a classic pattern of dualistic development with modem and traditional systems existing side by side. The Government of Indonesia (thru Presidential Decree No. 39/1980) has adopted policies to promote intensive production and increase the "tambak" area. Thus, coastal aquaculture development during the late 1980s was export-oriented, and "tambak" development was rapid and uncontrolled (Tables 3 and 4). As a result, various social and environmental problems occur with the extension of shrimp ponds into mangrove areas. Moreover, the environmental risks associated with supplying water to the "tambak" are great. Nutrient increases cause major algae blooms in "tambaks" and surrounding waters, which lead to a cascade of numerous problematic events. Thus, any assistance may serve to encourage still more environmentally damaging development of "tambak."

In 1977, "tambaks" covered an estimated 174,605 ha in Indonesia; by 1993, this had risen to 268,743 ha. Although this represents a 54% increase in annual conversion, it is only 5,884 ha/year over a 16-year period. This conversion is the main cause of mangrove destruction, and various estimates show that, at best, approximately 513,670 ha of mangroves have been lost between 1982 and 1993 or 46,497 ha/year. At worst, 17,760,825 ha have been lost or about 160,075 ha/year (Table 1).

At present, there are 109,000 "tambak" households in Indonesia holding about 309,247 ha in 1993 (Biro Pusat Statistik 1994). In the provinces of Riau, South Sumatra and South Sulawesi, large areas of mangroves have been converted to "tambak" shrimp ponds. However, most of these areas are isolated and lack the necessary labor and infrastructure to build an industry. The government's goal of extending "tambak" to these provinces has yet to be met. The mangrove forests in Java, Sumatra and Sulawesi, on the other hand, face a more serious threat from the expansion of aquaculture.

Issues pertaining to "tambak" development are particularly important to sustainability. Therefore, the Government of Indonesia should maintain ownership and control of the mangrove area. This will allow for a more controlled utilization in an integrated and environmentally sensitive manner (e.g., silvofisheries) under an approved ICZM (integrated coastal zone management) land-use plan. At present, the government concentrates on developing a co-existence scheme been mangrove conservation and aquaculture development.

Recognizing the need to conserve its rich biological resources, and following the Earth Summit in Rio de Janeiro in 1992 and Agenda 21 (a comprehensive global work plan for national actions and international cooperation for sustainable development and global environmental protection), the government made a commitment to protect 10% of the land area and eventually 20 million ha of coastal and marine habitats as conservation areas. In addition, it has formulated a *Biodiversity Action Plan for Indonesia* (BAPI) which provides the framework for biodiversity conservation during Replita V and VI and for the 25-Year Development Plan. BAPI covers both terrestrial and aquatic resources and provides the primary reference point for more detailed strategies and action plans that deal with specific biological resources such as mangroves.

Table 3. **Estimated areas of mangrove forest in Indonesia and their potential for "tambak" development during Pelita III (1975-1976 to 1980-1981)** (DGF 1982)

Province	Mangrove forest (ha)	Potentially converted		"Tambak" (ha)	Potentially converted	
		10%	20%		10%	20%
INDONESIA	4,250,361	421,300	840,300	212,695	367,985	1,053,295
Sumatra	67,335	67,700	133,400	27,125	93,825	160,525
DI Aceh	54,335	6,400	10,800	26,012	31,412	36,812
N. Sumatra	60,000	6,000	12,000	885	6,885	13,000
W. Sumatra	-	-	-	3	3	3
Riau	276,000	27,600	55,200	60	27,660	55,260
Jambi	65,000	6,500	13,000	-	6,500	13,000
S. Sumatra	195,000	19,500	39,000	-	19,500	39,000
Bengkulu	-	-	-	-	-	-
Lampung	17,000	1,700	3,400	165	1,865	3,565
Java	19,935.03	4,900	9,800	114,503	115,403	124,303
DKI Jakarta	95	-	-	1,163	1,163	1,163
W. Java	28,513.16	2,800	5,600	40,257	43,057	45,857
C. Java	13,576.87	1,400	2,800	23,166	24,566	25,966
DI. Yogyakarta	-	-	-	-	-	-
E. Java	7,750	700	1,400	49,917	46,617	51,317
Bali-Nura Tenggara	7,458	700	1,400	3,160	3,860	,560
Bali	1,950	200	400	304	504	704
W. Nusa Tenggara	3,678	350	700	2,558	2,908	3,258
E. Nusa Tenggara	1,830	150	300	298	448	598
E. Timor	-	-	-	-	-	-
Kalimantan	382,800	8,000	76,000	1,589	39,598	77598
W. Kalimantan	40,000	4,000	8,000	-	4,000	8,000
C. Kalimantan	10,000	1,000	2,000	-	1,000	2,000
S. Kalimantan	66,000	6,500	13,000	414	6,914	13,414
E. Kalimantan	286,000	26,500	53,000	1,184	27,684	54,184
Sulawesi	99,833	10,000	20,000	66,298	76,287	86,298
N. Sulawesi	4,833	500	1,000	193	693	1,193
C. Sulawesi	-	-	-	486	486	486
S. Sulawesi	66,000	6,500	13,000	63,787	70,287	76,787
SE. Sulawesi	29,000	3,000	6,000	1,832	4,832	7,832
Maluku	100,000	10,000	20,000	-	10,000	20,000
Irian Jaya	2,943	290,000	580,000	11	29,011	580,011

Table 4. **Extension and development of "tambak" at the end of Pelita IV (1987-1988 to 1992-1993) as consequence of KEPPRES No. 39/1980, by province**

Province	Area (ha)	Province	Area (ha)
DI. Aceh	*25,000*	*Bali*	*1,000*
Kabupaten Aceh Besar	4,000	Kaupaten Buleleng	250
Kabupaten Pidi	5,000	Kabupaten Jembrana	500
Kabupaten Aceh Utara	6,000	Kabupaten Badung	250
Kabupaten Aceh Timur	10,000		
Sumatera Utara	*5,000*	*Nusa Tenggara Barat*	*2,000*
Kabupaten Langkat	1,500	Kabupaten Sumbawa	750
Kabupaten Deli Serdang	1,500	Kabupaten Dompu	250
Kabupaten Asahan	2,000	Kabupaten Bima	1,000
Riau	*5,000*	*Nusa Tenggara Timur*	*1,000*
Kabupaten Bengkalis	2,000	Kabupaten Sikka	200
Kabupaten Indra Hilir	2,500	Kabupaten Belu	500
Kabupaten Riau Kep.	500	Kabupaten Sumba Timur	300
Bengkulu	*2,000*	*Timor Timur*	*1,000*
Kabupaten Bengkulu Utara	1,000	Kabupaten Dilly	500
Kabupaten Bengkulu Selatan	1,000	Kaupaten Kovalima	500
Sumatera Barat	*1,000*	*Kalimantan Barat*	*2,000*
Kabupaten Pasaman	500	Kabupaten Pontianak	500
Kabupaten Padang Pari	250	Kabupaten Sambas	500
Kabupaten Pesisir Selatan	250	Kabupaten Ketapang	1,000
Lampung	*1,500*	*Kalimantan Selatan*	*3,000*
Kabupaten Lampung Utara	300	Kabupaten Kota Baru	1,500
Kabupaten Lampung Selatan	500	Kabupaten Tanah Laut	1,500
Kabupaten Lampung Tengah	700		
Sulawesi Ultra	*2,000*	*Kalimantan Timur*	*7,000*
Kabupaten Minahasa	1,000	Kabupaten Bulungan	3,500
Kabupaten Gorontalo	1,000	Kabupaten Pasir	1,500
		Kabupaten Samarinda	1,250
		Kabupaten Balikpapan	750
Sulawesi Tengah	*3,000*	*Sulawesi Tenggara*	*8,000*
Kabupaten Bual Toll	3,000	Kabupaten Kendari	3,000
		Kabupaten Kolaka	4,000
		Kabupaten Buton	1,000
Sulawesi Selatan	*30,500*	*Sulawesi Selatan (con't)*	
Kabupaten Maros	1,000	Kabupaten Bone	4,000
Kabupaten Pangkap	1,500	Kabupaten Sinjai	2,000
Kabupaten Barru	1,000	Kabpuaten Polmas	1,500
Kabupaten Pinrang	3,500	Kabupaten Luwu	4,000
Kabupaten Takalar	2,500	Kabupaten Kajo	3,000
Kabupaten Bulu-Kumba	2,500	Kabupaten Mamuju	3,000
Kabupaten Jeneponto	1,000		
Total Indonesia			100,000

Organizations and systems related to mangrove preservation

The utilization of mangrove forests involves a multitude of government mainline agencies (at least 18). Considerable confusion has resulted due to overlapping actions by these agencies, and their actual or perceived rights to use the natural resources.

Historically, the planning and management system in Indonesia has been based on sectors or on administrative regions. Sectoral programs include programs for rice, tree crops, livestock and industrial development which are done regardless of socioeconomic, biophysical or topographical conditions. Other programs are designed to cover entire administrative regions, be it districts, provinces or the entire country. This approach does not consider the constraints imposed by local, cultural, economic or ecological factors. Figure 2 illustrates how the agencies and community interact through a mechanism and organization of mangrove management (including mangrove preservation) at the provincial level, while Figure 3 presents the national level diagramatically.

The conversion of mangroves to other uses falls within the domain of several government agencies. This includes the Department of Agriculture and its Directorate-General of Fisheries, the National Land Board (BPN), the Department of Home Affairs (Dalam Negri), the Department of Environment (LH), and the Department of Public Works (PU).

At times there has been legislative coordination between the Department of Forestry and other government agencies, such as the 1984 Joint Ministerial Decrees between the Department of Forestry and the Department of Agriculture (*SKB Menteri Pertanian dan Menteri Kehutanan No. KB/550/246/Kpts/1984 and No. 082/Kpts-II/1984 tentang Pengaturan penyediaan lahan kawasan Hutan untuk Pengembangan usaha budidaya Pertanian, and No. 837/Kpts?KB/550/10/1984 tentang Pembentukan panitia Kerja Tetap Penyediaan Lahan Kawasan hutan untuk Pengembangan Usaha Budidaya Pertanian*). This set of legislation discusses conversion of forest land for agricultural and fisheries uses.

Indonesia has basically three options for mangrove management and development:
- preservation of the ecosystem in its natural state
- utilization of the ecosystem to extract various goods and services on a sustainable basis
- conservation (or destruction) of the natural ecosystems, usually for a single replacement use

Policies, legislation and regulations
The legal principles for managing Indonesia's land and natural resources are based on three principles:

- Constitution of 1945
- Basic Agrarian Act No. 5 of 1960 *(Undang-Undang No. 5 Tahun 1960 tentang Peraturan Dasar Pokok-Pokok Agraria)*
- Basic Forestry Act No. 5 of 1967 *(Undang-Undang No. 5 Tahun 1967 tentang Ketentuan-Ketentuan Pokok Kehutanan)*

The elements of official policy and law related to coastal resources management, including mangrove management, arise from the fundamental principles contained in the 1945 Constitution, the State Philosophy *(Pancasila),* official policy guidance adopted as part of the development planning process, legislative enactments, regulatory and administrative actions, and traditional *(adat)* practices. Much of the detailed policies originate from policy statements adopted at the highest level and expressed through a Presidential Decree or through a coordinated government policy statement. Some of the most important policies may be found in the periodic GBHN (Outlines of State Policy) (Table 5), the Long-Term (25-year) Development Plans (PJPs) and the Five-Year National Development Plans (REPELITA).

At present, the legislative basis for policies related to coastal zone management (CRM), including policies on mangrove management, is somewhat limited. Most current laws establish general policies in three areas: maritime jurisdiction, general environmental protection, and overall management of living natural resources. Since the policies and legislation related to CRM is sectoral in nature, the role and activities of various line agencies are critical. In the case of mangroves, this means some 14 central government line agencies, 3 coordinating ministries and the Dewan Kelautan Nasional.

Legislation pertaining directly or indirectly to mangroves and coastal zones originates from a number of central government ministries and agencies if not directly from the President through Presidential Decrees. In addition to central government agencies, there are 27 provinces in Indonesia each divided into districts. Provincial and district governments are responsible for managing resources and enforcing regulations in their region. Implementation and regulation conform with local priorities via the Spatial Land Use Management Law.

All mangrove forests belong to the government of Indonesia, and mangrove deforestation is prohibited. Laws protecting mangrove forests exist locally via Peraturan Daerah at both provincial and district levels, including moratoria on mangrove conversion to "tambak" and maintenance of the coastal green belt. Government green belt regulations aim to restrict clearance of mangroves for "tambak" close to shorelines, estuaries, and rivers. However, these regulations are ignored (e.g., in Sulawesi), and law enforcement appears to be the main weakness in local mangrove management.

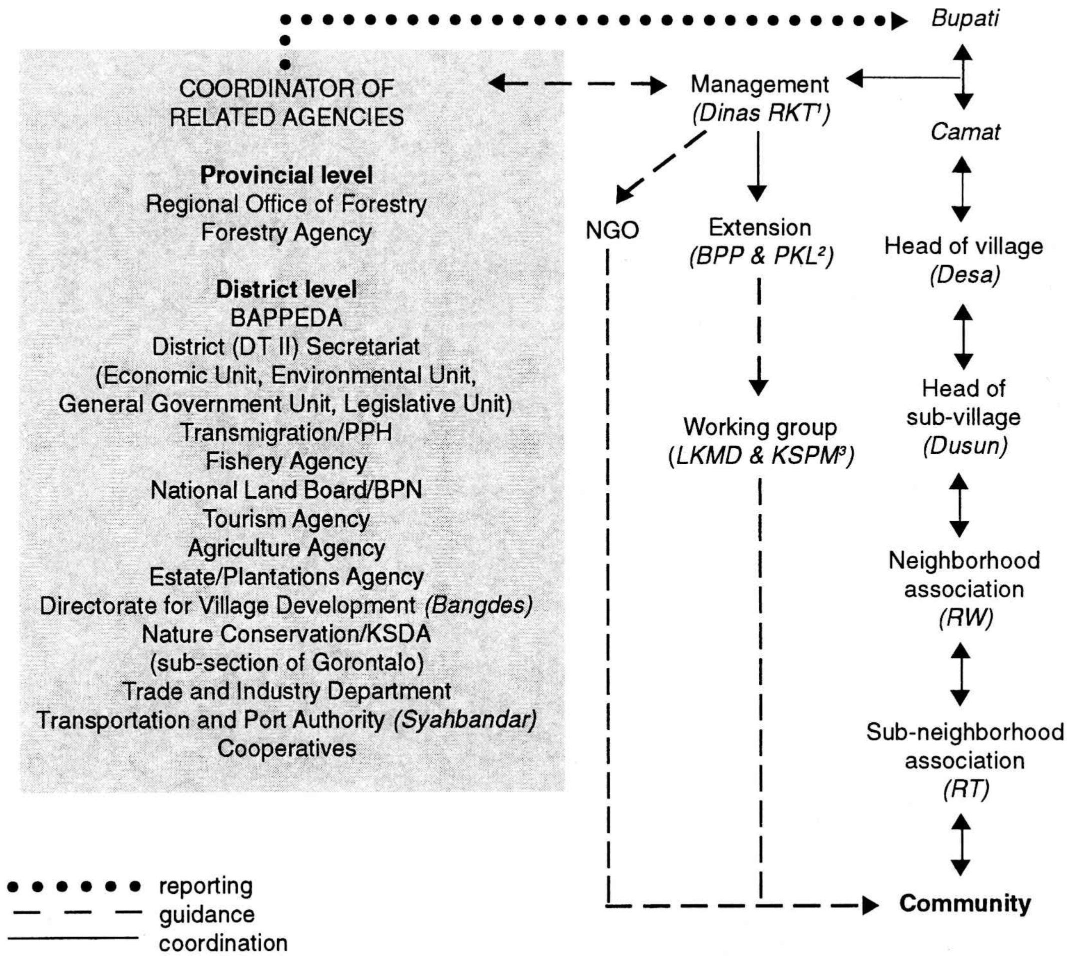
Law enforcement and coordination must be improved, beginning with the integration and coordination of similar but conflicting laws. This must include taking action against those who continue to convert mangroves illegally. Inter-agency coordination is also of paramount importance (Figures 2, 3 and 4).

Existing programs on sound utilization of mangrove areas

(with emphasis on mangrove-friendly aquaculture)

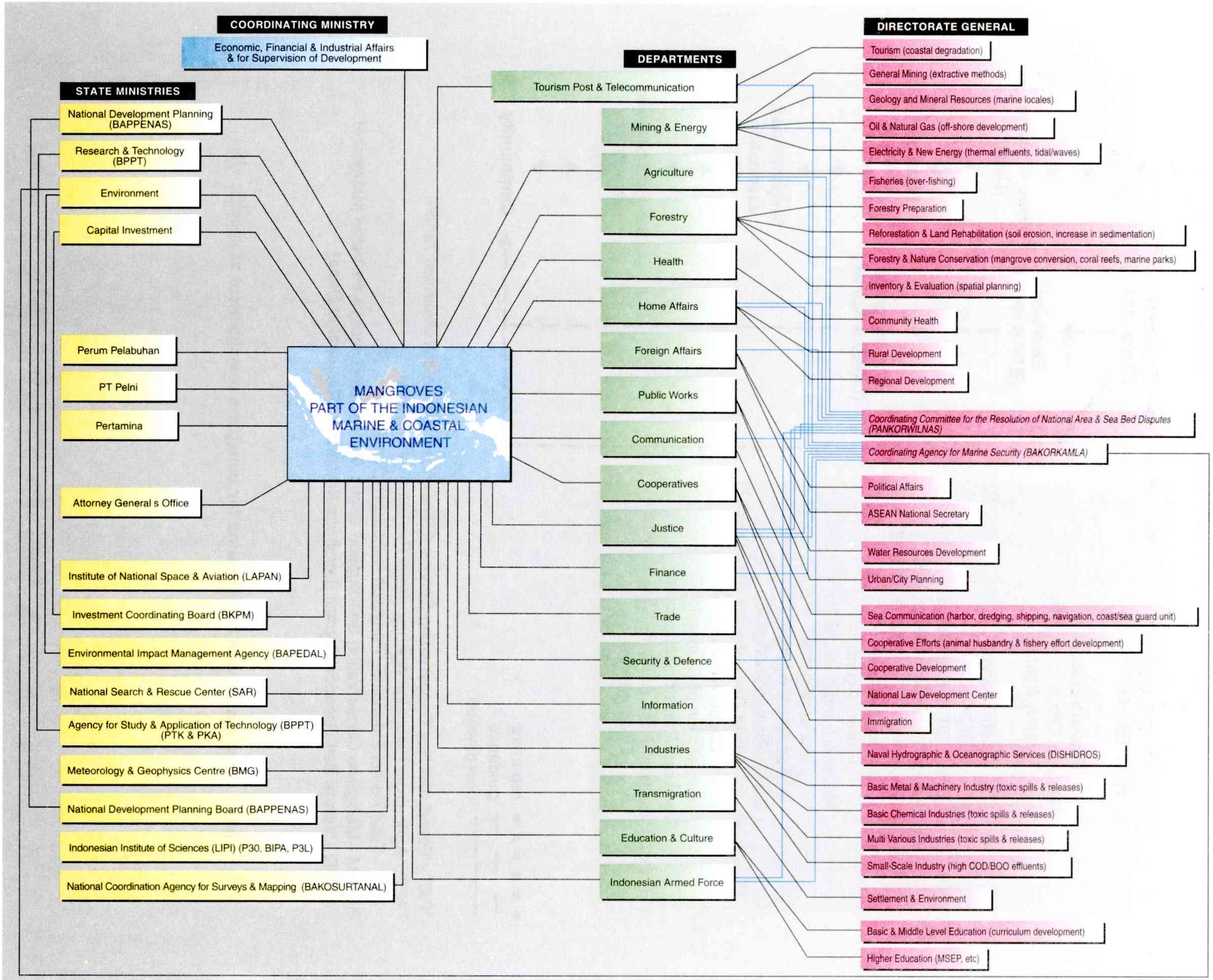
In the current Repelita VI, the government is engaged in a national rehabilitation program for mangroves which involves replanting of 150,000 ha in Java, Bali, Lombok, South Sulawesi, North Sulawesi, Southeast Sulawesi, South Kalimantan, Lampung, South Sumatra, Riau, North Sumatra and D.I. Aceh. Most of the provinces have been seriously affected by "tambak" construction and development (Tables 3 and 4). Reforestation is done in areas where mangroves have been cleared and along shorelines where they have not yet colonized.

Mangroves may be planted for hazard prevention alone or for a form of sustainable economic use. For the latter, there is a basic system dealing with mangrove-friendly aquaculture called "tambak tumpangsari" (sometimes referred as "empang parit") or silvofisheries which combines wood and



[1]PKT - Forest and Soil Conservation Service *([Dinas] Perhutanan & Konservasi Tanah)*
[2]BPP - Agriculture Extension Agency *(Balai Penyuluh Pertanian)*
PKL - Field Forest Extension *(Penyuluh Kehutanan Lapangan)*
[3]KSPM - Mangrove Conservation Self-Support Group *(Kelompok Swadaya Pelestari Mangrove)*
LKMD - Village Self-Reliance Council *(Lembaga Ketahanan Masyarakat Desa)*

Figure 2. **Mechanism and organization for mangrove management at specific sites**



Source: after Dobbin Milus International (1995)

Figure 3. **National Agencies relevant to mangrove resource management and pollution control in coastal and marine environments**

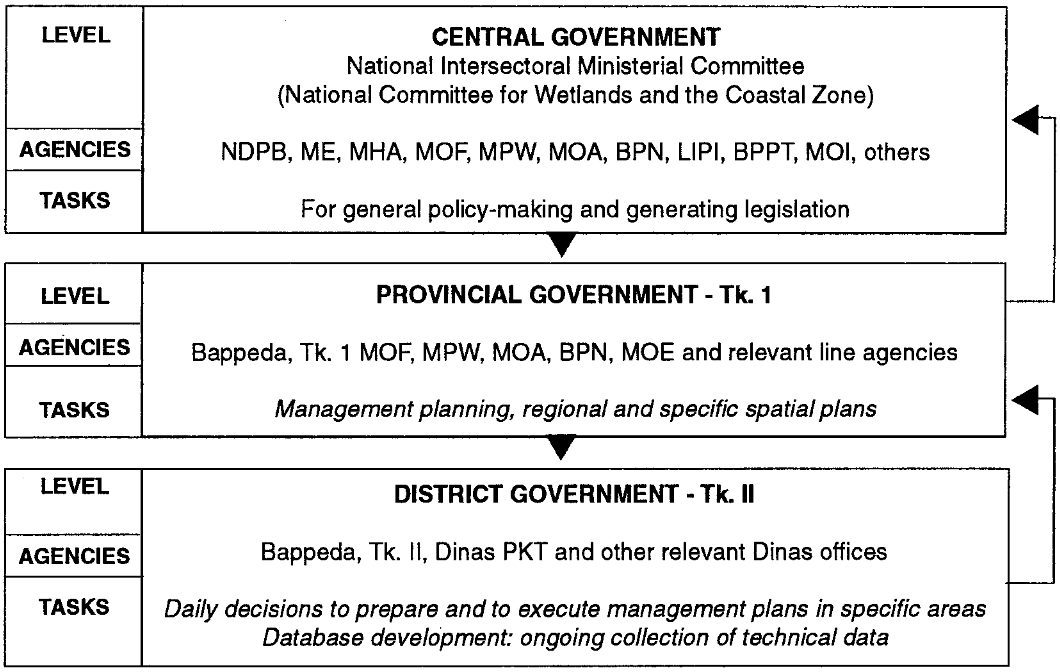


Figure 4. **National mangrove strategy: decision-making model**

Table 5. **The current legal policy guidelines on the environment: summary of the section on economy in the GBHN**

(1) The objectives of environmental development are to increase environmental quality, sustainable use, pollution control and rehabilitation

(2) Natural resources - land, water and air - must be managed and utilized in accordance with sustainable practices in order to ensure the carrying capacity of the environment to give maximum benefit to present and future generations

(3) Forests, including their plants and wildlife and their natural beauty, should be protected as well a biodiversity, germplasm, species and ecosystems. Inventories, monitoring and valuation of natural resources and the environment should be developed to ensure the sustainability of these resources

(4) The degraded environment should be rehabilitated in order to function as life support and to support the well-being of the people. Development of law enforcement should be achieved to decrease environmental pollution. Control should include incentives in combination and in harmony with technology so as to protect the environment and development

(5) With regard to sustainable development policy, spatial planning will be used to incorporate water and land uses of natural resources within a single framework. Spatial planning will be based upon integrated, regional approaches with emphasis on the characteristics of the natural and social environment. Land-use planning should be used to emphasis the prohibition on converting production agricultural land and disturbing the balance of natural ecosystems

(6) Regional and international co-operation in environmental protection and enhancement, participation in international environment policies, and dissemination of environmental knowledge and technologies should be increased to ensure sustainable development

fish output. Silvofisheries is a labor intensive technology appropriate for individual or family operation and can be a viable alternative to brackishwater pond culture.

In Indonesia, two project models have been permanently established to benefit the local people and the local government (e.g., Pemerintah Daerah, Perum Perhulani), and to serve as demonstration sites.

Existing programs
"Tambak tumpangsari" is a silvofishery model that is promoted through a national program by the Directorate General of Fisheries. There are large-scale silvofisheries programs in Cikiong (6,600 ha with 1,508 farmers) and Blanakan (5,300 ha with 2,060 farmers) in West Java under the Perum Perhutani (State Forestry Corporation). Unfortunately, controlled production trials with data collection and economic analysis have been very limited (Tables 6 and 7).

The "tambak tumpangsari" model represents the greatest level of reforestation or maintenance of existing forest to "tambak" area (Sukardjo 1989). It also permits a progressive multiplication in the use of mangrove resources from a simple to a more complex stage. The existing project in Sulawesi (MRMPS/Mangrove Rehabilitation and Management) has identified six possible conceptual models, *viz*:

(a) replanting for commercial wood harvest
(b) replanting for household wood harvest
(c) replanting for "empang parit" system
(d) replanting with mangrove to give optimum proportion for silvofisheries
(e) replanting with mangrove for woodlot silvofisheries model
(f) replanting for integrated mangrove farming

All of these concepts will require the full cooperation of local communities who will need sufficient motivation and incentives to participate. However, silvofisheries alone is not the solution to the problem of coexistence between mangrove and "tambak." Priority should be given to the preservation of critical mangrove areas including coastal and estuarine strips (for shoreline protection), and in sensitive coastal areas where mangrove would be difficult to replant due to existing wave action or thin soils.

Within the Sulawesi mangrove project, fishponds cover 13,048 ha in Luwu (about 40% of original mangrove forests), 332 ha in Lariang (about 6% of original forests), 314 ha in Kwandang (about 10%), and a relatively small area in Muna. It is important to stress that this is no indication of any effective government-mandated moratorium on local conversion of mangroves to "tambak," and there is a distinct lack of coordination among the relevant agencies for coastal management. Thus, the Sulawesi project funded a preliminary study on the constraints and feasibility of aquaculture (including "tambak" and mariculture). The project will continue this study in more detail, fund demonstration models, and provide training on silvofishery and mariculture (e.g., seaweed production) systems that are suitable within the mangrove ecosystem. The successful model will have a significant impact, through demonstration, on villagers willing to participate in silvofisheries development.

The culture system utilized by all farms in all project sites was polyculture while 24-31% of farms practiced monoculture. The species cultured were milkfish, shrimp, seaweed (*Gracilaria* sp.), and

Table 6. **Production (kg/ha/year) from "empang parit" in West Java** (Anon. 1991)

Location	Total area (ha)	Tilapia	Milkfish	Trash fish	Shrimp	Crab
Bogor-Tanggerang	1,113	-	700	200	200	-
Bogor-Ujung Karawang	7,934	-	600	200	200	-
Purwakarta-Cikiong	6,268	-	600	250	250	1
Purwakarta-Pamanukan	4,263	1,500	500	50	300	-
Indramayu-Indramayu	6,421	1,500	500	50	300	-

Table 7. **Profits from "empang parit" systems* in Cikiong and Cibuaya**
(Bagian Kesatuan Pemangkuan Hutan Cikiong and Cibuaya, 1994 and 1995)

	Annual net profit (Rp/ha/year)	Net profit per unit area (Rp/m^2/year)
Mangrove crab*	3,500,000	58,333
Snapper**	3,300,000	330
Tilapia with chicken coop**	6,372,000	637
Milkfish and shrimp**	6,144,000	614
Milkfish monoculture for food and bait**	3,240,000	324

*in 60 m^2 cage
**"empang parit" with 8:2 forest-to-"tambak" ratio

mud crab (*Scylla serrata*). Average production per unit area and farm income vary significantly among the four project sites (Table 8 a, b and c). There is considerable potential in increasing productivity of shrimp and milkfish. While improving the profitability of "tambak" would provide an incentive to accelerate the rate of mangrove conversion, assistance for aquaculture is justified in areas where the people have agreed to set aside mangrove areas for conservation. Therefore, further "tambak" development should be limited to the upper portion of the intertidal zone while maintaining a buffer zone along the coastline, estuaries and rivers.

Based on the existing program in West Java, it can be concluded that "tambak tumpangsari" has a number of disadvantages compared to "tambak" or open pond. These include:

- management difficulty
- potential toxicity of tannin from mangroves
- greater construction cost per unit of culture area
- lower productivity of phytoplankton and benthic algae due to reduced penetration of sunlight
- limitation on species cultured (e.g., seaweed would be shaded by trees, reducing growth)
- reduced water circulation and greater potential for stagnant waters with low dissolved oxygen

Further research is needed to gather a fuller assessment and an evaluation of the different silvofisheries models shown on Figure 5 a, b, c and d.

Table 8 a. **Production inputs in four "empang parit" project sites**

Project site	Total production	Milkfish seed	Shrimp seed	Labor Use* (person days/ha)	Feed (kg/ha/yr)	Fertilizer (kg/ha/yr)
Luwu	3,539,550	4,494	17,156	135	95	380
Kwandang	8,674,500	5,344	35,550	157	156	1,361
Lariang	2,075,446	3,868	4,836	162	0	66
Mura	179,250	670	1,000	87	13	0

Table 8 b. **Partial productivity by project site**

Project site	Milkfish (Rp/ha/day)	Shrimp (Rp/ha/ 1,000 fry)	Labor Use (Rp/ha/kg)	Feed (kg/ha/yr)	Fertilizer (kg/ha/yr)
Luwu	788	206	26,219	37,258	9,315
Kwandang	1,623	244	55,252	55,606	6,374
Lariang	537	429	12,811	0	31,446
Muna	268	179	2,060	13,477	0

Table 8 c. **Increase in average production towards a target value of 23,400,00 Rp/ha/yr**

Project site	Current average production (Rp/ha/yr)	Potential average production (Rp/ha/yr)	Percent increase
Luwu	3,539,550	8,504,663	14%
Kwandang	8,674,500	12,335,875	42%
Lariang	2,075,4455	7,406,585	257%
Muna	179,250	5,984,438	3,238%

Proposed programs

The current mangrove resources in the Sulawesi project area have been seriously affected by "tambak" construction. Proposed programs on sound utilization aim to address issues related to mangrove rehabilitation. The primary problems, causes and suggested solutions for mangrove degradation at the project sites are summarized in Table 9. The presentation may have oversimplified what is actually a complex set of causes and issues. It must be noted also that as the value of coastal resources rises (e.g., mangrove-friendly aquaculture), pressure on local institutions and its leaders also increases. The whole community must now participate in drawing up land use plans and incen-

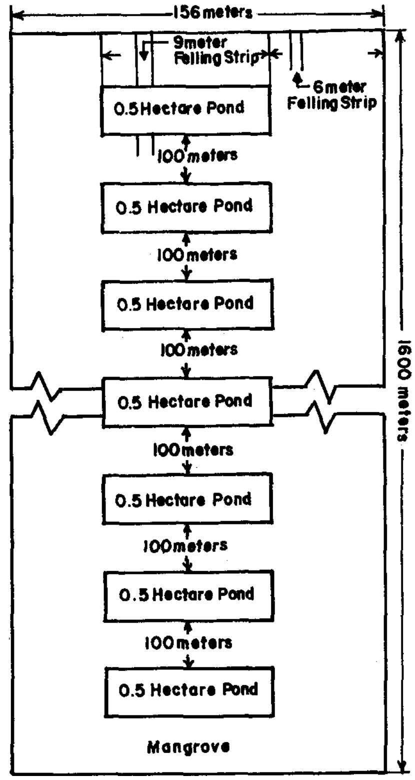


Figure 5 a. **Woodlot silvofishery design: layout plan for a 25-ha unit** (dimensions are to the nearest meter)

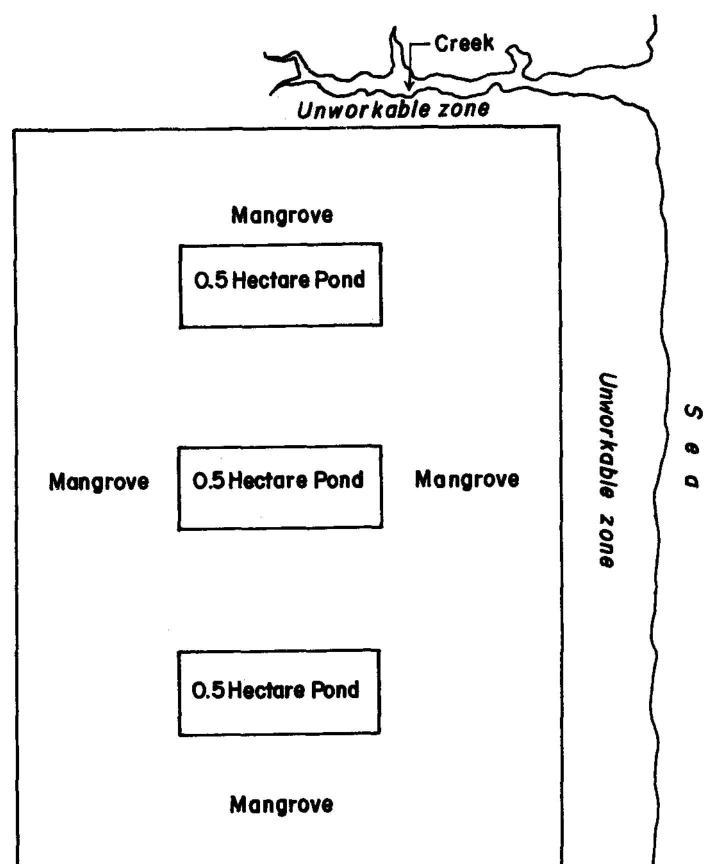
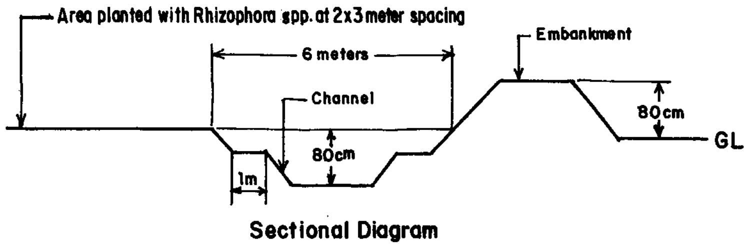


Figure 5 b. **Optimum proportion of silvofishery design: 20% pond and 80% mangrove**

Figure 5 c. **Existing empang parit design (e.g., West Java project)**



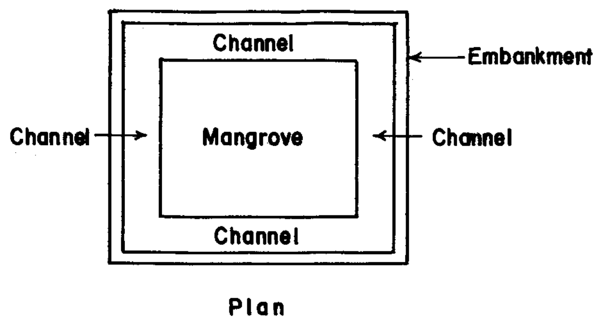
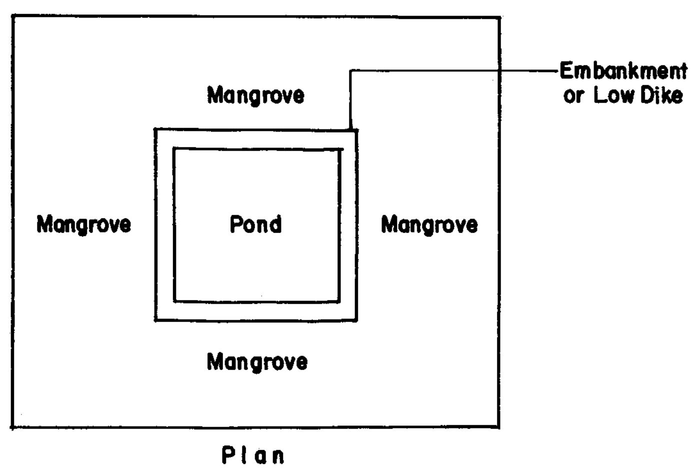
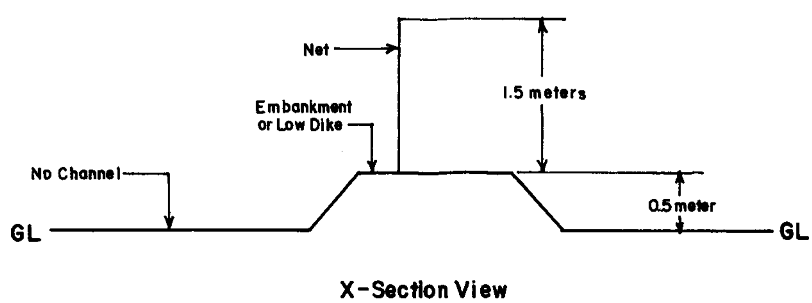


Figure 5 d. **Komplangan design**





tives in the form of village infrastructure and support for agriculture and "tambak" must be considered. The community win also be made aware of the value of mangroves to offshore fishery through a public awareness or extension program.

Once local communities have agreed to designate certain areas for mangrove conservation and others for "tambak" development, these areas will be mapped and the boundaries physically marked. In Indonesia, legal issues are among the obstacles to the maintenance and development of effective community management institutions. Customary law (Hukum Adat) and community territorial rights (Hak Ulayat) are not mentioned in the Indonesian fisheries statutes dealing with fisheries management, including "tambak tumpangsari." Similarly, the law which authorizes village level governance (Statute No. 5 of 1979) does not recognize community institutions and leadership roles (e.g., the program on mangrove-friendly aquaculture) other than formal government structure.

Given the potential advantages of effectiveness, efficiency and distributive equity offered by local government institutions in the Sulawesi project, the key question becomes whether the government is willing to recognize the rights and the responsibilities of local communities in managing and sustainably developing local mangrove resources. On the other hand, the drive for foreign exchange earnings has blinded Indonesian policymakers and researchers to other coastal aquaculture systems (*viz*. silvofisheries) that provide opportunities for employment and income.

Strategic plan for improving the mangrove areas

Throughout Indonesia, coastal resources have been used by local communities for millennia. Due to their high biological diversity and productivity, these coastal resources are in high demand and pressure to extract resources from them is great. Approximately 65% or more of Indonesia's population, estimated to be at least 215 million by the year 2000, live adjacent or very close to the coastal zone, increasing the complexities of resource management and the likelihood of coastal degradation (Sukardjo 1997). Furthermore, the majority of people within Indonesia's coastal zone live in poverty.

There is a need to develop a strategy that allows "tambak" to exist while the coastal ecosystem maintains its integrity. The preparation of community and government agreements on comprehensive land use including mangrove forest conservation will be prioritized.

Future direction, policies and regulations

With respect to the conservation of biodiversity, Law No. 5 of 1990 (Conservation of Living Natural Resources and Their Ecosystem) adopts the concepts of sustainable use and ecosystem integrity. This law also provides the basis for establishment and operation of protected natural areas, including the coastal zone, e.g., mangrove rehabilitation. One of the chief ways to achieve the purposes of this law is defined in another, Law No. 24 of 1992, which integrates management functions in the context of overall spatial land use management.

Law No. 24 is currently one of the most powerful in that it provides a mechanism for identifying sustainable land use options in the provinces and districts. This all-embracing legislation sees to it that implementation conforms to the spatial plan, especially in connection with efforts to improve mangrove areas in terms of mangrove friendly-aquaculture. It is this law which is likely to provide the foundation for strengthening the legal and institutional framework. However, it must be remembered that even with detailed legislation in place and an improved understanding on the part of

Table 9. **Logical framework for proposed investment project activities**
(The overall project objective is mangrove conservation)

Problem (location)	Cause	Solution	Project output	Risk to project output
Uncontrolled conversion of mangrove forest (all areas)	Mangrove forest has low value to individuals External value unknown Land use plans do not include mangroves	Incentives for conservation taking into account external value Assess total value of mangroves Comprehensive land use plan	Employment and trade off - (see below) Extension programs Mangrove resource valuation Land use plans agreed with villages	Difficult to deliver incentives In practice, external value is low Insufficient will to enforce land use plans and regulations
	Regulations not enforced	Enforcement of agreed regulations	Enforcement mechanism	
Non-sustainable wood cutting (Muna)	Lack of employment Good demand for wood	Create other employment Create new uses for mangroves Forest management Reforestation of denuded areas	Micro-enterprises, eco-tourism, handicrafts Forest management plan Replanted areas	Enterprises not profitable or inadequate Incentives, enforcement Poor follow-up care and maintenance
Conversion to "tambaks" (all areas, especially Luwu)	Perceived profitability Source of livelihood Desire to own land	Identify inappropriate areas Trade-off tambak improvement for mangrove conservation Reforest tambak in greenbelt Reforest abandoned tambak	Limit "tambak" development More productive tambak with conservation areas (silvo-fishery) Replanted greenbelt areas Replanted forest areas	Desire to acquire land is over-riding Increased incentive to convert mangroves into tambak Owners require compensation Poor follow-up, care and maintenance
Loss of mangroves on some foreshores (Luwu, Muna, Lariang)	Timber and firewood cutting Foreshore erosion	Reforestation of foreshores Agree on mangrove conservation policy with local people	Replanted foreshore areas	Continuing erosion, site unsuitable Lack of protection from local people

the various agencies of the laws and regulations relating to mangrove use, effective law enforcement can still be undermined by social and economic factors such as low wages for forest guards.

Expanding the resource

The problems and issues pertaining to sustainable management of Indonesia's mangrove resources, including "tambak development," are generally well known and understood. To ensure that potential user conflicts (e.g., among aquaculture, mariculture, fisheries, eco-tourism in the mangrove environment) are kept to a minimum, an integrated coastal zone planning and management scheme (ICZM) needs to be established and implemented.

Strategic plans

The general strategy involves cross-sectoral land use planning that is an integral part of provincial and local spatial planning activities coordinated by local agencies (BAPPED). Some form of ranking or priorities must be given to action plans, and the agency (ies) best qualified to undertake each action must be identified. These action plans, requiring immediate implementation, are referred to as Key Strategic Action and are considered the trigger mechanisms for implementing national and provincial strategies. Strategic plans include key ecological, institutional, socio-economic, and legal aspects (Table 10).

Development programs

Further "tambak" development in the mangroves should be limited to the upper portion of the intertidal zone with maintenance of a site-specific minimum buffer zone along the coastline, estuaries, and rivers (i.e., behind the green belt and preservation areas). Aquaculture zones (i.e., areas for potential development) will be further identified and delineated as part of the second phase of coastal planning and land zoning process. Aquaculture development will be incorporated into an ICZM planning process that identifies the environmental characteristics and carrying capacity of specific areas. Determining the carrying capacity of mangroves, its estuary and coastal areas will be done as part of a baseline data collection.

Existing aquaculture programs

Below are several programs related to aquaculture and concerned with general development of mangrove-friendly aquaculture:

- Identification of suitable areas for aquaculture and the different farming systems
- Development of zoning plans that promote sustainable aquaculture
- Establishment of aquaculture zones (AZs) protected from external environmental pollution (e.g., agriculture chemicals, industrial discharge):
  - Monitoring and protection of water sources for AZs
  - Treatment of farm effluents
  - Provision of long-term leases, infrastructure, training and access to credit
  - Environment impact assessment to be conducted for the AZs as a whole and therefore not required for individual aquaculture activities within the zone provided design and operation comply with established best management practices
- Establishment of an incentive program that promotes sustainable aquaculture development and complies with environmental guidelines:
  - Cheaper and more accessible loans, infrastructure, training and technical assistance for farms that follow set environmental guidelines and best management practices
  - Tax incentives to areas in the industry that need development, for example, hatcheries

Table 10. Key ecological, institutional, socio-economic and legal strategic objectives and action plans

• Key Strategic Institutional Actions (KSIA)

KSIA-1 *Objective:* To precisely define the location and condition of mangrove resources

Action: Implementation of a *Nationwide Country Study of Mangrove*

KSIA-2 *Objective:* To assist the integration of data on mangrove and other coastal resources that are generated by the project under different agencies

Action: Prepare *Provincial Strategic Action and Mangrove Management Plans* for the preservation and sustainable use of mangrove and integrate into a *Provincial Coastal and Marine Mangrove Strategy*

KSIA-3 *Objective:* To protect and conserve a significant proportion of the one million plus hectares of undisturbed mangrove in Irian Jaya

Action: Inclusion of mangrove forests in the *Lorentz National Park* and declaration of this conservation area as a World Heritage Site

KSIA-4 *Objective:* To establish an effective body to coordinate the formulation, implementation and monitoring of a strategy and action plan for the sustainable management of mangroves within the concept of coastal zone resources management

Action: The amalgamation of the *National Committee on Mangrove Ecosystems and Coastal Zone Management* with a recently formed *National Wetlands Committee* with the prime objective of planning an integrated sustainable resources management in the coastal zone (ICZM). Mangrove and seagrass would be among the resources to be considered by Working Group Subcommittee

• Key Strategic Socio-Economic Actions (KSSEA)

KSSEA-1 *Objective:* To improve knowledge and awareness of the values of mangrove among all levels of society but particularly among decision-makers and local people who live in and around the mangrove forests

Action: Initiation of a *National Mangrove Awareness Program* in the media and in educational institutions

KSSEA-2 *Objective:* To formulate an appropriate economic evaluation system for mangroves (and other coastal resources) that takes into account the externalities present in any natural system and apply this to the development of sustainable management plans on sustainable development

Action: Formulation of a Mangrove Evaluation Sub-Committee or Working Group in the National Committee to address these issues and act as a "clearing house" for proposed methods of measuring "externalities" and as a management plan

• Key Strategic Legal Action (KSLA)

KSLA-1 *Objective:* To strengthen the understanding, application and enforcement of the Spatial Planning Act in Law No. 24 of 1992 with respect to coastal zone planning

Action: Initiate a *National Workshop on the Application of the Spatial Planning Act* with special reference to its application to the coastal zone in general and mangrove resources in particular

KSLA-2 *Objective:* To achieve legal recognition of the importance of the coastal zone in national development, the interdependence of the natural resource in an integrated manner

Action: The coastal environment should receive special legal recognition through the issuance of a *Presidential Decree* that shows an integrated approach to coastal issues including the management of mangrove which can reduce dependency on wild seed and related pressure on fishery resources (e.g. loss of target and non-target species through collection for aquaculture)

Proposed improvements
The proposed program to improve mangrove areas will need provisions for monitoring and impact evaluation (e.g., changes in land use and vegetation cover, socio-economics). Also, the activities will involve GIS/mapping, field survey and proposals for potential sites for mangrove rehabilitation and management. Soil investigations will be limited to reconnaissance level surveys with measurements for pH and salinity made in the field.

Recommended approaches (national and regional levels)

The recommended approach will be ICZM which can maximize coastal zone benefits and minimize conflicts and constraints that work against these benefits.

Creating awareness
National plans will need to include educational and training programs and publicity at the community level on how mangroves contribute directly and indirectly to people's livelihood through mechanisms such as support to offshore fisheries and land protection from wave erosion.

Indonesia has very diverse human culture and ethnic groups. There are also very diverse perceptions on mangroves and "tambak." Clearly linking income generating activities and mangrove conservation will be essential in creating awareness.

National plans must promote community organization and participation. Village organizations will also be involved in joint forest management and in identifying income-generating activities. There are SPAP (Social Preparation and Awareness Program) undertaken by NGOs, among others, including reorienting community members to community-based management. To provide villages with further incentives and immediate benefits from project participation, small but significant infrastructure (e.g., small bridges, walkways, landing stages or piers, improving water supply) may be funded.

Licensing
As part of the regulatory control process, a licensing program of all commercial activities based within mangrove areas should be established. This is to serve as a basis of development control that balances all needs (environmental, development, and social). The licensing program, along with regulations, requires diligent and equitable enforcement. Without enforcement, uncontrolled development and law/regulatory abuse will be detrimental to conservation programs.

Sustainable and responsible management plans
In Indonesia, there is still a lack of understanding of mangrove ecosystems and many decisions on the future use of mangrove land are based on inadequate knowledge. Sometimes, this has resulted in sometimes irrevocable loss of valuable mangroves. It is particularly important that local community aspirations are assessed through direct personal contact and considered in sustainable management plans or district spatial plans (Figure 2). For planning purposes, Resource Management Areas (RMAs) have been identified to manage coastal resources. The RMAs contain different combinations of resource-use options and/or activities. RMAs in the intertidal zone focus on options for

managing mangroves and "tambak" (Mangrove Management Zones). Before any management plan can be made effective it is essential that the district authorities clarify ownership status in mangrove zones and in the whole coastal zone. With its broad jurisdiction over all coastal forests, including mangrove forests, the Ministry of Forestry should be considered the most influential agency with respect to the direct management of mangroves and other living coastal resources.

Education and training

The current mangrove resources have been seriously impacted by "tambak" development. Therefore, assistance programs to "tambak" farmer communities should be part of of an overall management strategy for the mangrove habitat. For any conservation program to succeed, the full participation of the "tambak" community is essential due to their intimate physical and economic connection with mangroves. Being a full participant strengthens the final development, conservation and zoning regulations and raises the likelihood of compliance with regulations concerning preservation of the mangroves. Education and training should include:

- Training of fisheries extension officers -- technical skills in aquaculture need to be improved to effectively implement an extension and training program directed at "tambak" farmers
- Skill enhancement of “tambak” farmers -- improvement of skill and entrepreneurship is essential for the sustainable development of mangrove-friendly aquaculture
- Community-based training in environment awareness -- there is very low awareness of environmental and ecological issues concerning the mangroves or the marine environment in the general community
- Mariculture training -- marine fish, sea cucumbers, shellfish, seaweed, and other marine crops cultured in the "tambak" should be targeted for special training modules
- Backyard hatcheries for milk fish (BHM’s) specialized training -- for Fisheries Extension Officers and prospective entrepreneurs
- Comprehensive Project-Related Training Framework Plan -- academic training for M.Sc. and Ph.D. degrees within the country or overseas in the field of brackishwater aquaculture, mangrove, spatial planning, remote sensing, others

- Project Participant training -- the courses are for village leaders (formal and informal), farmers, fishers, women, and the youth
- On the job training (OJT) -- a summary of OJT courses includes GIS, spatial planning, mangrove rehabilitation and management planning, and communication (SPAP component)
- In-Service Technical Training -- this is training for trainers (TOT) covering mangrove extension for forestry, fisheries, food crops, estate crops PPL’s, mangrove rehabilitation and management for local NGOs; laws and regulations for *camats* and *kades*; spatial planning for mangroves and coastal areas for Bappeda TK. II and SBRLKT; and GIS orientation for managers and technicians

Applied research

Ecosystem research tends to focus on natural and pristine systems where the influence of human activities need not be considered. But for mangroves, there is growing awareness that the social and economic sciences and management aspects must be included in ecosystem research. Table 11 lists research modules that need to be studied in detail.

Table 11. **Mangrove research modules in line with an ICZM land-use plan**

Module 1 --
- Record of the space-and time-related variables of abiotic parameters: geographic description of the hydrographic system and abiotic parameters in the study area and its seasonality; the regional climate
- Concomitant investigations of the environment

Module 2 Mechanisms for the maintenance of biodiversity in mangroves --
- Inventory of the fauna: investigation of the distribution, abundance and dominance of relevant species
- Ecological niches; competition and displacement phenomena; critical minimum size of populations and areas
- Importance of a decrease in biodiversity for function and structure of the mangrove ecosystems; consequences of a sustainable utilization of mangrove resource on biodiversity

Module 3 Description of the socio-economic environment --
- Assessment of structure and functionality of the economic, socio-cultural section of the system in this region
- Interactions between the sections; role of external socio-economic enforcement
- Change through time, and their present development trends; assessment of resource extraction and its sustainability

Module 4 Availability, biomass, productivity and utilization of animal and plans --
- Assessment of the primary production of mangrove trees and their epiphytes as well as of phytoplankton
- Primary productivity of microbial organisms
- Assessment of the spatial and time variability of individual primary producers with regard to the total production

Module 5 Identification of the major energy-and material-transport paths --
- Assessment of energy sources and carriers
- Chemical cycles (carbon and nitrogen)
- Definition of trophic levels; detritus food chain and microbial loops

Module 6 Modelling of the mangrove system and recommendations for a sustainable development --
- Establishment of a data bank (Mangrove Information System, MAIS); evaluation of existing ecosystem models for mangrove
- Quantitative assessment of energy and material within the various compartments of the ecosystem as well as of the socio-economic general conditions, formulation of their mathematical relationship with the objective to describe and predict the behavior of the mangrove ecosystem
- Derivation of management recommendations under consideration of political, social and legal circumstances following the ICZM concept

Assessment studies

- Environmental Impact Assessments (EIA) in planning for large projects and conduct area-wide EIA's for areas zoned for aquaculture development (AZs). Rehabilitation bonds or guarantees may be required for large aquaculture developments to protect the environment from potential unsustainable or mismanaged aquaculture investments
- Environmentally sound guidelines on site selection, water quality, and effluent discharge; or best management practices for aquaculture farms in general

Impact research

- Conduct applied research relevant to on-farm production needs
- Develop commercial hatchery production procedures for key species and promote establishment of private sector hatcheries
- Establish a priority listing of species for a focused research program oriented towards commercialization within a reasonable time frame (e.g., 5 years)
- Research the optimalization of inputs (e.g., water, seedstock, fertilizer, chemicals) for sustainable aquaculture/mariculture activity at different production intensities
- Research and develop silvofishery design and operational procedures to maximize production within an integrated mangrove and aquaculture system

Socio-economic goals

- Develop clear, reasonable and implementable national and local policies for aquaculture that are consistent with national goals of economic growth and environment protection
- Develop a coherent comprehensive national aquaculture plan that promotes sustainable use of resources
- Establish a coherent legal framework for the aquaculture industry at all levels. A recommended procedure is as follows:
  - Review existing legislation affecting aquaculture to determine relevance and compatibility with national objectives
  - Establish a Code of Practice which outlines general practices and guidelines for environmentally sound design and operation. These Code is an interim step prior to legislation and formulation of a national aquaculture plan. All stakeholders in the industry, including small-scale operators, should be involved
  - Develop specific legislation that clearly promotes the national policy regarding aquaculture development
  - Establish a review committee of relevant agencies with private sector representation that periodically reviews legislation
- Establish an industry monitoring system that involves farmers and commercial investors to assure that policies would accurately reflect the status and composition of the industry
- Establish an aquaculture licensing system for balancing conflicting interest in the coastal zone. The licensing system limits the number and size of established farms and allows the control needed to harmonize the needs of aquaculture with those of the local community, health standards and environmental quality
- Establish policies linking conservation with economic incentives and incorporate them into national development plans (e.g., incentives for silvofisheries)
- Integrate aquaculture into national development policies
- Provide adequate funding to carry out national goals and objectives regarding aquaculture development and monitoring

• Provide adequate resources to the Fisheries Service (Department of Agriculture) to carry out development, management, and monitoring programs (e.g., research, extension demonstration, infrastructure)

Mangrove-related fisheries

Indonesia is an archipelagic state where the physical characteristics of the islands are reflected in the extent of mangrove forests. These physical dynamics influence mangrove productivity, and healthy mangrove ecosystems can benefit offshore fisheries. Greater densities or wide greenbelts would reduce coastal erosion, and make sure that mangrove habitats serve as fish nurseries (e.g., milkfish and other seafood species). This would positively affect demersal fisheries. Therefore, the continued destruction of mangroves could cause a rapid collapse of what is still a highly productive fishery.

In Bone Gulf, it has been reported that commercial capture fisheries is quite lucrative because the mangrove ecosystem and associated seagrass and coral communities still retain their functional integrity. The ecosystems also support coastal fishery, seaweed mariculture, and aquaculture. In Kwandang, North Sulawesi the mangrove supports a productive crustacean fishery with an estimated yearly harvest of 5.5 tons of shrimp (=2 kg/ha/year) and 15 tons of crab (6 kg/ha/year).

Resource evaluation

Ecological and economic considerations can not be separated in evaluating management alternatives for mangroves. This statement reflects the growing appreciation of the social and economic importance of mangrove ecosystems. To measure the value of mangroves accurately, the value of the goods and services produced by the ecosystem needs to be considered and incorporated into the assessment of the relative merits of development alternatives. This requires the application of innovative economic evaluation techniques that take into account such externalities.

Minimum areas of mangrove to be conserved/preserved

The following management interventions are recommended, *viz:*

• Protection areas -- all mangroves along the coastline should be reasserted as Protection Forest, with DG-RRL Department of Forestry as responsible for its management. This area is primarily for protection and maintenance of a 200 m greenbelt

• Rehabilitation areas -- mangrove areas that are degraded or damaged need enrichment planting and reforestration

• Community forestry area -- healthy mangroves areas wider than 200 m greenbelt, especially along the populated coasts, could be managed by communities using low impact and other sustainable forestry practices

The above designation is used to describe and define areas recommended for Protection Forest status under the Ministry of Forestry classification system. In areas showing extraordinary biodiversity or that remain relatively intact as wide expanses of mangrove habitats, the most logical land use is a very restricted one. Protection should be formalized by declaring that all mangrove areas of 200 m or less width are afforded Protection Forest status.

Regarding "tambak" development, there is still debate on the criteria for the minimum area of mangroves to be conserved/preserved. Generally, about 10% of total mangrove forests should be conserved and/or preserved as nature reserve, marine national park, sanctuary, greenbelt, and protected forest.

Aquaculture/mariculture models

The recommended aquaculture/mariculture model in Indonesia consists of four zones across the mangrove area (seaward to landward) as the ecological basis for further development (Figure 6). The width of the zones will vary according to the site or total width of mangroves. A narrow band will result in the constriction or elimination of landward zones.

This model calls for a shift of new "tambak" pond (non-silvofishery) development to the area behind the mangroves. A description of the zones is as follows:

- Zone I - Mariculture. The area seaward of the mangroves and the adjacent estuaries has potential for mariculture, including raft, cage, pen and stick-line culture of seaweeds, coral reef fish, lobsters (mainly holding), sea cucumbers, shellfish, and other species
- Zone II - Greenbelt or preservation area. No aquaculture activity should take place here
- Zone III - Conservation or silvofishery. The area is a transition zone that would allow limited economic utilization of the mangrove area, but in an integrated sustainable manner that preserves the overall integrity of the mangroves. Silvofisheries would be an appropriate activity at the ratio of 8:2 (mangrove area to water canal). Silvofisheries should be restricted to designated aquaculture zones (AZs) within this zone
- Zone IV - Utilization or silvofishery. The proposed utilization zone still maintains a level of integrity in the mangroves with the use of silvofisheries. The proposed ratio is 1:1 (mangrove area to water canal) in silvofishery ponds. Silvofisheries should be restricted to designated AZs within this zone

The model is mainly targeted at areas with currently limited aquaculture activities but are under pressure for development (e.g., in Sulawesi-Lariang, Muna and Kwandang). An important point in implementing this model is the enforcement and maintenance of controlled development within an overall land-use program. In locations where the mangrove area is under government ownership, it is recommended that this remain unchanged or used only for long-term conditional leases. Certificates of ownership will not be issued.

In privately owned areas, land-use regulatory measures can be implemented, however, this has proven to be difficult to enforce. Private land ownership will require greater economic usage of the land compared to government ownership. Therefore, "tambak" development would have to be considered as land-use option; however, this should be controlled and limited to specific areas (AZs).

Practical technologies on mangrove-friendly aquaculture

The alternation of mangrove and pond (Figure 7) is the recommended silvofisheries model. It has the maximum ratio of mangrove to pond culture area and still be able to provide superior management and production. Variations in the ratios can be made based on environmental conservation, development and policy considerations. It is recommended that units of 2 and 4 ha pond areas be standardized as the model units with individual pond size of 1 ha.

Some key considerations in design include the following:

- ratio of water area to pond dike length -- reflects proportion of production area to capital investment)
- gate width -- important in allowing wild seedstock to enter pond and in flushing out decayed excess mangrove debris). It should be more than 50 cm/ha

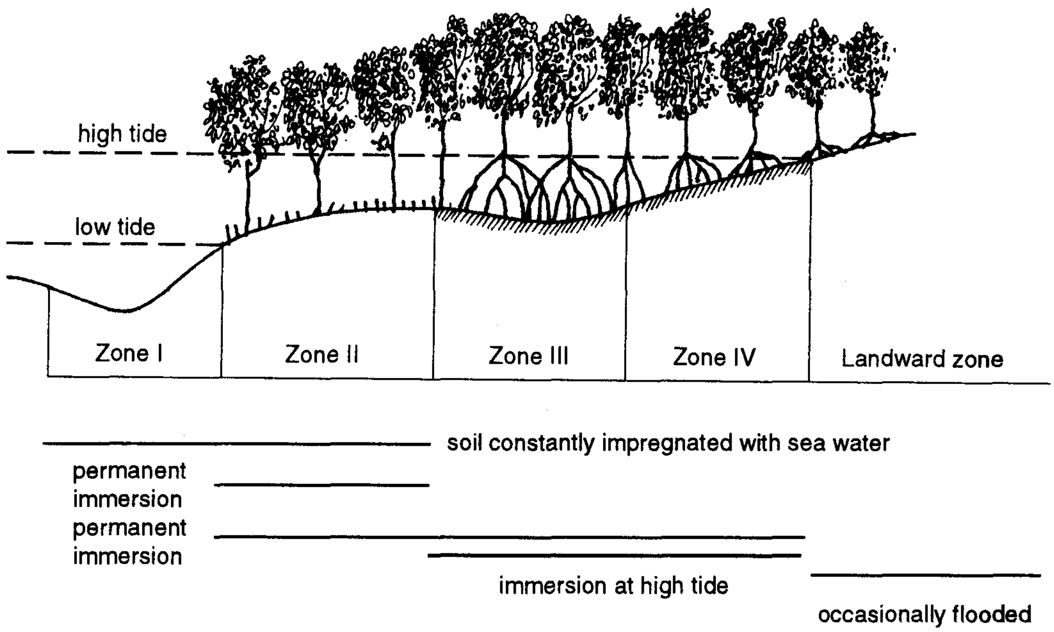


Figure 6. **Aquaculture/mariculture zones across the mangrove area**

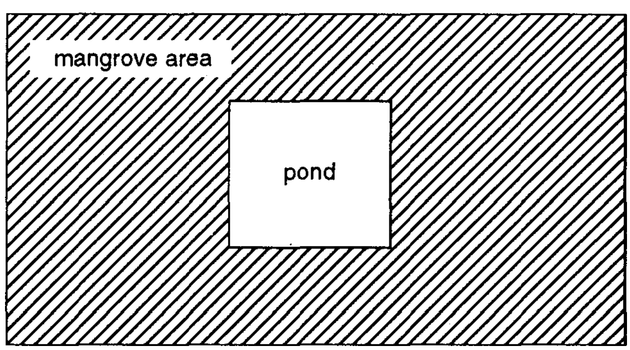


Figure 7. **A 10 ha silvofisheries site with 8:2 mangrove to "tambak" area (not to scale)**

- tidal flushing rate and tidal range
- flow of water within a pond to prevent stagnation and low oxygen level
- depth of water, depth and width of perimeter channel
- site location -- soil sustainability and abundance of natural stocking material

For fish culture, the traditional system is used. For crustacean culture, there is mud crab culture in pens and traditional shrimp culture method. Mollusc culture uses rafts, seaweed culture uses stick-and-line and anchored floating rope systems. All these farming systems are constrained by the level of inputs, skills and capital. It is advisable, however, that aquaculture is limited to semi-intensive culture practices (moderate stocking density, supplemental feeding, increased water exchange, no mechanical aeration) on the current cleared land holding.

"Tambak" farmers also need to be trained. It is evident from surveys and interviews that technical training has been minimal or nonexistent. Experiences have been gained through trial and error, often without full understanding of why changes in production occur. Without this understanding, sustained improvement of the aquaculture industry will be constrained. Training programs must be a vital and fundamental component of any effort to improve production of "tambak" operations in the country, particularly in silvofisheries.

Problems related to mangrove-friendly aquaculture

The government policy with regards to extensification and intensification of "tambaks" is not appropriate to the sustainability of "tambak" operations. Extensification has had a negative impact on mangrove forests, with the greatest expansion of "tambak" occurring in the 1980s (Tables 5 and 6). Intensification, on the other hand, creates a substantial increase in nutrient loads in pond effluents, and with the high level of "tambak" development in the project areas, this would likely place an excessive burden on the environment with resulting eutrophication problems. Also, high acidity and acute toxicity of heavy metals cause problems in aquaculture in general.

With regards to "empang parit" system, the problems as observed in the farms at Sinjai, S. Sulawesi are:

- The two gates are located on the same side of the pond. This results in canal water having a reduced water flushing, resulting to a greater build-up in organic matter on the bottom and greater chances of water stagnation
- The mangrove trees are extremely dense in the central platform. The trees contribute a large amount of organic matter to the pond. With the reduced water flushing, this has the potential of increasing BOD and reducing oxygen levels
- The construction of pens for mangrove crab culture in the central platform will further add to the organic matter and associated decomposition of by-products. The additional input of 5% of mangrove crab biomass may increase the BOD to a detrimental point and the build up of hydrogen sulfide in the pond bottom
- With the tidal height of only 50 cm in the pond, this reduces water exchange
- The pond canals cannot be completely drained, since the bottom is below the lowest tide. This results in greater stagnation potential and eliminates the periodic drying and oxidizing of built up organics in the pond bottom
- Large amount of organic debris in pond dikes make the dike susceptible to shrinkage, leakage and erosion (some already occurring on the inner slope)

Concluding remarks

"Tambak" will become the single important means of expanding fish production in Indonesia during the coming decade. This is a potentially controversial statement considering the vast breadth and diversity of the country's fishery and aquaculture sectors. However, the statement is based on: (a) indisputable trends that Indonesia's population will continue to increase while its natural resources will certainly decrease on a per capita basis; and (b) strong hypotheses that aquaculture will continue to expand, while capture fishery production will soon stabilize and eventually decline.

Indonesia's population of 182 million in 1990 is increasing at an annual rate of about 2.1% (2.15% from 1980-1985, BPS 1987). New government population data released after December 1990 indicate that Indonesia's population is actually about 178 million. Although efforts to curb population growth have produced measured success (Indonesia and President Suharto have received international acclaim for this), population growth is likely to continue at about 2% because the Indonesian population is exceptionally young with 36% below 14 years of age and 80% (146 million) under age 40. Based on age distribution of the 1990 population, the number of potential parents will increase at a rate of more than 1 million per year through at least year 2010. At 2% growth rate, the population will double to 365 million persons within 35 years (by 2025), during the life-time of at least two-thirds of the present population. This means 5 million new persons per year. The government is concerned about how to feed, employ and otherwise provide services to so many persons.

Indonesia is a nation of fish eaters, and in the next 35 years -- or even in the next 5 years -- the scenario would be as follows:

- Demand for fish to fulfill domestic and export markets will grow at an even greater rate
- Arable land area will decrease as competition for land resources increases (arable land will be required for increased housing, roads, industry and other non-agricultural purposes even with efforts to protect those lands)
- Capture fishery yields will stabilize and likely decrease because of overfishing (as well as pollution and other causes) as a direct result of increased competition for all fisheries resources. In order of probable decline will be the (1) traditional high-value food species, (2) the low-value food and (3) eventually the industrial or fish meal/trash species
- Some freshwater and marine fish stocks will disappear from the fishery (this has already happened in some areas)
- Capture in some freshwater and shallow sea fisheries will decline to a principally subsistence level (this has also become a reality in some locations)
- Employment throughout all fishery sub-sectors will decline primarily because of a stabilizing and declining fishery and modernization of fishing technology

Consequently, a socio-economic shift to other resources for employment alternatives will likely be necessary for a very large segment of the population.

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Cambodia: Mangrove-friendly aquaculture

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Abstract

Cambodia has 435 km of coastline with 85,000 ha of mangrove forest. A big part of the mangrove area is in Koh Kong province (63,700) where intensive shrimp culture activity is also concentrated. Shrimp (*Penaeus monodon*) farms occupy 850 ha, producing 450 tons/yr (1995). But lately, production decreased by 20% due to diseases and self-pollution. The government has since placed restrictions on shrimp farming.

Introduction

Cambodia has rich and diverse natural resources. Along its 435 km coastline are large estuaries with a total of 85,100 ha of mangrove forest. Though its coastline is smaller than those of other countries in Southeast Asia, it still has large and small bays, inshore and offshore islands with relatively pristine habitats. Fortunately, Cambodians for a long time were more interested in inland waters, leaving the coasts relatively pristine. But beginning the 1970s, these areas became disturbed by exploitation and development, and management has been poor, if not absent.

Cambodia has joined the Biodiversity Convention in February 1994, but because of economic depression and poverty, national awareness on the importance of biodiversity conservation is very limited. Competition for coastal and marine resources has been very aggressive in recent years.

There are many efforts and attempts by non-government organizations and international organizations to collaborate with the Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries to improve environmental protection.

Exploitation of mangrove forests

The mangrove vegetation of Cambodia spreads nearly all along the coastline, though large and dense forests are found at Peam Krasob, Andong Tuk, Sre Ambel, Chak Sre Cham and the delta of Prek Kompot. LANDSAT (1994) showed that in 1992-1993 mangroves cover about 85,100 ha -- 63,700 ha are located in Koh Kong province, 13,500 ha in Sihanouk Ville city and 7,900 ha in Kompot province and Kep resort city (Figure 1). The mangrove flora of Cambodia belong to 35 families, 53 genera and 74 species. *Rhizophora mucronata* and *R. conjugata* are dominant.

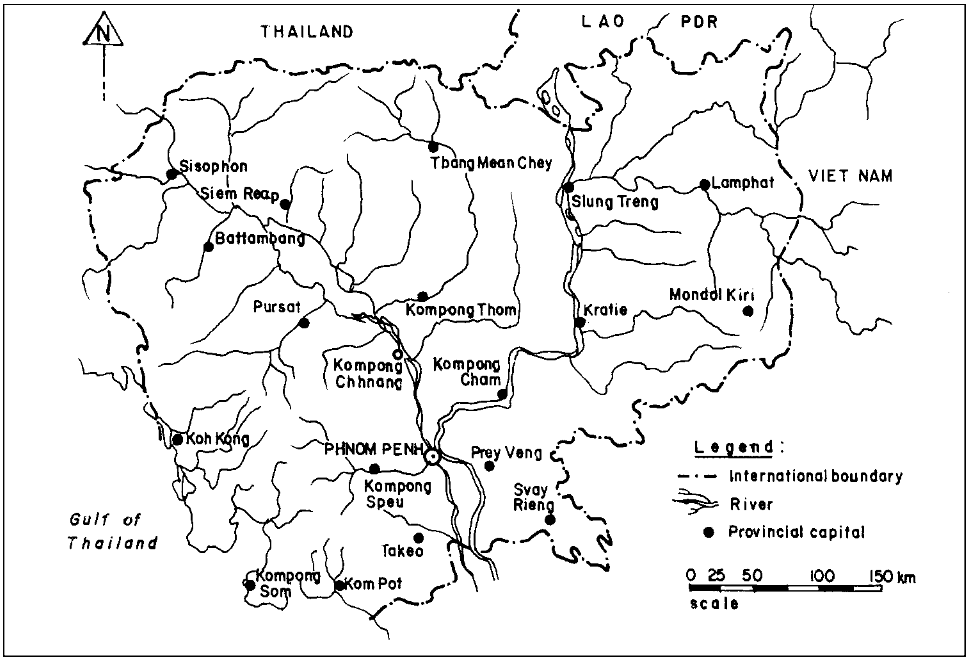

Figure 1. **Map of Cambodia**

Unplanned exploitation of coastal resources including mangroves, fisheries, and forestry resources has led to environmental degradation. This will continue while local communities are still developing economically. The current kinds of exploitation of mangrove areas are:

- fire wood and construction materials for domestic purposes and for export
- intensive charcoal production for domestic use and for export
- land claims for intensive and extensive shrimp culture
- land claims for salt pans and/or occupation of land for other purposes

Mangrove exploitation reportedly started during the French Protectorate period though there was a reforestration program in Koh Kong province. The use of mangroves for firewood and charcoal took place during the war, and has intensified due to poor management. Smuggling charcoal to Thailand has been recorded to be about 20 tons/day since 1994.

Until now, there is no comprehensive management or conservation activities such as inventory and reforestation. The mangrove resource has been placed under the jurisdiction of the Department of Fisheries (DOF) in 1989. Some measures to stop illegal or non-licensed activities have been frustrated due to poor strategy.

Aquaculture in mangrove areas

Intensive shrimp culture activities in Cambodia is carried out mainly in Koh Kong province which is near Thailand's Trat province. A DOF survey in 1995 showed that shrimp farms cover an area of 850 ha with production of 450 tons/year. But these areas have been reduced by 20% due to disease outbreaks.

The main cultured species is *Penaeus monodon.* Pond yields are reportedly high (up to 7-8 tons/crop) for new starting farms, and profits are attracting further investment. However, the industry in Koh Kong is increasingly feeling the negative side-effects common to intensive shrimp farming, including economic losses due to shrimp disease outbreak and self-pollution caused by indiscriminate discharge of pond effluents. There are also resource conflicts, particularly with farms located in or near mangrove areas.

A survey by the Bangkok-based Network of Aquaculture Centres in Asia (NACA) in early 1996 concluded that intensive shrimp farms have an average production of 7,545 kg/ha/year with a sale value of US$42 million/year. But shrimp farmers face significant environmental problems (especially in sites located in acid sulfate and/or acidic sandy soil) with an estimated loss of US$28.6 million/year. These high losses require urgent action to improve environmental sustainability of shrimp farming in Cambodia. These problems have pushed the local government and concerned ministries (Agriculture, Forestry and Fisheries, and Environment) to place a moratorium on further licensing of shrimp farms for the time being.

Other farming systems like oyster and mussel culture are not significant in terms of production.

Management of shrimp farms

DOF has placed the following restrictions on shrimp farming:

- no encroachment of mangrove forests by shrimp farms
- treatment of shrimp pond wastes before these are discharged to the sea
- construction of shrimp farms 150 m behind the shoreline

However, these guidelines are not respected and enforced, even though the shrimp farmers are aware of the negative impact of shrimp farming on the environment.

To reduce the threats to mangroves, a series of workshops has been conducted and attended by 130 participants from 26 villages. Guidelines on the conservation and sustainable use of mangrove resources were formulated. Though the designation of reserves and protected areas provide benefits to the environment, the local communities fear losing their benefits from daily use of the mangrove resources.

Policies on fisheries management

National policy

In the current Socio-economic Development Plan (1996-2000), the national fisheries policies aim to:

- improve fisheries products for home consumption and export
- manage, conserve, protect and sustainably develop sustainable fisheries resources
- emphasize inland aquaculture in rural areas as a protein source and as supplementary food produce

Development objectives and strategies
DOF objectives are to:

- supply enough food for all Cambodians
- protect and conserve natural fisheries resources
- revise the existing fisheries law
- improve the management of capture fisheries
- develop the inland and marine aquaculture sectors
- involve local people in fisheries management, conservation and development
- develop fish processing, handling and marketing technologies
- develop scientific research and extension in fisheries

Conclusion

The approach to coastal development, management and conservation needs to be systematically done through the basic objectives remain to be sustainability, equity and efficiency for the targeted provinces along the Cambodian coastline. This development program requires:

- strong provincial government support
- capacity building
- well-placed production infrastructure and services
- master plan for human settlement and its management
- master plan for coastal zone management
- people participation in development and management of natural resources
- international/regional cooperation

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Myanmar: Mangrove-friendly aquaculture

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Abstract

Myanmar has extensive mangrove forests in Ayeyarwady Delta, Rakhine, and Tanintharyi, but these have been drastically reduced due to paddy rice cultivation. Today, only 382,032 ha remain.

Myanmar is only now starting to modernize shrimp farming. Current government policy supports and encourages foreign investment in shrimp culture.

Brief overview of aquaculture

Aquaculture has a long tradition in Southeast Asia. Ponds and lakes have for centuries been used for fish farming. With the region's rising population and with seas getting crowded with fishers, there have to be other ways to satisfy the demand for additional fish protein. The potential for aquaculture in Myanmar is so good that a large part of the food demand can be met by expanded aquaculture, and in this way taking the pressure off "wild stocks."

Aquaculture and mariculture give small-scale fishers a chance to widen the scope of their activities and provide them additional profits. These may be the best long-term possibilities that enable a lot of people to stay in the fishing sector. Coastal aquaculture has the greatest potential for future development.

History and present status

Fish culture probably began about 1,000 BC in China, possibly due to the desire of an emperor to have a constant supply of fish. Over the years, various principles for fish culture were established by observation. Only later was the scientific basis for these principles understood, and today, these principles are the basis of all aquaculture enterprises. Brackishwater aquaculture, on the other hand, began at a later date, probably in Indonesia, with the culture of milkfish and gray mullet. This, too, became an established part of the rural economy of Asia.

Fish has always provided the main source of protein for Myanmar's people. The consumption rate of seafood is estimated to be 18 kg/person/yr. Myanmar practices extensive fish farming particularly in the Rakhins State adjacent to Bangladesh. While the shrimp industry has developed rapidly in ASEAN countries, Myanmar is only now embarking on modernizing this industry. Current government policy supports and encourages foreign investment in shrimp culture.

The shrimp industries in Thailand, Indonesia, Malaysia and Philippines had confronted problems caused by the uncontrolled development of shrimp culture. Diseases and environmental degradation are problems that confront the industry's sustainability. The conversion of mangrove forest to shrimp farms with its attendant effects on fisheries and local communities has drawn the attention of environmental groups.

Myanmar shrimp farmers are in the fortunate position of learning from the mistake of other countries. The focus of technological development in shrimp farming is now the reduction of environmental impact and the more efficient use of increasingly scarce resources. The Myanmar industry can incorporate these advances through technology transfer and adoptation.

Neither intensive nor semi-intensive culture of shrimps has developed in Myanmar though farming of marine shrimps has spread rapidly in Southeast and South Asia. Myanmar's neighbors Bangladesh and Thailand are both major producers of cultured shrimps.

Culture of marine shrimps is a major earner of foreign exchange. There are about 12,000 ha of traditional fish farms in operation which are mainly located in the Rakhine State bordering Bangladesh. The yield is very low, about 100 kg/ha/year. The culture of seabass (*ka-ka-dit*), grouper (*kyauk-nga*), milkfish (*nga-tain*), and mullet (*ka-ba-lu*) is still pilot-scale.

The Myanmar government considers aquaculture in general and shrimp farming in particular as high priority sectors of the economy. Shrimp farming is potentially a very large generator of foreign exchange. If the 40,000 ha can be brought under semi-intensive culture, the export income could be US$400-500 million. The government at its highest level, the State Peace and Development Council, has established a special program for shrimp culture development. It endorses a strategy which prioritizes semi-intensive culture as the main vehicle for shrimp culture development.

Fisheries, including aquaculture, are considerably important in Myanmar, providing vital sources of food and generating income and employment.

Aquaculture development and mangrove area conservation

The mangrove ecosystem is one of the most productive. It helps maintain the foodweb in aquatic environments, protects the soil, moderates salinity, and provides timber, fuelwood, charcoal and a range of non-forest products. Protection and conservation of mangrove is therefore essential for sustainable food security of coastal communities.

Aquaculture spreads across the boundary between land (shrimp ponds) and sea (salmon cages or artificial reefs). It represents one of the fast-growing sectors of the coastal zone in some countries and is seen as a valuable supplement to local diets and source of foreign currency. Aquaculture may, however, be both a petitioner for a clean environment and a polluter. On the other hand, success in aquaculture may itself pollute the environment. Uncontrolled aquaculture expansion and resulting habitat conversion could reduce biodiversity and the natural reproduction potential of species used in aquaculture.

Table 1. **Distribution of mangroves in Myanmar**

Location	Area (ha)	Percent (%)
Rakhine State	64,752	16.9
Ayeyarwady Division	177,256	46.4
Tanintharyi Division	140,024	36.7
Total	382,032	100.0

Mangrove areas

Myanmar had extensive mangrove forest in Ayeyarwady Delta, Rakhine and Tanintharyi. The mangroves in Ayeyarwady Delta has been substantially decreased due to expansion of paddy cultivation to supply rice to the city after the Second World War. However, there was no expansion of the prawn hatchery. The recorded forests of these areas are Rakhine 64,752 ha, Ayeyarwady 177,256 ha, and Tanintharyi 140,024 ha (Table 1). But there is substantial reduction of forest cover in all the areas over the years. The satellite imagery of the Delta in February 1995 indicated 5.8% of forest area remaining in Laputta (in place of 32.2%), and 19.5% remaining forest area in Bogalay (in place of 51.89%). No forest exists in Mawlamyinegyun at present.

Value of mangrove resources

The importance of mangrove to fisheries has been reviewed by MacNae (1974). It is apparent that white (banana) shrimp (*Penaeus merguiensis*), probably the most important shrimp species in Myanmar, is dependent on mangrove forests for shelter during its juvenile stage. Other shrimps which have been seen to depend on mangroves at certain phases of their life cycles include *P. monodon, P. indicus,* and *Metapenaeus* spp. Htay Aung (1982) noted that the larvae, postlarvae and juveniles of some penaeids enter estuarine mangrove areas in Myanmar, though details are not given.

Causes and consequences of mangrove destruction

Environmental problems faced in Myanmar today are not ones associated with industrialization and urbanization but those related to deforestation and loss of biodiversity. Although Myanmar has a relatively low population density when compared to other countries in the region, its forest resources and natural environment have come under growing pressure. However, deforestation in Myanmar, unlike in some other developing countries, is not the result of commercial extraction of timber but due mainly to shifting cultivation and fuelwood demand.

The country's forests particularly in Ayeyarwady Delta have come under pressure due to its overexploitation for charcoal production. Moreover, as most rural homes in Myanmar depend heavily on fuelwood for cooking, it has resulted in depletion of forest cover in marginal forests outside the reserve forest areas.

Wildlife

There are wildlife inhabiting Myanmar's mangrove forests. Among these are four species of marine turtles (loggerhead turtle, green turtle, hawksbill turtle and olive ridley turtle); the crocodile *Crocodilus* *porosus*; the hog deer *Cervus porcinus*; wild pig; wild clog; jackal; samber deer; otters; monitor lizard; wild cat; and elephant.

Uses of forest resources

Mangrove forests provide a wide range of goods and services from which local people in coastal areas have benefited from time immemorial. There is a wide range of direct and indirect products, as follows:

Timber. Under favorable conditions, mangrove trees can grow big. *Rhizophora* ("byuchidauk") over 40 m tall are not uncommon and trees over 62.5 m have been reported (Sukardjo 1978). However, large trees are fast disappearing as most of them are removed before they can attain large sizes. In the Asia-Pacific region, "byuchidauk" is not normally used as timber, although a small amount is used for walling and flooring in Myanmar.

Heritiera formes ("kanazo") is the prime timber species used for house and boat construction, while the top is used for firewood. Timber in the form of poles is in great demand as fishing stakes by coastal fishers. It is also used in the construction industry.

Firewood/charcoal. Firewood and charcoal are the main products extracted from the Delta Working Circle. "Kanazo" the favored charcoal-making species, is now becoming rare. During the past year, yield of 1.68 ton/acre/year was produced and with the manual coupe of 33,280 acres, the turn-out was fixed conservatively at 50,000 tons/year (Working Plan 1958-1970).

The annual fuelwood requirement for Yangon is about 700,000 hoppus tons, and this demand is increasing due to population growth. However, the Ayeyarwady fuelwood production, including some 432,200 hoppus tons of charcoal, is sufficient to meet even over 60% of this demand.

Nipa. The versatile palm has provided useful products to traditional village communities living near or in the coastal and estuarine mangrove forests. A variety of products were obtained from the leaves, the juice or sap from the inflorescence stalk, and the fruit. These uses continue, and some have become the bases for cottage industries and commercial operations. Nipa palm leaves have traditionally been harvested for roof thatching and for walling. In fishing, nipa leaf petioles are used as floats for fish nets, the axes for fish poles, and as rope. Nipa is also used to produce vinegar, alcohol, and other fermented beverage.

Policies and legislation

The Government of the Union of Myanmar has promulgated a new Myanmar Forest Policy in 1995. The new law is in line with Myanmar's forest policies focusing on the protection of nature and sustainability of natural resources, on satisfying the basic needs of the people, and on the participation and awareness of the people in biodiversity conservation. The old Wildlife Protection Act of 1936 was replaced with the new "Protection of Wildlife, Wild Plants and Natural Area Law" in June 1994 in order to rehabilitate threatened wildlife and sanctuaries. The government has been extending the protected area to 5% of the country's total, with the long-term objective of increasing it to 10%.

Existing programs on sound utilization of mangrove areas

Model project where mangrove utilization for aquaculture is implemented
In collaboration with the Food and Agriculture Organization, the Myanmar Forestry Department implements the *Environmentally Sustainable Food Security and Micro-Income Opportunities in the Ayeyarwady (Mangrove) Delta Project* (MYA/96/008) in the towns of Laputta and Bogalay. The project area is tidal and heavily influenced by brackishwater intrusion. Tides are semi-diurnal with two lows and two highs in a 24-hour period. The tidal range is about 2.5 m.

Three salinity regimes are identified within the project area: freshwater, low salinity and high salinity. In the freshwater area, there is no brackishwater intrusion, although the influence of the tide reaches well into the regime. Freshwater-emergent vegetation and nipa inhabit the mid- to upper intertidal zone.

Mangrove species are the typical intertidal vegetation of the low and high salinity regimes. Common genera are *Rhizophora apiculata*, *R. mucronata*, *Brugeria* sp., *Avicennia* sp. and *Sonneratia apetata.* Degraded and denuded mangrove stands are invaded by *Phoenix* spp. and three species of the fern *Acrosthichum.* Severe deforestation has accompanied the movement of humans into the delta in recent times. Forest reserves in Laputta township stand at 100,000 ha but illegal incursions have left only 40,000 ha intact to some extent Deforestation has been followed by conversion of degraded land to rice cultivation. Anecdotal evidence clearly reflects the decline in fish landings that has accompanied this destruction.

There are 65 fish and mollusc species and 13 crustacean species harvested commercially. The most important in market value are "hilsa" and sea bass. Economically important crustaceans include the mud crab, freshwater prawn and tiger shrimp.

Two rice crops per year are possible in freshwater areas, but only single cropping is feasible in brackishwater areas. The rice crop in the latter is produced during the southwest monsoon (rainy season). Potable freshwater becomes scarce during the northeast monsoon (dry season).

Current aquaculture activities
The project strategy of aquaculture technology transfer relies on locally available resources to the maximum extent possible (Table 2). This translates into simple, appropriate culture methods using seed stock captured in local waters. Feeds are made from farm by-products such as rice bran and trash fish produced in towns.

Stocking is based on wild fingerlings in the case of seabass, snakehead, and mrigal. Crustacean culture uses juveniles of the giant freshwater prawn *Macrobrachium rosenbergii* and the tiger shrimp *Penaeus monodon.* Juveniles of the latter species are seasonally available.

The project introduced hybrid tilapia broodstock which is now beginning to produce fry and fingerlings in participating villages. Farming of Chinese and Indian major carps was initiated using fry from hatcheries outside the project area. However, hatchery is now under construction in Bogalay which will be able to supply fry and fingerlings to participants.

Seabass, tiger shrimp and mud crab are euryhaline, enabling culture throughout brackishwater areas. Sea bass are amenable to freshwater growout, as well. Freshwater prawns can be cultured up to 10

Table 2. **Aquaculture technologies being promoted in Ayeyarwady Delta**

Classification	*Aquaculture technology*	*Current status*
Freshwater	Chinese and Indian major carps	Grass carp, mrigal and robu fingerlings provided to participants. Full polyculture not yet begun due to shortage of fry and fingerlings
	Hybrid tilapia	Broodstock provided to participants
	Rice-cum-prawn	Limited fingerling production
	Rice-cum-fish	Some participants in commercial production
	Other pond culture	Limited stocking with mrigal wild fry. Sea bass stock and brackishwater ponds
	Sea bass culture in ponds, pens and cages	Sea bass stocked and cultured in ponds and pen. Cage culture not yet initiated
	Silvofisheries	Several demonstration units under construction. Careful economic analysis will be required to evaluate the different systems under construction
Brackishwater	Crab fattening	Participants undertaking crab fattening in small ponds and floating cages. Both fattening and culture pose conservation issues
	Shrimp culture	Juveniles available for stocking from April to August Trials will be started next year
	Bivalve mollusc culture	Spat sources have been identified for *Crassostrea belcheri.* A culture trial for this species is underway in Laputta

ppt but are best suited to freshwater. Notwithstanding, freshwater fish farming is possible in rain-fed ponds even in brackishwater regimes.

A widespread network of traders works in the delta, marketing fish, shrimp and crabs to major towns, to Yangon and for export. Crab trading is particularly active, stimulated by rapidly growing demand and rising prices.

Identification of target villages and participatory planning

The project undertook town planning exercises in collaboration with other sectoral projects to identify poverty pockets. After the exercises, priority villages were identified with the help of village representatives and available secondary town data.

The project organized orientation and training of project personnel, counterpart department staff, and formed a project team for implementation. The team members and experienced villagers were also trained in participatory rural appraisal. Baseline data of target villages were gathered and participatory planning was carried out in each of the target villages for income generation, women in development, forestry and environmental conservation. Village organizations were developed based on the bottom-up approach.

Here is an outline of the possible activities for agriculture, forestry, fishery, livestock and home industry sectors for eco-friendly generation and environmental conservation:

Agriculture sector

- Provision of fertilizers, power tillers, pumps, others, to increase yield from marginal land of poor households
- Encourage the making and use of compost to ameliorate effects of salinity and improve productivity
- Provision of soil amendment (lime) to control acidity
- Provision of seeds, seedlings, fruit grafts and vegetable plants for home gardens
- Encourage development of private village nursery for production of fruit and vegetable planting materials
- Initiation of double cropping wherever possible
- Paddy-cum-fish culture subject to permission of appropriate authority

Forestry sector

In villages or adjoining forest areas:

- Afforestation including nursery development by target communities in buffer areas of forests to be conserved
- Plan for maintenance of natural regeneration in and around the area
- Training of villages for participative management of forests within the provision of Community Forestry Instruction by the Forest Department
- Production and distribution of fuel-saving stoves

Villages outside forest areas will take up forestry activities including (1) development of a decentralized nursery for production of seedlings in target villages; (2) production and distribution of fuel saving stoves; (3) bank protection; and (4) planting in unutilized land. Besides awareness generation and sensitization through workshops, seminars, local study tours, essays and drawing competitions in schools were conducted and information-education-communication materials like posters, leaflets, stickers, video were produced.

Fisheries sector

- Construction of nets, traps and gears
- Development of backyard hatchery for production and distribution of fish fingerlings by community initiative, in suitable areas
- Aquaculture of freshwater prawn and fishes
- Semi-intensive culture of tiger prawn
- Crab cage and pen culture
- Pen and cage culture of shells and fishes
- Supply of boats, nets, traps, cage, others
- Setting up of small scalefish feeding unit
- Village scale fish processing facilities

Livestock sector

- Supply of pigs, chicken, ducks, others
- Setting up of feed-making machines in few places based on local available raw materials
- Provision of veterinary medicine, care and training wherever necessary

Other sectors

- Setting up centre for nipa thatch and reed-making for poor women
- Training on weaving and production of traditional ethnic dress
- Fish net weaving center in villages
- Other cottage-scale income generation activities based on natural resources

Development of community-based organizations

The target groups were identified during the process of participatory planning with the help of PRA tools. Gradually groups for income generation activities, women development, environmental conservation and village development extension worker were set up to develop village system, to facilitate income generation, for environmental conservation and women development in village were identified. The village development committee with units composed of the groups above mentioned was formed to coordinate activities.

Capacity building

Community representatives are trained by an experienced team composed of a sectoral specialist, counterpart department staff, and other national resource persons on book and stock keeping, operation of revolving fund, community-organizing skills, participatory planning and monitoring, formation of rules for participatory development activities, and participatory forest management. The trained representatives are responsible for training their own village group members.

Knowledge and skills training for various income generation activities have been imparted by project team members and national and international professionals. This includes training on forest nursery, production of fish fingerlings, stove-making, weaving, vegetable cultivation, vegetative propagation, fish chip making, aquaculture, net weaving, crab fattening, and cage culture.

Participatory technology development trials have been planned for integrated management of land, double cropping, and introduction of new varieties of fruits, vegetable and forest species.

Supply of inputs

Participating village groups were provided inputs like fertilizers; seeds; planting material tillers; pumps; various types of fishing nets, traps, twines; livestock such as pigs, chicken, ducks, among others; feeds; and fish fingerlings. Several centers have been set up in villages either by groups or individuals for production of forest seedlings, fish fingerlings, supply of fish nets and traps, and fuel-saving rice husk stoves.

Extension mechanism

Each Village Development Committee (VDC) constructs a room for displaying various extension materials for income generation, environmental conservation, health, education, and water supply and sanitation; and an office for village development activities. About 25 centers have already been set up. VDCs act as extension agents of the village, providing information about technology and other messages from the project that can improve the villages. Extension materials like leaflets, booklets, comic books, and posters are produced, focusing on conservation and income-generation activities. Villagers are taken on study tours to other villages which have achieved success, conservation, income generation and women development.

Micro-income generation and environmental conservation activities

The landless poor of project villages proposes income-generation activities based on their resources, knowledge and skills. The project also provides training on income generation opportunities and allows recipients to participate in technology development trials.

Villagers plant trees in unutilized areas and develop forest nurseries for the sale of seedlings. They are also motivated to take up bank protection. Fuel-saving and rice husk stoves are also introduced to minimize the use of wood.

Recommended approaches (national and regional levels)

Like in other countries, the responsibility in Myanmar for coastal zone management is fragmented along sectoral lines or between various departments and ministries. The agencies responsible for particular resources usually manage and operate independently of each other and the mechanisms for interministerial coordination on natural resource management issues still need to be established. At present, there is no well-developed arrangement for managing the country's coastal and marine zone. Much of Myanmar's coastline is sparsely populated and features natural ecosystems which have suffered relatively little exploitation except the Ayeyarwady Delta.

ICZM approaches will be considered in the future to establish an appropriate policy, planning and regulatory framework to ensure that the coastal zone is indeed managed well. The innovative strategy being applied in Ayeyarwady Mangrove Delta is still in juvenile stage. The generation of environmental awareness is deemed essential to its success.

Biodiversity conservation in Ayeyarwady Delta will greatly help preserve the rare species of plants and animals as a national heritage to future generations. Certain forest reserves should be maintained in perpetuity and managed purely for the conservation of biological diversity.

The following recommendations are made to improve coastal zone management in Myanmar.

(1) Develop the ICZM approach involving close cooperation between line agencies on the national and local levels
(2) Develop regulations for comprehensive management in coastal zone and marine resources exploitation
(3) Define clearly the responsibilities of agencies and departments and strengthen institutions involved to improve coordination and their regulation roles
(4) Develop the coastal and marine environmental monitoring and marine resource information system

Concluding remarks

Aquaculture has only really started to develop rapidly in the past few decades, due to better knowledge of cultured species, improved methodologies and techniques in breeding and nutrition, and increasing demand for food fish of high-value species such as shrimps, seabass and groupers. In recent years, attention has focused on developing intensive shrimp culture for export while marine fish culture is not yet as intensive as that of crustaceans. But intensive shrimp culture may have a negative impact on coastal capture fisheries and the environment. In Thailand and Vietnam, mangrove deforestation for expanded shrimp culture activities has resulted in the loss of habitats for breeding and spawning of a number of commercially important species of fish, crustaceans and molluscs and could have a long-term negative impact on coastal fisheries.

Mangrove deforestation also has an impact on shrimp culture itself. The success of the latter (when traditional culture method is used) depends on stocking of wild-caught postlarvae. For intensive shrimp culture, the number of wild-caught spawners may decrease because wild shrimp population also use mangrove swamps as its feeding ground.

Other negative effects of mangrove destruction to make way to shrimp ponds include water pollution from pond effluents; sedimentation from the release of solid materials from ponds; interruption of the tidal water flow regime; introduction of disease-causing organisms; loss of natural shrimp and fish stock due to increased pollution or product contamination due to indiscriminate use of chemicals. In recent years, an epidemic was prevalent among intensively cultured fish and shrimp in a number of Southeast Asian countries; this might have been due to mismanagement in fish culture, e.g. high stocking density and overfeeding. Chemicals and antibiotics have also been used in fish and shrimp culture to prevent and control bacterial and viral diseases; however, their implications on human health are not clear.

In order to ensure the sustainable development of aquaculture, it is important to bear in mind the interdependence of technology and natural resources under various socioeconomic settings.

SEAFDEC experience

SEAFDEC/AQD has established a model farm where mudcrabs are raised in a mangrove area reforested by the local community

Marine fishes and coastal resource management: Mangrove-friendly development strategies

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Recent statistics of fishery production in the Philippines reveal outputs that are either declining (municipal fishery) or levelling off (commercial fishery and aquaculture). These trends are, in part, a reflection of the serious effects of unregulated economic activities in the coastal zone. The degradation of coastal ecosystems means a loss of livelihood among many communities of impoverished fishers as catches from municipal waters have declined over the years. Considering that mangroves, seagrasses, and coral reefs are vulnerable to anthropogenic perturbations, several development strategies are presented to meet the twin issues of ecosystem conservation and food security for coastal fishing communities. Mariculture, searanching, habitat alteration and restoration are a few of these strategies. Our recent experience in village-based reef resource management in Mararison Island, central Philippines may likewise be a viable option in the management of shoreward ecosystems (mangroves and seagrasses). In particular, the establishment of a marine reserve in the island may find some relevant applications in mangrove management and development.

The practice of raising and harvesting fish from man-made impoundments has been considered an answer to the worldwide food shortage anticipated in the early 1970s. Population growth particularly in many developing countries has been increasing at rates that national natural resources cannot sufficiently support. As a consequence, many countries undertook aquaculture and fishery development as a matter of national priority.

The conditions in the Philippines exemplify this situation. Typically, the country's population subsists on rice and fish, the latter having a per capita annual consumption of about 36 kg (BFAR 1997). Of this figure, 78% consists of marine fishes, crustaceans, and molluscs or commodities that are dependent on the integrity of coastal ecosystems from where they are harvested from the fishery and aquaculture. But, the country's population has been rising at 2.3% annually, which is now slightly higher than the overall annual growth rate of fish production from aquaculture and fisheries (BFAR 1997). In fact, a closer analysis will reveal distressing signals from the country's overall capacity to produce fish to feed its growing population. Clearly, this scenario calls for sustainable strategies to meet the twin issues of attaining national food security and the conservation of coastal resources. This paper examines these possible strategies, with emphasis on the conservation of coastal ecosystems, particularly mangroves, in the Philippines.

Fish production and coastal ecosystems

Being an archipelago, the Philippines has one of the world's most extensive coastlines that stretches for more than 17,400 km. Its coastal area of 2.2 million km^2 comprises 12% of its total territorial waters including its exclusive economic zone. Indeed, the rich fauna and flora in mangroves, seagrasses, soft-bottom communities, and coral reefs have supported the high biological productivity of coastal areas.

The functions and services of these major coastal ecosystems are interdependent with each other such that the degradation of one will result in a decline in other ecosystems (Figure 1). Generally, shoreward coastal ecosystems (mangroves and seagrasses) buffer the influence of terrestrial perturbations on seaward ecosystems (coral reefs), which in turn buffer oceanic influences on mangroves and seagrasses (Ogden 1987). For instance, mangroves and seagrasses act as sediment traps to ensure the clarity of nearshore waters that promotes the growth of coral reefs; in turn, reefs protect the coastline to enable the growth of mangroves and seagrasses. This symbiotic relationship among coastal ecosystems is highly vulnerable to natural and anthropogenic perturbations, especially when juxtaposed with the basic issue of food security for impoverished fishing communities.

Indeed, this dilemma has been reflected in declining levels of fish production from coastal areas in recent years. Total fish production has been steadily rising to over 2 million tons since 1985. However, the outlook of the various sectors of the fishing industry reveals a different picture (Figure 2). While aquaculture production has been increasing, municipal fishery production has been declining since 1991 to date. Commercial fishery production appears on the rise, but it also began to decline

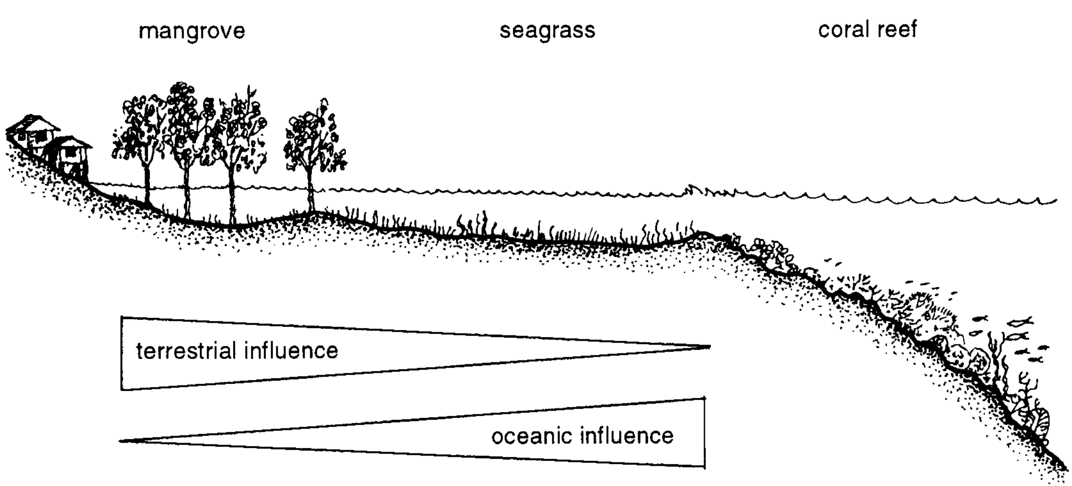

Figure 1. **Interactions of coastal ecosystems (Ogden 1987)**

beginning in 1995. These recent figures reflect a very serious conflict in the use and exploitation of resources in the coastal zone. As well, these developments have serious socioeconomic consequences, which have spawned issues in coastal zone management that are difficult to resolve.

A clear example of such a conflict is the utilization of mangroves and its associated resources. Half of the loss of mangroves in the Philippines has been a result of extensive conversion to brackishwater aquaculture ponds (Primavera 1995). Ironically, these conversions have, in part, been promoted by the national government in order to utilize these so-called “swamp and wastelands” for the generation of revenue for the national treasury. What was once common property utilized by communities of traditional users in the coastal zone has now been transformed into a single-use property employed by a few entrepreneurs (Bailey 1988). When taken as a complete system, mangroves produce multifunctional services and goods worth US$10,000/ha annually (about equal to net profits gained from intensive shrimp culture) that benefits many traditional resource-users (Primavera 1997; Constanza *et al.* 1998).

In addition, the loss of mangrove ecosystems and its attendant goods and services has consequently reduced fishery harvests over the years. Indeed, recent fishery statistics support the notion that the mangrove ecosystem is essential in maintaining productive catches from the municipal fishery (Camacho & Bagarinao 1987; Figure 3). Reduced catches from municipal waters translate into further marginalization of about 2 million impoverished coastal fishers. These fishers comprise the municipal fishery sector who, unlike aquaculture and commercial fishery workers, do not have the means to easily shift from their resource-based livelihood. Wise-use of the mangrove resource base, in addition to other critical coastal resources, that support the municipal fishery must therefore become a national priority.

Mangrove-friendly development strategies

Food production and resource conservation are at two opposing extremes. To illustrate, open pond development in brackishwater entails in varying degrees damage to mangroves, thereby increasing demands on the carrying capacity of the environment. Reconciling these two goals is a difficult issue to resolve, especially in the face of increasing population in the coastal zone. But, there are development strategies in the coastal zone that may be appropriate in the conservation of the mangrove ecosystem. These aquaculture and fishery strategies do not however totally downgrade the importance of other coastal ecosystems (seagrasses, coral reefs, soft-bottom communities), which are as critical as mangroves in supporting the biological productivity of the coastal zone. In fact, these strategies are applicable and appropriate to the other coastal ecosystems as well. For aquaculture, the impacts of producing fish may be minimized by either locating culture activities outside of mangrove areas or, if necessary, utilizing the natural biological productivity of mangroves to supplement the dynamics of the culture system. Hence, if well-managed, low-impact aquaculture may be viewed as mangrove-friendly aquaculture.

Mariculture

Mariculture in nearshore waters may be in the form of stake and bottom culture of oysters, mussels, and seaweeds, a low-impact practice for augmenting income from artisanal fisheries. Rock mounds ("amatong") deployed in shallow waters aggregate fishes and crustaceans (Yao & Bojos 1988).

A practice called "tambak tumpangsari" introduced from Indonesia involves the integration of open

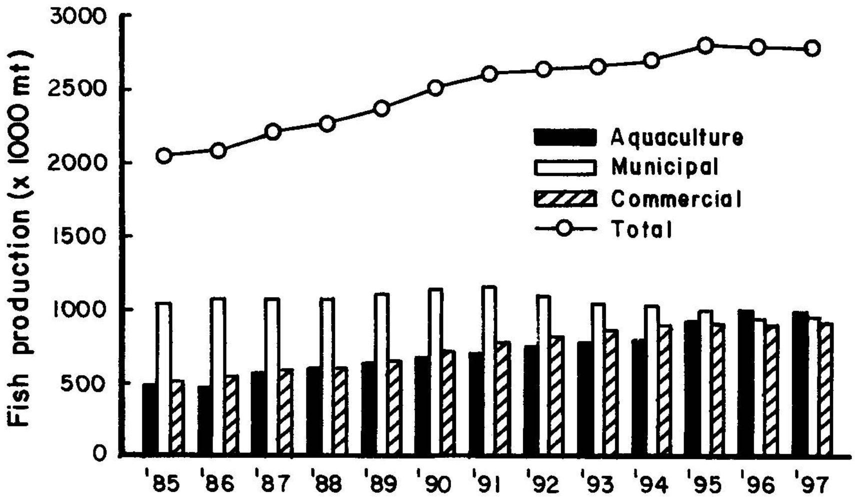

Figure 2. **Fish production of the Philippines 1985-1997** (BFAR 1997)

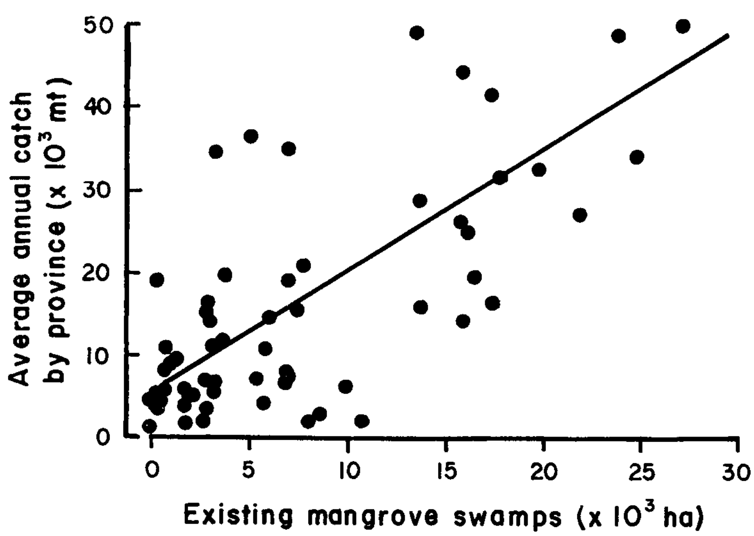

Figure 3. **Relationship between existing mangrove area and municipal catch in the Philippines** (Camacho & Bagarinao 1987)

ponds in mangrove areas. The dikes of these open ponds and seaward tidal flats are planted various mangrove trees for protection against wave action, firewood, and organic fertilizer (from leaf litter) for natural plankton growth in the pond (Primavera 1993). In this practice, forestry and aquaculture activities (aquasilviculture) appear compatible with one another. Relative to the pond area, the areal cover of the mangrove forest may vary from 60% to 80% (JH Primavera, F Takashima, WJ Fitzgerald, this volume). Instead of open ponds, a variation of "tambak tumpangsari" is the integration of pen culture in mangroves. The feasibility of such method has been recently tested in grouper and mud crab (JD Toledo and A Triño & E Rodriguez, this volume).

Searanching

Searanching refers to the release of hatchery seed to the open sea and their harvest after attaining market size. Although well established for over a century in Japan, very few successful attempts have been recorded with open water releases of warmwater fishes (Bohnsack 1996). Practical aspects that must be considered in applying this strategy for resource enhancement includes low survival and potential damage to wild populations. And, for many temperate species, the economic feasibility of hatchery seed releases depends on the cost of juveniles, return rate, and the market price of re-captured fish (Moksness & Stole 1997).

In the Philippines, there is no report of any large scale attempt at searanching in mangroves or in the other marine ecosystems, in part, because of these practical considerations. Reports of the number of fish released by government agencies are common, but survivors and effects on fishery yields are lacking. The application of searanching initiatives developed in Japan may not, as yet, be suitable in developing countries. Obstacles in these countries abound in the form of prevailing values and attitudes towards resource use (e.g., “catching more fish means more money”), infrastructure (e.g., few hatcheries, poor research practices), legal framework and capacity (e.g., poor enforcement of fishery regulations), and capital (Ungson 1993). Nonetheless, this strategy may in time be a viable option to re-seed the fishery in the coastal zone.

Habitat alteration and restoration

A major impact of increased anthropogenic activities in the coastal zone has been the degradation of natural habitats provided by coastal ecosystems. Extensive deforestation of mangroves over the years have reduced fishery harvests as mangrove-associated habitats produced recruitment failures of economically important fishes (Pauly & Chua 1988; Turner 1977; Figures 2 and 3). Recently, various initiatives to restore these habitats have been attempted, but the magnitude of the effort remains insignificant due to the extensive loss of mangrove areas estimated at 3,000 km^2 (Primavera 1995). These efforts were initiated by a development aid-funded government program in 1991 until 1994, but the actual reforested area fell short of targeted levels (FSP 1996). In contrast, a development strategy involving coastal communities fared better, supporting the concept that involving local stakeholders positively promotes co-management of fishery resources (Johannes 1981; Jentoft 1989; Christie & White 1997; Baticados *et al.* 1998). With support from both local government and non-government organizations, and the pre-requisite need for community preparation and organizational development, mangrove reforestation initiatives have been carried out with a measure of success. Each awarded a 25-year land tenure on the mangrove reforestation area, households belonging to a fishermen’s cooperative in Kalibo, Aklan were able to re-plant a 50 ha foreshore area near an estuary, maintain, and then derive income from it to date (through partial harvesting of nipa and other mangrove-associated by-products). Similar cases have been documented in Thailand and Vietnam (Quarto 1996).

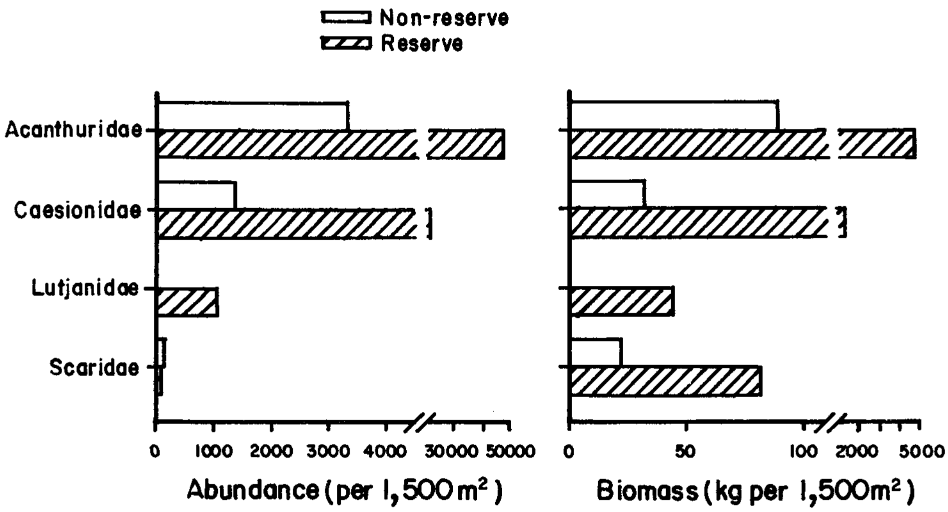

Figure 4. **Abundance and biomass of target fishes from adjacent reefs in Mararison Island, central Philippines declared a reserve (Gui-ob) or a non-reserve (Nablag)**

Protective management

A conservation strategy is a realization of the importance of coastal ecosystems in supporting the municipal fishery. Indeed, a conservation strategy that sets aside a certain area as a "no-take" zone is becoming widely popular, particularly in many reef areas (Roberts & Polunin 1993). The establishment of these zones or marine reserves has been justified with its perceived benefits on coastal fisheries, notably the replenishment of recruits that will seed fished areas by protecting spawning stock biomass (Roberts & Polunin 1991). Available evidence from marine reserves show an increase in abundance, mean size, and fecundity of fishes that are preferably targeted by fishers, including the emigration ("spillover effect") of fishes from the reserve to adjacent fished areas (Bohnsack 1996; Russ & Alcala 1996). Likewise, site-attached grouper from marine reserves appeared to have a higher age range compared with those from fished areas (Ferreira & Russ 1995). Dramatic differences in the biomass and abundance of target fishes from fished and no-take zones after two years of protection of a 28 ha reef in Mararison Island, Antique support these previous reports (Figure 4).

The magnitude of degradation and loss of mangroves in the Philippines and elsewhere now calls for the preservation of the remaining growth. The establishment of reserves may be applied to these remaining mangroves as well, enhancing its role in providing critical nursery habitats for many food fishes (Primavera 1998). For instance, the Matang mangrove reserve appeals vital to the maintenance of shrimp fishery in Malaysia by providing a hydrodynamic trap whereby recruitment is enhanced at spring tides, thereby trapping young shrimp at neap tides (Chong *et al.* 1996). In the Philippines, mangrove reserves are few in number (e.g., Bais Bay, Pagbilao Bay) and have yet to be integrated in village-based co-management strategies (Alder 1996). Nonetheless, designating the few remaining stands of mangroves as protected areas may be the last viable option left to arrest the decline of this valuable resource.

Prospects

The need to attain food security has compromised the integrity of natural resources. This dilemma has become very apparent in the coastal zone wherein impoverished fishing communities depend on the municipal fishery for sustenance. Indeed, mangroves and other coastal ecosystems that support fishery productivity have not been spared from degradation. Yet, the promotion of aquaculture and other food production activities may still be compatible with mangroves. Low-impact development activities whether outside of or within mangroves should be viewed as a recognition of the overall importance of this resource to sustain the productivity of the coastal zone. Efforts that involve the participation of all resource stakeholders are essential to maintain the delicate balance of food security and mangrove resource conservation.

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Property rights and collective action in the management of mangrove ecosystems: Implications of the adoption of mangrove-friendly aquaculture

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Abstract

The SEAFDEC/AQD experience in Malalison Island on the Community Fishery Resources Management Project is well used in the Aklan project on community-based mangrove-friendly aquaculture. The territorial use rights in fisheries that was implemented in Malalison has become a model in investigating property rights regime in state-owned mangrove areas in Ibajay, Aklan. The concept of property rights as a management strategy in arresting the further destruction of mangroves and rehabilitating destroyed mangrove forest requires the collective effort of different users and stakeholders. There is a need to balance environmental conservation and food security in the management of mangrove resources.

Introduction

The Philippine waters used to be one of the most productive and diverse in the world. It is home to 2200 species of fish (Sale 1980) and 488 species of coral (Nemenzo 1981). But rapid population growth, industrialization, overfishing, and destructive fishing practices have continuously ravaged marine ecosystems over the past three decades. Coral reef fish production declined steeply, from 429,000 tons in 1966 to 269,000 in 1986 (McAllister 1988). Only 25% of coral reefs are in good condition now, with barely 5% in excellent state (Yap & Gomez 1985). Thick mangrove forests used to cover a large portion of the coastal areas.

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 socioeconomic well-being of the coastal communities (Field 1995).

Mangrove ecosystems provide the following ecological and economic benefits: (1) provision of nursery grounds for fish, crustaceans and molluscs that are recruited into the fishery resources; (2) 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; (3) protection of lagoons and estuaries from storm and erosion; (4) reduction of some organic pollution in nearshore waters by trapping or absorption; (5) recreational grounds for bird watching and observation of other wildlife; and, (6) access to a high diversity of mangrove plants and animals, and their adaptations (Saenger *et al.* 1983; Hamilton & 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. 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 of the ponds were too large while there were few sluice gates for tide water exchange resulting in the degradation of pond environment. Many people 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 due to conversion to fishponds and recreational facilities and indiscriminate cutting of firewood and materials for house construction (Primavera 1993, 1995).

Studies have shown positive correlation between nearshore fish and shrimp yields and mangrove areas in the Philippines (Camacho & Bagarinao, 1986) and in Indonesia (Martosubroto & 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 economics with the much needed foreign exchange. 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 to the detriment of 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.

In the Philippines, mangrove forests are state-owned common property that have been "privatized" through the fishpond leasehold agreement (FLAs) under the Fisheries Code of 1975 (P.D. 704) and the new Fisheries Code of 1998 (Republic Act 8550). Aquaculture remains the major cause of decline of mangrove forests -- around half of the 279,000 ha of mangroves lost from 1951 to 1988 were developed into fish ponds. In 1990, the Department of Environment and Natural Resources (DENR) through Administrative Order No. 15 disallowed conversion of vegetated mangrove areas into fishponds. Moreover, the Order instructed the Bureau of Fisheries and Aquatic Resources (BFAR) that all mangrove swamps that were not utilized and had been abandoned for five years be reverted back into the category of forest land.

The advent of aquasilviculture provides options for ensuring food security through the practice of mangrove-friendly aquaculture techniques. Aquasilviculture 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 to ensure the sustainability of both the resource and the technology.

SEAFDEC/AQD experience in territorial use rights in fisheries

The Community Fishery Resources Management Project in Malalison Island was a learning experience for SEAFDEC/AQD's interdisciplinary team in the implementation of territorial use rights in fisheries (TURFs). One of the objectives of the project is to provide the organized fisherfolk (Fishermen’s Association of Malalison Island) exclusive rights in the management and utilization of the coastal resources surrounding the island. The concept of TURF is to instill a sense of ownership and responsibility for the common property resource such as the coastal resources (Siar *et al.* 1992).

The SEAFDEC team explained to the local government officials the importance of granting TURF to resource users especially the fisherfolk. In recognition of the importance of TURF and in support of the CFRM project of SEAFDEC/AQD, the Culasi Municipal Council passed Ordinance No. 5-90 granting TURF over a one-kilometer area between the island of Malalison and the mainland of Culasi for seafarming and other fishery resource management projects. As an addendum to the ordinance, the Culasi Municipal Council passed another resolution (Ordinance 2-91) allowing the deployment of concrete artificial reefs in the TURF area to serve as a fish sanctuary.

For purposes of granting TURF to other coastal communities, SEAFDEC conducted a study on the traditional and existing marine boundaries and sea tenure practices (Siar 1996). The study revealed that the waters around Malalison Island area is a shared resource. The Malalison fisherfolk had to make arrangements with those from other neighboring fishing villages regarding the setting up of gears and conflict resolution mechanisms.

The Malalison fisherfolk established a Fisheries and Aquatic Resource Management Council whose primary function is to prepare a coastal resource management plan. The first activity of the Council was to propose the establishment of a fish sanctuary in one of the reef areas. The Barangay Council approved the proposal which was subsequently approved by the Culasi Municipal Council. SEAFDEC researchers provided biological resource data to FARMC and the local government legislators to be used as scientific bases for the declaration of fish sanctuaries.

Because of the importance of these aspects in granting TURF and declaration of fish sanctuaries in the CFRM project, SEAFDEC employed the Process Documentation Research methodology (de los Reyes 1988) to fully document all the important events leading to the formulation of policies for the conservation and management of fishery resources.

The learnings from the Malalison experience has become very useful in the community-based project in Aklan especially on matters concerning property rights regimes for the adoption of mangrove-friendly aquaculture.

Property rights regimes

The concept of property rights as a management strategy in arresting 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 such 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: (1) exclusivity or the right to determine who can use or access the resource; (2) transferability or the right to sell, lease or bequeath the rights; and (3) 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 & Carlos 1997; Agbayani & Babol 1997; Primavera & Agbayani 1996). The people-centered approach of CBCRM encapacitates 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. These people-empowering activities have prepared 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 Local Government Code of 1991 and the Fisheries Code of 1998. In mangrove forests, Administrative Order No. 15 (1990) of the DENR or the Department of Environment and Natural Resources sets aside public forest as "communal mangrove forest" for the exclusive use of residents of the municipality from which 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 systems of appropriation of their construction, logic, and historical transformation. There is a need to look into the social circumstances of the actors 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), unsustainable practices and inequitable distribution of benefits (Ruddle 1994), considering the multiple-use characteristic of this resource.

There is 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.

SEAFDEC/AQD proposes to undertake a research project on the assessment and evaluation of the property rights regimes in selected mangrove areas in two Southeast Asian countries to determine which type of regime and institutional framework can be a viable management strategy under varying conditions (political, social, cultural, biophysical and technological). This effort is in relation to the adoption of mangrove-friendly aquaculture technologies. Backed by past learnings, particularly when the government gave private rights to certain individuals in the use of mangroves, this proposal considers the need to focus on local forms of organization, such as informal use-rights. Moreover, the role of the state in legitimizing local strategies in mangrove resource management is essential. Failure to recognize the difference in perspective between the two may result in unlikely consequences (Ostrom 1991). Specifically, maintaining mangrove forests and collective action at the local level might not evolve. Even if there are cases of sound collective action evident in the formation of local cooperatives to reforest degraded mangrove areas, documentation in regard to the process of their creation and present status needs to be done.

Research studies fall into four areas:

(1) Assessment and documentation of mangrove situations in the project sites (Philippines and Vietnam) particularly current resource-use practice, extent of aquaculture development and plans for development by the government

Gather a profile of mangrove-users (sex, age, education, etc.)
Document prevailing property rights regimes and institutional arrangements in the use and

management of mangroves

(2) External interventions (e.g., technology, organizing, etc.)

Conduct a resource valuation of mangrove sites, specifically their carrying capacity when aquaculture technologies will be introduced

(3) Conduct impact assessments of several aquaculture technologies introduced in mangrove areas, using the following indicators: efficiency, sustainability and social equity

(4) Develop a model of complementation between the state and the local community, specifically in decision-making and developing strategies

With regard to aquasilviculture projects, SEAFDEC/AQD has started collaborating with local government units (LGUs) and peoples' organizations in implementing mangrove-friendly aquaculture technologies. There are several sites in the Philippines where this project is being conducted: Banate (Iloilo), New Buswang, Tangalan and Ibajay (Aklan) and Bgy. Manalo (Palawan).

SEAFDEC/AQD conducted various fora and training programs to familiarize the participants on the concepts, principles, and potentials on mangrove-friendly aquaculture and coastal resource management as well as update them on the fishery laws to enable them to formulate policies related to coastal resource management.

SEAFDEC/AQD has identified and started working on mangrove-friendly aquaculture in Bugtong Bato, Ibajay, Aklan province. A resource and socioeconomic assessment were conducted and a report has been prepared for discussion with the LGUs, both from provincial to village levels. The output aims to have a joint resource management plan to minimize use conflict and establish sanctuaries both in marine and mangrove areas with the participation of the fishing community. It also plans to conduct training courses on mangrove-friendly aquaculture in SEAFDEC member countries.

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Mud crab (*Scylla serrata*) culture in tidal flats with existing mangroves

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Abstract

The performance of the mud crab *Scylla serrata* (Forsskal) in 200 m^2 pens installed in tidal flats with existing mangroves was determined in a factorial experiment with stocking density (0.5 or 1.5/m^2) and feed (salted fish by-catch or a mixed diet of 75% salted brown mussel flesh and 25% salted fish by-catch) as main factors. Duration of the experiment was 160 days. Results showed no interaction between feed and stocking density so data were pooled for each feed and stocking density treatment. There was no significant differences in growth, feed conversion ratio (FCR), survival, and production among two types of feed. Regardless of feed, the FCR was significantly more efficient and survival significantly higher at 0.5 than at 1.5/m^2 stocking density. Growth, however, was not significantly different. Cost-return analysis on a per crop/200 m^2 basis showed that the use of either of the two stocking density levels with either of the two types of feed was economically viable with a return on capital investment of 65-87%. Partial budgeting analysis, however, revealed that net earnings were increased by P1,128.00 if crabs were stocked at 1.5/m^2 and P881.00 if fed a mixed diet of 75% salted brown mussel flesh and 25% salted fish by-catch compared with crabs stocked at 0.5/m^2 and fed salted fish by-catch alone.

Introduction

In the Philippines, fishing villages are generally located in fringes of arable land along coastal plains and the people 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, mud crab culture was introduced to provide alternative livelihood for fishers in the village. A rearing system (pen) was designed such that the main function of mangroves as nursery grounds for fish and crustacean fry and juveniles was not hampered. The design allowed inundation of the system at highest tide. Structures were installed to minimize siltation of canals and retain water depth requirement of the cultured species.

The present study was undertaken to determine the performance of the mud crab *Scylla serrata* Forsskal in this type of rearing system (200 m^2 pens installed in tidal flats with existing mangroves) when stocked at two stocking density levels and fed two types of feed.

Materials and methods

The study was conducted in 200 m^2 pens installed in existing mangroves at New Buswang, Kalibo, Aklan, central Philippines in collaboration with the USWAG Foundation, Inc; Department of Environment and Natural Resources - Kalibo (DENR); the local government unit of the Municipality of Kalibo (LGU-Kalibo) and the people's organization Kalibo Save the Mangrove Association (KASAMA).

A completely randomized 2 x 2 factorial experiment with stocking density (0.5 or 1.5/m^2 of mixed sex mud crab) and feed (salted fish by-catch or mixed diet of 75% salted fresh brown mussel *Modiolus metcalfei* flesh and 25% salted fish by-catch) as the main factors was replicated thrice.

The pen enclosures used nylon net (12 mm mesh and 2 mm twine diameter) and bamboos as structural framework. The lower end of the enclosures was buried 60 cm into the bottom while the inner side of the upper end was lined with 30 cm wide plastic sheet (gauge #18) to prevent crab stock from escaping. The bottom of the pens was provided with peripheral and central canals 50 cm deep and 50-100 cm wide representing about 20-30% of the pen area.

The set-up was flooded during high tide but a dike, 40-50 cm wide and 50 cm high, was constructed surrounding the enclosure to retain additional water level of 30-50 cm during lowest tide. Thus, the water level in pens at low tide if measured from the bottom of the canal was maintained at 80-100 cm. The dike was further enclosed with fine-meshed nylon screen to minimize siltation of canals in pens; however, net with a wider mesh size (5 mm) was used at the side where drain gates are installed. Two 50 cm wide and 50 cm high drain gates were installed to allow draining of pens at night time for 3 consecutive nights every 7 days to expose mangrove roots. Continuous submergence of mangrove roots may cause death of mangroves (J.H. Primavera, pers. comm.).

The crabs were fed 10% of the crab biomass daily when the carapace length was ≤6 cm and 5% when ≥ 6 cm, with 40% of the daily feed ration given at 0700 h and 60% at 1700 h. Stock sampling was done monthly. The daily ration was then adjusted based on overall estimate of the survival for all treatments and the estimated biomass for each treatment replicate.

The growth, apparent FCR, survival, production, and cost of production were calculated from the total harvest. The means were compared by analysis of variance and Duncan's multiple range test (SAS 1988). The economic viability of the culture methods was evaluated by cost-return and partial budgeting analysis (Shang 1990).

Results

There was no interaction between stocking density levels and feed on the growth, apparent FCR, survival, and production of mixed sex mangrove-reared mud crab so that data were pooled for each feed and stocking density treatment (Table 1). There was no significant differences in growth, FCR,

Table 1. Growth, FCR, survival, and production (mean ±SE) of mixed sex mangrove-reared mud crab *Scylla serrata* using pooled data*

	Stocking density		Feed	
	$0.5/m^2$	$1.5/m^2$	Salted fish by-catch	Salted mixed diet
Body weight (g)	317.4 ±9.13[a]	316.4 ±5.96[a]	310.0 ±3.96[a]	324.0 ±8.43[a]
Weight gain (g)	297.4 ±9.02[a]	298.1 ±4.90[a]	290.8 ±3.73[a]	304.7 ±7.39[a]
Carapace length (cm)	7.82 ±0.14[a]	8.00 ±0.09[a]	7.92 ±0.08[a]	7.89 ±0.12[a]
Carapace width (cm)	11.55 ±0.14[a]	11.71 ±0.08[a]	11.69 ±0.09[a]	11.17 ±0.14[a]
SGR (%/day)	1.74 ±0.08[a]	1.79 ±0.03[a]	1.75 ±0.08[a]	1.75 ±0.03[a]
FCR	5.30 ±0.34[b]	7.60 ±0.63[a]	6.70 ±0.63[a]	6.20 ±0.84[a]
Survival (%)	56.00 ±0.34[b]	33.00 ±3.61[b]	44.00 ±5.04[a]	45.00 ±5.36[a]
Production ($kg/200m^2$)	17.77 ±0.93[b]	31.34 ±3.48[a]	23.59 ±3.91[a]	25.56 ±3.76[a]

*There was no interaction between stocking density levels and diets so data were pooled for each stocking density or diet treatment. Values±SE with similar superscripts within stocking density or feed treatment are not significantly different (P>0.05)

survival, and production between the two types of feed. Regardless of feed, the FCR was significantly more efficient and survival significantly higher at the 0.5 than at $1.5/m^2$ stocking density. Growth, however, was not significantly different across stocking densities. Proximate analysis of the feeds used is shown in Table 2.

The total investment (Table 3) was expressed in terms of development cost and operating cost (variable and fixed costs). The development cost consisted of cost of materials for the construction of net enclosures. Labor was not included as it was assumed to be provided by family members. Crab juveniles and feed comprised the major component of the variable costs (47-54% and 42-47%, respectively). Production costs are summarized in Table 4 for the two stocking densities and two types of feed.

Table 2. **Proximate analysis of feedstuffs (% dry matter)**

	Salted fish by-catch*	Salted brown mussel flesh
Moisture	4.72	5.35
Crude protein	47.08	32.16
Crude fat	5.14	3.52
Crude fiber	1.18	1.06
Nitrogen-free extract	3.18	7.74
Ash	43.42	55.52
Metabolizable energy (Kcal/100 g)	263.00	198.00

*Fish by-catch consisted of *Mirogobius* sp.

Table 3. **Investment required for a mixed sex mangrove-reared mud crab monoculture. Values in Philippine pesos are on per 200 m² pen/crop basis***

	Stocking density		Feed	
	0.5/m²	1.5/m²	Salted fish by-catch	Salted brown mussel
Development costs				
Construction of net enclosures	5,275	5,275	5,275	5,275
Total development cost	5,275	5,275	5,275	5,275
Operating costs				
Variable costs				
Crab juveniles	850	2,580	1,700	1,700
Feeds	860	2,178	1,580	1,315
Materials for pen preparation	76	76	76	76
Miscellaneous expenses**	36	96	67	62
Total variable cost	1,822	4,900	3,423	3,153
Fixed costs				
Interest on capital investment***	211	211	211	211
Depreciation	26	26	26	26
Total fixed cost	237	237	237	237
Total operating costs	2,059	5,137	3,660	3,390
Total investment	7,334	10,412	8,935	8,665

*Prevailing market price in Iloilo, Philippines as of December 1997

**2% of variable cost

***8% of capital investment per year

Table 4. **Costs-and-returns and partial budgeting analysis for a mixed sex mangrove-reared mud crab monoculture. Values in Philippine pesos are on a 200 m² pen/crop basis**

	Stocking density		Feed	
	0.5/m²	1.5/m²	Salted fish by-catch	Salted brown mussel
Total revenues at sale price of P350 for female, P270 for male and P310 for mixed sex*	5,509	9,715	7,313	7,924
Less: Operating cost	2,059	5,137	3,660	3,390
Net revenue	3,450	4,578	3,653	4,534
Production cost (/kg)	116	264	155	133
Return-on-investment	65	87	69	86
Incremental benefit		4,206		611
Incremental cost		3,078		(270)
Net benefit		1,128		881

*Prevailing prices in Roxas City, Philippines export market at the time of harvest, February 1998

The sale price (Table 4) per kg of mud crab produced [P350 for fat or roed females, P270 for full males and P310 for fat or roed mixed sex (exchange rate at harvest, February 1998 is P35 = $1)] was based on the farm gate price offered by exporters. Price of mud crab in the export market in the Philippines fluctuates with season and is highest in December to February. Net revenue was highest at 1.5/m². Net revenue went up as stocking density level was increased from 0.5 to 1.5/m². The use of either of the two stocking density levels with either of the two types of feed was economically viable with a return on investment of 65-87%. Partial budgeting analysis (Table 4), however, revealed that net earnings were increased by P1,128.00 if crabs were stocked at 1.5/m² and P881.00 if fed a mixed diet of 75% salted brown mussel flesh and 25% fish bycatch.

Discussion

The growth, survival, FCR and production of mixed sex mangrove-reared mud crab were not influenced by feed type but were more affected by stocking density levels. The two stocking density levels did not adversely influence the growth of crab, however, the FCR, survival, and production were significantly affected. Similar observation was reported by Triño et al. (in press) for pond-reared mixed species of *Scylla serrata* and *S. tranquebarica.*

An investigation on the effect of stocking density on the performance of mud crab fed fish by-catch (Baliao *et al.* 1981) and a mixed diet of 75% fresh brown mussel flesh and 25% fish by-catch (Triño *et al.* in press) pointed out that the lower the stocking density the higher the survival. This observation is in agreement with the trend noted in this study. Survival of 56±1.9% at $0.5/m^2$ and 33±3.61% at $1.5/m^2$ were obtained.

Production, net revenue, and return on investment (ROI) were higher at $1.5/m^2$ primarily due to high yield but may not be cost-efficient whereas survival and production cost were higher and lower respectively at $0.5/m^2$.

From the economic point of view, the study shows that mixed sex *S. serrata* monoculture in tidal flats with existing mangroves is a viable aqua-mangrove integrated farming venture in the Philippines using either of the stocking density levels (0.5 or $1.5/m^2$) with either of the diets (salted fish by-catch alone or a mixed diet of 75% salted brown mussel flesh and 25% salted fish bycatch) with return-on-investment of 56-87%. Higher profit, however, can be earned from the $1.5/m^2$ stocking density and mixed diet due to high yield and cost-efficiency of the diet.

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Mangrove-associated mollusc research at SEAFDEC/AQD

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Abstract

Mollusc research at the Aquaculture Department of the Southeast Asian Fisheries Development Center started in 1975 and focused on two commercially important mangrove-associated bivalves, the slipper-shaped oyster (*Crassostrea iredalei*) and the green mussel (*Perna viridis*). Studies conducted were on spatfall forecasting to increase collection of seeds from the wild; improvement of farming techniques; seed production in the hatchery; bivalve sanitation; and transplantation. These studies have led to the development of a suitable spat collector for oyster and mussel; promotion of the raft culture method for oysters and mussels to prevent siltation of growing areas, including a low-cost raft designed for this purpose; refinement of transplantation techniques to increase production and to grow oyster and mussel in suitable areas without natural populations; and design of a prototype low-cost depuration unit.

A socio-economic study of oyster and mussel farming practices in Western Visayas provided information on current farming practices and profitability. A study done on the use of green mussels as biofilter in a semi-intensive shrimp pond showed that shrimp stocked with mussels grew faster than those without.

A study on the biology and fishery of the "imbao" *Anodontia edentula*, another mangrove-associated bivalve, is ongoing. Spawning has been achieved in the laboratory and larval stages monitored were first polar body, 2-cell stage, morula, ciliated gastrula, trocophore, veliger, and pediveliger.

Introduction

Molluscs are considered cheap sources of protein. In 1996, world production of mollusc constituted about 32% of total world aquaculture production. Oysters and mussels together constitute 49% of world production of molluscs (FAO 1997).

The SEAFDEC Aquaculture Department started work on molluscs in 1975. Studies focused on two mangrove-associated bivalves, the slipper-shaped oyster (*Crassostrea iredalei*) and the green mussel (*Perna viridis*=*Mytilus smaragdinus*) (Young & Yap 1984). Techniques were developed to: (1) increase collection of seeds from the wild, (2) improve farming techniques, (3) produce oyster and mussel seeds in the hatchery, and (4) improve sanitation and quality of bivalves (SEAFDEC/AQD 1983).

Another mangrove-associated mollusc studied is the brown mussel, *Modiolus metcalfei*, which is also widely distributed in the Philippines. However, a study on spat settlement showed that the brown mussel is not a good candidate for aquaculture because the spats do not settle on or attach to any type of artificial substrate except to adult mussels (Yap 1978).

Studies were also conducted on other species with high economic value, including the window-pane oyster or "kapis" (*Placuna placenta*), the Asian-moon scallop (*Amusium pleuronectes*), and the saddle-shaped oyster or "bay-ad" (*Placuna sella*).

At present, studies are being conducted on the broodstock management, seed production, grow-out culture techniques and artificial feeding of the donkey-eared abalone, *Haliotis asinina.* The biology and fishery of another mangrove-associated bivalve, *Anodontia edentula* are also being studied.

Oysters and mussels

SEAFDEC/AQD started the Mussel Research Project in 1976 with a grant from the New Zealand Government. The Project undertook a survey of the mussel farming industry in the Philippines to assess the status of the industry and to identify research gaps, and conducted studies on the biology and farming of green mussels (Tortell *et al.* 1978; Yap *et al.* 1977; Yap *et al.* 1979).

Oyster and green mussel farming are dependent on natural spatfall. To improve settlement success, a spatfall forecasting program for oyster was started in Himamaylan River, Himamaylan Negros Occidental in 1979 and for the green mussel in Batan Bay, Batan, Aklan in 1981. This program had two main monitoring activities: (1) daily counts of oyster/mussel larvae in the plankton and (2) actual settling of larvae on standardized collectors installed in oyster/mussel farm sites. Researchers from SEAFDEC/AQD developed a suitable spat collector for oyster and mussel which can also be used for grow-out culture (Figure 1). Observations showed that spatfall is imminent when the count of mature larvae exceeds 5/100 ml and persists for at least 3 days. For commercial farming operations, a good or substantial set of oyster seed should yield at least 15 spats/shell for a 40 m surface area, while for mussels, it would be a seed count of 200-500 spats/m of rope or 70-85 spats per 30 cm (Young & Traviña 1983; Young *et al.* 1981).

Oyster and green mussel farming in the Philippines makes use of bamboo stakes as cultch for settling oyster-mussel larvae and for grow-out. Fishfarmers using this method do not practice thinning or transplantation. The main problem with the prolonged use of bamboo stakes is siltation. To overcome this problem, researchers at SEAFDEC/AQD advocated the use of the raft method for mussel culture (Figure 2) which was also adopted for oyster culture (Yap *et al.* 1979; Sitoy *et al.* 1983). This culture method has several advantages: (1) mussels/oysters grow faster and have higher survival rate, (2) transplantation and thinning can be done easily, (3) production is higher, and (4) the hanging ropes do not accumulate silt and are thus more environment-friendly. The raft culture method has a potential return-on-investment of 74% and a payback period of 0.9 years.

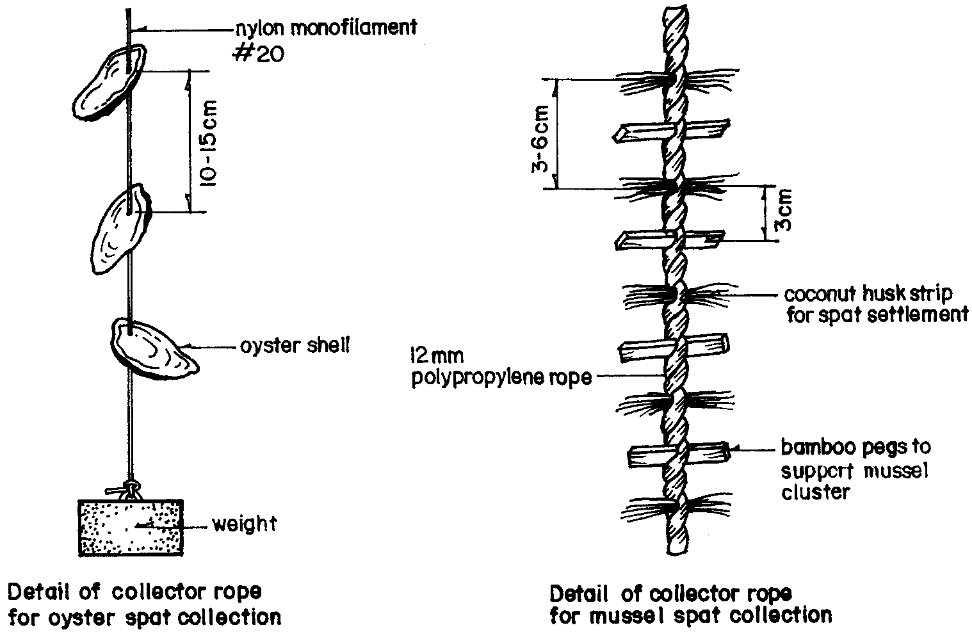

Figure 1. **Details of collector ropes for oysters and mussel spat collection**

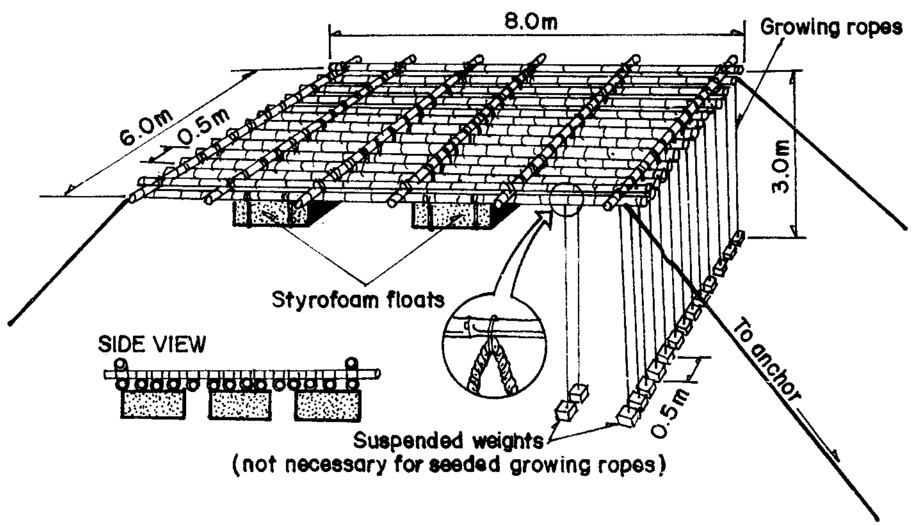

Figure 2. **Details of raft for mussel and oyster culture (Yap *et al.* 1979; Sitoy *et al.* 1983)**

In 1997, SEAFDEC/AQD started verification studies on the use of the raft culture method in commercial scale in three towns in Capiz and Aklan. Initial results have shown that it is commercially viable to culture oysters and mussels using the raft culture method.

To ensure continuous supply of seeds, SEAFDEC/AQD started seed production of bivalves in 1979. Young (1979) successfully spawned the green mussel in the laboratory. The slipper-shaped oyster was also successfully reared through its larval stages to metamorphosis and settlement (Ver 1986; Young unpubl.). Although there is available technology for the mass production of spats in the hatchery, oyster and mussel farmers still prefer to collect spats in areas with abundant natural spatfall because it is cheaper.

Oyster and green mussels can be transplanted or grown in suitable areas without natural populations. SEAFDEC/AQD in collaboration with the Philippine Council for Agriculture Resource and Research and private cooperators established mussel farms using transplanted mussel spats in Ticpan Bay and Calape Bay, Calape, Bohol and Balete Bay, Mati, Davao Oriental. These areas do not have natural mussel spatfall (SEAFDEC/AQD 1981).

Mussel spats for transplantation need a binding material to temporarily bind them to the new growing rope. Researchers from SEAFDEC/AQD found that medical gauze is effective. The gauze disintegrates just as the mussel spats have attached themselves to the new growing rope. Oyster spat collectors only need to be transferred to the new growing area.

The export market for oysters and mussels is quite attractive but public health concerns make it difficult for the Philippines to pass rigid standards for export. In 1983, SEAFDEC/AQD researchers devised a prototype low-cost depuration unit suitable for local conditions (Figure 3). Oysters were

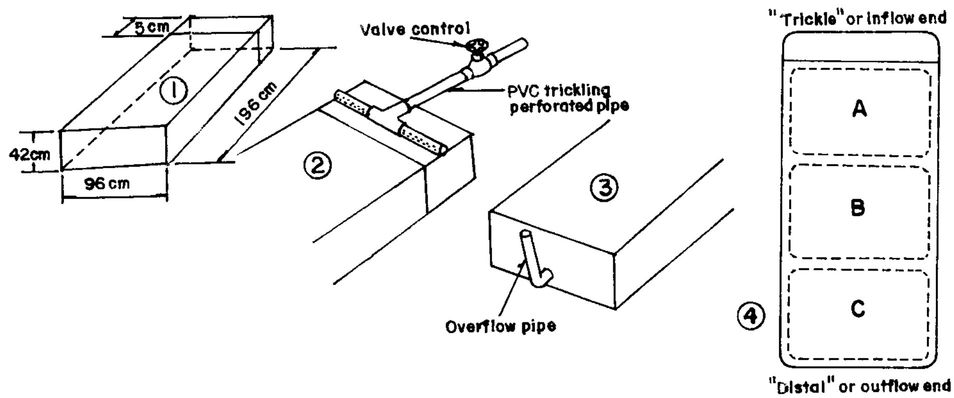

Figure 3. **Prototype low-cost depuration unit** (Gacutan *et al.* 1986): (1) depuration tank of marine plywood; (2) water trickles through this perforated pipe; (3) overflow of pipe where water is drained; (4) depuration tank areas (a, the inflow area nearest the water trickle; b, the middle area; c, the outflow end)

depurated using seawater sand-filtered in a flow-through system and seawater sterilized either through chlorination, ultraviolet radiation, ozonation, and treatment with polyvinyl-iodine-iodine. Ultra-violet-treated water was found to be 99% efficient after 48 h in terms of bacterial disinfection efficiency (Gacutan *et al.* 1986). UV radiation of seawater has no residual effect, is easy to use, and is comparatively inexpensive.

The increasing incidence of red tide in the country is cause for alarm. The first report on red tide occurred in 1983 in Western Samar and Leyte. The causative agent, *Pyrodinium bahamense* var. *compressa* can cause fatal Paralytic Shellfish Poisoning (PSP) in humans. SEAFDEC/AQD did studies to determine the toxicity of contaminated green mussels (Gacutan *et al.* 1984) and to test the use of ozone and PVP-iodine-iodine to inactivate the PSP toxin.

Studies on the socio-economics of oyster and green mussel farming practices in Western Visayas (Samonte *et al* 1992) provided information on: (1) culture methods practiced by oyster and mussel farmers; (2) profile and social conditions of oyster and mussel farmers; (3) profitability of each culture methods; and (4) problems and constraints, and development potential of the oyster and mussel industry.

Another study made evaluated the use of green mussel as biological filter in semi-intensive shrimp (*Penaeus monodon*) ponds. Levels of suspended solids were lower while water transparency was higher in shrimp ponds with green mussels compared to those without. Shrimp grown in ponds with green mussel had significantly higher per cent weight gain and specific growth rate but survival and production were not significantly different (Corre 1997).

Imbao *(Anodontia edentula)*

A study on the biology and fishery of the "imbao" *Anodontia edentula,* another mangrove-associated bivalve, is now on-going. Field samplings revealed that "imbao" can be collected at mean depths of 25-30 cm (JH Primavera, pers. comm.). Monthly range of sizes of "imbao" was 42.8-51.1 mm mean shell length and 21.3-170.0 g total weight. Spawning and larval rearing in the laboratory showed that 0.3 ml of 4mM serotonin was effective in inducing spawning in female and male adults, but not temperature shock and ammonium hydroxide injection. Females that spawned ranged from 60 g, 57.4 mm shell length to 125 g, 73.1 mm shell length. The maximum eggs spawned by a 71 g female was 892,000. Developmental stages monitored were first polar body, 2-cell stage, morula, ciliated gastrula, trocophore, veliger and hatching of D-veliger.

Conclusions

Oyster and mussel farming is basically mangrove-friendly because it does not require the use of animal protein as feed. The raft culture method can be modified for shallower areas. Fishfarmers should be encouraged to use the raft culture method because it is environment friendly. Transplantation can be done in mangrove areas where natural oyster and mussel populations are scarce or absent.

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SEAFDEC/AQD experience in mangrove-friendly aquaculture training and extension

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Abstract

SEAFDEC Aquaculture Department (SEAFDEC/AQD) is mandated to develop human resources and disseminate and exchange information in aquaculture. Towards this direction, AQD's recent thrusts are focused on the verification, packaging, and commercialization of the technologies developed through research. AQD disseminates and exchanges information on aquaculture research and technology through training, extension services, community-based projects and mass media. Through these strategies, AQD aims to reach out to more clientele which include among other sectors the private industry, research and academic institutions, regional and international organizations, policy-makers, non-government organizations, resource managers, SEAFDEC member-countries, local and national government and the fisherfolk.

For the past two years, the scope of training courses and extension services of AQD have been expanded from technological viability to sustainability i.e., technological feasibility, economic viability, environmental sustainability and social equity. To attain sustainable aquaculture the following elements were considered: status of technology, conditions of the coastal resources, socio-economic attributes of the community and other stakeholders and institutional arrangements on sustainable aquaculture.

Starting 1997, subjects on mangrove-friendly aquaculture and coastal resource management were incorporated into the curriculum of training courses. These courses are the following:

- Third Country Training Program on Coastal Aquaculture and Resource Management for trainees from Asian countries
- On-site Training on Sustainable Aquaculture and Coastal Resource Management in Vietnam
- Sustainable Aquaculture and Coastal Resource Management for extension workers and fishery school teachers

In terms of technology verification and extension, the culture of mudcrab (*Scylla* sp.) was tested in mangroves or tidal flats with existing mangroves in two different sites (Puerto Princesa, Palawan and Kalibo, Aldan) in collaboration with local government units and the fisherfolk. These activities started in 1997 and will be replicated in other areas of the country. Also in 1997, AQD published and distributed an issue on integrated farming with aquasilviculture in its SEAFDEC *Asian Aquaculture* newsletter. In 1998, AQD produced a 12-minute video on *Conserving Mangrove Resources.*

Introduction

The Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD) is mandated to: (1) promote, undertake and coordinate aquaculture research relevant to the region; (2) develop human resources for aquaculture development; and (3) disseminate and exchange information in aquaculture. The first mandate is the primary function of AQD's Research Division which undertakes research on commercially important species of fish, crustaceans, seaweeds, molluscs, and other aquatic organisms. The succeeding mandates are the major responsibility of the Training and Information Division whose functions are focused on the verification, packaging, and commercialization of the technologies developed through research. In carrying out these mandates, AQD is guided with its shared vision which states that "SEAFDEC/AQD shall be a dynamic, relevant regional R & D organization for sustainable aquaculture responsive to the needs of the industry and society."

Framework for sustainable mangrove-friendly aquaculture

For the past two years, the scope of training courses and extension services of AQD have been expanded from technological viability to sustainability. Sustainability is viewed in terms of different interrelated aspects, namely, technological feasibility, economic viability, environmental sustainability and social equity. In the expansion process, different elements were also considered to ensure that sustainable aquaculture systems are promoted on a wide scale. These are the status of technology, conditions of the coastal resources, socio-economic attributes of the community and other stakeholders and institutional arrangements on sustainable aquaculture. Sustainable aquaculture systems that are environmentally sound and appropriate for low-level producers and consumers are given emphasis to address the major issue of the needs of the small fisherfolk who make up the bulk of the population of the Asian region.

AQD disseminates and exchanges information on aquaculture research and technology through training, extension services, community-based projects and mass media. Verification projects in selected aquaculture farms and other sites to field test various technologies with consideration to site-specific conditions (i.e., socioeconomic, environmental factors, among others) are undertaken to hasten technology transfer. An important feature of this program is the active participation of the fisherfolk, the private sector and local government units. Dissemination and exchange of information of aquaculture research and technology are also done through symposia, conferences, seminars, workshops, demonstrations, and publications. Likewise, AQD makes use of media strategies such as print, television, internet, and radio in an effort to disseminate widely the aquaculture information. Through these strategies, AQD aims to reach out to more clientele which include among other sectors, the private industry, research and academic institutions, regional and international organizations, policy makers, non-government organizations, resource managers, SEAFDEC Member Countries (Malaysia, Singapore, Vietnam, Thailand, Brunei Darussalam, and the Philippines) and non-member countries, local and national government and most especially the fisherfolk.

Training design and curriculum

The training programs of AQD may be classified into three: regular short-term courses, collaborative or special courses, and individual training programs. The regular short-term courses are offered yearly with a duration of 4-7 weeks and with funding from the Government of Japan through fellowship grants which are made available to SEAFDEC Member Countries. Non-member countries are also given limited slots depending on availability of funds.

Collaborative or special courses are offered upon request. The course content and the duration of training may depend on the field of interest of requesting parties.

Individual training programs are classified into two: the internship and student practicum. In the internship training, individuals are assigned in areas of interest such as fish hatchery, feed development, fish health or disease diagnosis, natural food production, abalone hatchery and other laboratory work. Student practicum is designed for graduating students in fisheries or related fields to satisfy the 400 hours requirement. It aims to provide students practical knowledge in aquaculture to supplement their theoretical orientation in school by assisting in ongoing research and verification studies at AQD.

The training courses curriculum are designed to consist of 10-20% lectures and 80-90% laboratory and field activities. Field trips to selected aquaculture facilities such as fishponds, hatcheries, fisheries institutions and laboratories, feed mills, fish cages, mangrove areas, etc. are undertaken to provide participants the opportunity to observe and interact personally with aquaculturists and practitioners in the industry.

AQD training courses with mangrove-friendly components

Six regular training courses are being implemented annually, namely: Aquaculture Management, Fish Health Management, Marine Fish Hatchery, Freshwater Aquaculture, Shrimp Hatchery Operations alternate with Culture of Natural Food Organisms, and Fish Nutrition. Of the six, none had so far contain topics on mangrove-friendly aquaculture. However, starting 1997, subjects on mangrove-friendly aquaculture and coastal resource management were eventually incorporated into the course curriculum. The training courses implemented with mangrove-friendly aquaculture components in its curriculum are the following:

- *Third-Country Training Program on Coastal Aquaculture and Resource Management*
  First conducted in 1995, this two-month course is a five-year collaborative effort of SEAFDEC/AQD and the Japan International Cooperation Agency (JICA). The course aims to provide the participants from Asian countries with the opportunity to upgrade their knowledge and skills on coastal aquaculture and resource management. Two sessions were implemented in 1995 and one each for the succeeding years with a total of 68 participants (12-14 per session). The participants

are from Bangladesh, Cambodia, People's Republic of China, India, Indonesia, Myanmar, Sri Lanka, Thailand, Vietnam, and the Philippines. For the 1997 and 1998 sessions, the course content has been expanded to include more topics on coastal resource management anchored on sustainable aquaculture. Under the resource management subject, topics on Mangrove Ecosystems, Management and Conservation, and Aquasilviculture has been dealt with

- *On-site Training on Sustainable Aquaculture and Coastal Resource Management in Vietnam*
  In cooperation with Can Tho University in Can Tho Province, Vietnam, this two-week course was conducted by AQD in October 1997. Twenty-two (22) Vietnamese participants coming from academic, research and other government institutions nationwide attended the course. The course was designed to introduce local government officials to the concept, methods, practices of coastal resource management (CRM) and acquaint them with participatory and gender-sensitive aquaculture activities in their respective areas with the context and concerns of CRM and biodiversity conservation and management

- *Sustainable Aquaculture and Coastal Resource Management*
  Sponsored by the Philippines' Technical Education and Skill Development Authority (TESDA), this three-week course has been conducted for two consecutive years, in November-December 1997 and May-June 1998. Nineteen (19) fishery teachers from different schools of fisheries in Region VIII attended the first session, while 20 fishery teachers and TESDA staff from Region V attended the second. The course aimed to upgrade the knowledge and skills of the teachers on sustainable aquaculture technology and coastal resource management

Aside from the special training courses, a 3-day seminar-workshop on *Mangrove Friendly Aquaculture and Coastal Resource Management* was conducted on 19-21 August 1998 at Tangalan, Aklan, Philippines with twenty seven (27) participants comprising of local government Units (LGUs) and peoples organizations (POs) from the municipalities of Ibajay and Tangalan in Aklan and nearby coastal barangays. The activity aimed to familiarize the participants on the concepts, principles, and potentials of mangrove-friendly aquaculture and coastal resource management; and update them on the fishery laws so that they could formulate policies related to the management and conservation of resources.

The major subjects that are included in the courses mentioned above are as follows:

- Resource assessment and management (mangroves, corals, and seagrasses)
- Coastal ecosystems and biodiversity
- Mangrove management and aquasilviculture (mangrove ecosystem, management, conservation, utilization and valuation)
- Fish sanctuary and marine resources
- Socio-economic considerations in sustainable aquaculture
- Community organizations and institutional building of fisherfolk cooperatives
- Management of cooperatives
- Property rights in fisheries
- Institutional and policy analysis of coastal resource management
- Economic resource valuation (with emphasis on mangroves)
- Farming systems
- Seed production
- Feed and nutrition
- Fish health management

Of the total number of 129 participants who attended the AQD training courses with mangrove-friendly aquaculture and resource management components, 52% came from the academe, 33% extension workers, 9% researchers, and 6% policy makers.

Mangrove-friendly technology and verification projects

In terms of technology verification and extension, AQD has conducted a verification study on "Mudcrab Production in Mangrove or Tidal Zone Using Nylon Net." This study was conducted at Brgy. Manalo, Puerto Princesa, Philippines in collaboration with local government units and barangay fisherfolk. Results of this study showed that after a 6 month culture period and with a stocking density of 2/m^2, crabs attained an average body weight of 275 g; yield of 485 kg; feed conversion ratio of 5.1; return-on-investment of 59%; and payback period of 1.6 years.

Another verification study on "Aqua-mangrove integrated farming: Mudcrab, *Scylla serrata,* Culture in Tidal Flats With Existing Mangroves" was conducted in Buswang, Aklan, Philippines in collaboration with local government units (LGUs), the Philippines' Department of Environment and Natural Resources, and a people's organization (the KASAMA) in Kalibo, Aklan. (See Triño & Rodriguez, this volume.)

A verification study on "Semi-intensive production of mudcrab in natural mangrove stands" is an on-going activity and is conducted at Bo. Bugtong Bato, Ibajay, Aklan, Philippines in collaboration with LGUs in Ibajay, Aklan and the community of the said barangay.

Mangrove-friendly aquaculture information materials

AQD publishes *SEAFDEC Asian Aquaculture,* a quarterly newsletter containing updates on aquaculture research and development of the Department. In November-December 1997 issue, the newsletter contained articles which focused on integrated farming and aquasilviculture. The newsletter are sent to AQD's subscribers, composing of fisheries institutions, government agencies, extensionists, aquaculturists and other interested parties. In 1998, AQD made available a 12-minute video on *Conserving Mangrove Resources* for the general public.

Future plans

AQD will continue to implement and conduct its regular short-term training courses but the course curriculum will be expanded to include more topics anchored on responsible and sustainable aquaculture. More collaborative training courses, extension services and information dissemination will be undertaken with LGUs and the national government, non-government agencies, regional and international organizations.

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Available technologies
Workshop recommendations

Workshop participants visit Ibajay, Aklan where mangrove pens are stocked with mudcrabs

List of participants
Acknowledgments

Available mangrove-friendly technologies

The workshop defined mangrove-friendly aquaculture technologies as benign, with minimal adverse impact on the environment. These technologies also integrate mangrove forestry with brackishwater aquaculture. The following technologies in existence are considered mangrove-friendly. Countries that practice them are indicated.

Technology	Country (culture system)
SILVOFISHERIES (POND)	
• mangrove+fish	Indonesia (monoculture, polyculture); Vietnam (monoculture, polyculture); Philippines (monoculture, polyculture)
• mangrove+shrimp	Indonesia (monoculture, polyculture); Vietnam (monoculture, polyculture); Thailand (monoculture); Myanmar (monoculture); Cambodia (monoculture)
• mangrove+mudcrab	Indonesia (monoculture, polyculture); Myanmar (monoculture); Philippines (monoculture, polyculture)
• mangrove+seaweeds	Indonesia (monoculture, polyculture); Philippines (monoculture, polyculture)
SILVOFISHERIES (PEN)	
• mangrove+mudcrab	Vietnam (monoculture); Malaysia (monoculture), Indonesia (monoculture); Brunei
BIVALVE CULTURE	Thailand (monoculture); Malaysia (monoculture); Philippines (monoculture); Indonesia (monoculture); Vietnam (monoculture)
CAGE CULTURE	
• mudcrab in cages	Vietnam (monoculture); Philippines (monoculture); Indonesia (monoculture, polyculture)
• fish cage culture	Thailand; Malaysia; Brunei; Vietnam; Philippines; Indonesia
OTHERS	
• rearing of sea horses	Philippines
• rearing of sea cucumbers in pens	Indonesia

Details of available technologies on mangrove-friendly aquaculture

I. SILVOFISHERIES - POND **(MANGROVE+FISH)**	Practicing country	
	Philippines	Vietnam
Site selection criteria		
• *water quality* (salinity, temperature, D.O.)	not too wide range	15-30 ppt, 26-30°C 4-6 ppm D.O.
• *soil quality*	mud, fine sand, sandy	
• *tidal regime-range, depth*	water depth of 0.5 m below low tide in canal	0.8-1.0 m
• *protection*	protected from strong wind and waves	
• *pollution*	area far from source of pollution	
• *security*	fenced to prevent poaching	
• *vegetation*	not thickly forested to avoid cutting of trees	
• *peace and order situation*	should be peaceful in order to be managed effectively	
Design and construction		
• *dimension*	depends on available area, at least 1,000 m^2	
• *materials*	locally available, i.e., bamboo, nets	
• *land (mangroves) to water (pond) ratio*	70:30 or 80:20	70:30
• *water body*	brackishwater	
Preparation		
• *drying of bottom*	can be drained completely when needed	yes
• *eradication of pests and predators*	by drying the pond	
• *tilling*	canal bottom can be tilled except the mangrove area	
• *fertilization*	for ponds, 16-20-0 at 2 bags/ha; organic fertilizer could also be used	
Water management		
• *frequency*	daily (tide water is allowed to enter the pond and to drain slowly until the next tide cycle	

	Practicing country	
	Philippines	Vietnam
• *volume*	at least 10%	
Stocking		
• *monoculture or polyculture*	both can be done	
• *species*	fishes, crabs, shrimps, tilapia, milkfish, grouper, rabbitfish, and other species that enter the area	*Mugil* spp, *Chanos, Lates calcarifer*, *Oreochromis mossambicus* and *O. niloticus*
• *stocking density*	2,000-3,000/ha for fishes, 1,000 pcs for crablets, 3/m^2 for fishes	
• *stocking size*	fingerlings, juvenile	natural and hatchery seed
• *source of seed*	tidal entry, wild seed, hatchery seed	
Feeding		
• *type of feed*	natural food, trashfish	no feeding
• *source of feed*	locally available	
• *feeding rate*	5-10% of biomass	
• *preparation*	commercially prepared, fresh or locally made	
• *method of feeding*	broadcast, split morning and afternoon	
Monitoring		
• *physico-chemical*	daily	
• *security*	guarded	
• *stock sampling*	monthly	
Harvest and postharvest		
• *method of harvesting*	selective harvest	total harvest
• *harvest size*	500-1,000 g for fish, 200-400 g for crabs	
• *gear*	seine, liftnet	
• *packing and transport*	ice boxes for dead	60/40%
• *live vs. dead*	live	60/40%
Marketing and economics		
• *consumption (home or local, export market)*	both	home/local market
• *production cost*	depends on local condition as prices fluctuate from area to area	
• *capital outlay*	as above	
• *net profit*	as above	
• *return-on-investment*	as above	
• *yield*		

II. SILVOFISHERIES - POND **(MANGROVE+SHRIMP)**	Practicing country		
	Cambodia	Thailand	Vietnam
Site selection criteria			
• *water quality* (salinity, temperature, D.O.)	20-35 ppt, normal D.O	5-30 ppt, 25-30°C, >3 ppm D.O.	15-30 ppt 26-30°C, 4-6 ppm
• *soil quality*	muddy loam	clay	
• *tidal regime-range, depth*	2 m	2-3 m	1.5-3.5 m, 0.8-1.0 m
• *protection*			
• *pollution*			
• *security*			
• *vegetation*	mangrove in front of shrimp farms		
• *peace and order situation*			
Design and construction			
• *dimension*	rectangular pond	0.1-2.0 ha	5-10 ha
• *materials*		earthen ponds	
• *land (mangroves) to water (pond) ratio*	no data	50:50	70:30
• *water body*			long, narrow canal, surrounding canal
Preparation			
• *drying of bottom*	being done		being done
• *eradication of pests and predators*	being done	dry the pond bottom	being done
• *tilling*			
• *fertilization*	being done	used as less as possible	
Water management			
• *frequency*	last 2 months of culture	each week	every 15 days/ month, 3 hours a day
• *volume*	10%	5-20%	10-20%
Stocking			
• *monoculture or polyculture*	monoculture	monoculture	monoculture
• *species*	*Penaeus monodon*	*P. monodon*	*P. monodon* or *P. indicus*
• *stocking density*	50 pcs/m^2	30-80/m^2	0.1-1.0/m^2
• stocking size			
• source of seed			

	Practicing country		
	Cambodia	Thailand	Vietnam
Feeding			
• *type of feed*	pellet	pellet	trashfish, agricultural by-products
• *source of feed*	commercial		
• *feeding rate*	4-5 times a day	3-5% of body wt	3-5% of shrimp biomass
• *preparation*			
• *method of feeding*		demand feeding	once a day at 3 PM
Monitoring			
• *physico-chemical*	being done	D.O., NH_3, alkalinity	
• *security*	yes		yes
• *stock sampling*	every week	once a week	
Harvest and postharvest			
• *method of harvesting*	total harvest	total	selective (on 2nd month); total harvest on 4th month)
• *harvest size*	30-50 pcs/kg	70-25/kg	20-40 g apiece
• *gear*	open pond gate	net	
• *packing and transport*	frozen	clean and low temperature	
• *live vs. dead*		dead	50-60% live, 40-50% dead
Marketing and economics			
• *consumption (home or local, export market)*	100% export	>90% export	20% home and local market; 80% export
• *production cost*	no data	about 50%	
• *capital outlay*	no data		
• *net profit*	no data	about 50%	
• *return-on-investment*	no data		
• *yield*			200-250 kg/ha/ crop after 6 months

III. SILVOFISHERIES - POND **(MANGROVE+MUDCRAB)**	Practicing country Vietnam
Site selection criteria	
• *water quality* (salinity, temperature, D.O.)	10-30 ppt, 26-30°C
• *soil quality*	
• *tidal regime-range, depth*	
• *protection*	
• *pollution*	
• *security*	
• *vegetation*	
• *peace and order situation*	
Design and construction	
• *dimension*	500-5,000 m^2 or cage 3 x 4 x 1.2 m
• *materials*	bamboo enclosure
• *land (mangroves) to water (pond) ratio*	
• *water body*	
Preparation	
• *drying of bottom*	
• *eradication of pests and predators*	
• *tilling*	
• *fertilization*	
Water management	
• *frequency*	
• *volume*	
Stocking	
• *monoculture or polyculture*	monoculture
• *species*	*Scylla serrata*
• *stocking density*	2-4 pcs/m^2 or 10-25 kg/m^2 (cage)
• *stocking size*	25-40 g/piece
• *source of seed*	natural seed
Feeding	
• *type of feed*	chopped trashfish
• *source of feed*	natural food
• *feeding rate*	10%
• *preparation*	
• *method of feeding*	once a day

	Practicing country
	Vietnam
Monitoring	
• *physico-chemical*	
• *security*	yes
• *stock sampling*	
Harvest and postharvest	
• *method of harvesting*	hand-picking at low tide
• *harvest size*	200-250 g/piece
• *gear*	
• *packing and transport*	
• *live vs. dead*	40-60% live, 60-40% dead
Marketing and economics	
• *consumption (home or local, export market)*	20% local market, 80% export
• *production cost*	
• *capital outlay*	
• *net profit*	
• *return-on-investment*	
• *yield*	375-600 kg/ha/crop (6-7 months)

I. SILVOFISHERIES - PEN **(SEAWEEDS)**	Practicing country
	Vietnam
Site selection criteria	
• *water quality* (salinity, temperature, D.O.)	25-35 ppt, 24-30°C, 4-5 ppm
• *soil quality*	
• *tidal regime-range, depth*	
• *protection*	
• *pollution*	
• *security*	
• *vegetation*	
• *peace and order situation*	
Design and construction	
• *dimension*	
• *materials*	
• *land (mangroves) to water (pond) ratio*	
• *water body*	

	Practicing country
	Vietnam
Preparation	
• *drying of bottom*	
• *eradication of pests and predators*	
• *tilling*	
• *fertilization*	
Water management	
• *frequency*	
• *volume*	
Stocking	
• *monoculture or polyculture*	monoculture
• *species*	*Kappaphycus alvarezii*
• *stocking density*	
• *stocking size*	
• *source of seed*	natural seed
Feeding	
• *type of feed*	
• *source of feed*	
• *feeding rate*	
• *preparation*	
• *method of feeding*	
Monitoring	
• *physico-chemical*	
• *security*	
• *stock sampling*	
Harvest and postharvest	
• *method of harvesting*	
• *harvest size*	
• *gear*	
• *packing and transport*	
• *live vs. dead*	
Marketing and economics	
• *consumption (home or local, export market)*	70% home or local market, 30% export
• *production cost*	
• *capital outlay*	
• *net profit*	
• *return-on-investment*	
• *yield*	2,500 kg dry seaweed and 15,000 kg seed

II. SILVOFISHERIES - PEN (**MUDCRAB**)	Practicing country Brunei Darussalam	 Malaysia
Site selection criteria		
• *water quality* (salinity, temperature, D.O.)	25-28 ppt	20-30 ppt, 26-32°C, >4 ppm
• *soil quality*	muddy	clayey mud
• *tidal regime-range, depth*	3-5 m	4 m
• *protection*		
• *pollution*		no problem
• *security*		good
• *vegetation*		mangrove
• *peace and order situation*		
Design and construction		
• *dimension*	30 x 30 m pen	pens measuring 18 x 9 m
• *materials*	palm tree	"nibong" palm *Oncosperma higillaria*
• *land (mangroves) to water (pond) ratio*		100% in mangrove area
• *water body*		
Preparation		
• *drying of bottom*		
• *eradication of pests and predators*		
• *tilling*		
• *fertilization*		
Water management		
• *frequency*		seawater allowed to enter pen during high tide; stale water drained out at least once a week
• *volume*		
Stocking		
• *monoculture or polyculture*	monoculture	monoculture
• *species*	*Scylla serrata*	*S. tranquebarica and S. olivaceous*
• *stocking density*	varied	1,000-1,500 pcs/pen
• *stocking size*	juvenile (30-50 g)	100 g
• *source of seed*	wild	wild
Feeding		
• *type of feed*	trashfish	trashfish
• *source of feed*	traders	local fish
• *feeding rate*	2-3 times	600 kg in 5 months per pen

	Practicing country	
	Brunei Darussalam	Malaysia
• *preparation*	chopping	chopped to 9-12 cm pieces
• *method of feeding*	by hand	fed during high tide
Monitoring		
• *physico-chemical*		
• *security*		
• *stock sampling*		
Harvest and postharvest		
• *method of harvesting*		partial harvest
• *harvest size*		average size 300 g
• *gear*		scoop net, lift net ("bintol")
• *packing and transport*		pincers tied up and crab transported dry in rattan baskets
• *live vs. dead*	live	live
Marketing and economics		
• *consumption (home or local, export market)*	local market	local
• *production cost*		RM 995 per pen per crop
• *capital outlay*		RM 3,180 per pen
• *net profit*		RM 2,204.15 per pen
• *return-on-investment*		
• *yield*		

BIVALVES	Practicing country	
	Malaysia	Viet Nam
Site selection criteria		
• *water quality* (salinity, temperature, D.O.)	10-30 ppt, 25-32°C, >4 ppm	25-35 ppt
• *soil quality*	silty, clayey	
• *tidal regime-range, depth*	2 m	1.5-3.5 m, 0.3-0.5 m
• *protection*		
• *pollution*	free from pollution	
• *security*	patrolled by owners	
• *vegetation*	mudflat vegetation	
• *peace and order situation*		

	Practicing country	
	Malaysia	Viet Nam
Design and construction	not applicable	
• *dimension*		
• *materials*		
• *land (mangroves) to water (pond) ratio*		natural tidal flat
• *water body*		
Preparation		none
• *drying of bottom*	no	
• *eradication of pests and predators*	manual removal	
• *tilling*	not necessary	
• *fertilization*	not necessary	
Water management	not applicable	
• *frequency*		
• *volume*		
Stocking		
• *monoculture or polyculture*	monoculture	monoculture
• *species*	Anadara granosa	Meretrix lyrata, Arca granosa
• *stocking density*	500 pcs/m^2	300-350 pcs/m^2, 75-125 pcs/m^2
• *stocking size*	6.4 mm	800-1,000 pcs/m^2, 300-700 pcs/m^2
• *source of seed*	wild seed	tidal entry, wild seed
Feeding		
• *type of feed*		
• *source of feed*		
• *feeding rate*		
• *preparation*		
• *method of feeding*		
Monitoring		
• *physico-chemical*		
• *security*	daily patrol	yes
• *stock sampling*		
Harvest and postharvest		
• *method of harvesting*	selective	selective and total
• *harvest size*	>28.9 mm	
• *gear*	kor harvester	hand picking
• *packing and transport*	packed into jute bags and transported by truck	
• *live vs. dead*	live	

	Practicing country	
	Malaysia	Viet Nam
Marketing and economics		
• *consumption (home or local, export market)*	local and export	20% home, 40% local, 40% export
• *production cost*		
• *capital outlay*		
• *net profit*		
• *return-on-investment*		
• *yield*		30-35 tons/ha/crop for *Meretrix* after 9-12 months 10-14 tons/ha/crop for *Arca* after 9-12 months

I. CAGE CULTURE (MUD CRAB)	Practicing country Viet Nam
Site selection criteria	
• *water quality* (salinity, temperature, D.O.)	10-30 ppt, 26-30°C, 3.5-5 ppm
• *soil quality*	
• *tidal regime-range, depth*	
• *protection*	
• *pollution*	
• *security*	
• *vegetation*	
• *peace and order situation*	
Design and construction	
• *dimension*	3 x 4 x 1.2 m
• *materials*	bamboo, wood, nylon net
• *land (mangroves) to water (pond) ratio*	
• *water body*	
Preparation	
• *drying of bottom*	
• *eradication of pests and predators*	

	Practicing country Viet Nam
• *tilling*	
• *fertilization*	
Water management	
• *frequency*	
• *volume*	
Stocking	
• *monoculture or polyculture*	
• *species*	*Scylla serrata*
• *stocking density*	10-25/m^2
• *stocking size*	25-40 g/pc
• *source of seed*	wild seed
Feeding	
• *type of feed*	
• *source of feed*	
• *feeding rate*	
• *preparation*	
• *method of feeding*	
Monitoring	
• *physico-chemical*	
• *security*	
• *stock sampling*	
Harvest and postharvest	
• *method of harvesting*	total
• *harvest size*	200-250 g/pc
• *gear*	
• *packing and transport*	
• *live vs. dead*	40-60% live, 60-40% dead
Marketing and economics	
• *consumption (home or local, export market)*	20% home or local, 80% export
• *production cost*	
• *capital outlay*	
• *net profit*	
• *return-on-investment*	
• *yield*	80-100 kg/cage

II. CAGE CULTURE (FISH)	Practicing country		
	Brunei Darussalam	Malaysia	Thailand
Site selection criteria			
• *water quality* (salinity, temperature, D.O.)	25-28 ppt, 30°C, 5-6 ppm	10-30 ppt, 28-32°C, >4 ppm, current <0.5 m/sec	
• *soil quality*	muddy		
• *tidal regime-range, depth*	15 m	1-2 m, depth >3 m or twice the depth of cage	2-3 m
• *protection*	inside the bay	sheltered / protected bay/ lagoon	net
• *pollution*	oil from bay, rubbish, sewage detergents	free	in channel
• *security*	slightly ok		
• *vegetation*	mangrove		
• *peace and order situation*			
Design and construction			
• *dimension*	5 x 5 x 2.5 m, 4 x 4 x 2.5 m, 2.5 x 2.5 x 2.5 m (nursery)	4 x 4 x 2 m, 3 x 3 x 2 m	3 x 3 x 2 m
• *materials*	polyethylene nets, hope drums	wooden platform with fiberglass coated styrofore float, polyethylene net	bamboo, pipe
• *land (mangroves) to water (pond) ratio*			
• *water body*			
Preparation			
• *drying of bottom*		net drying every 2 or 4 weeks	
• *eradication of pests and predators*		by drying the net	
• *tilling*			
• *fertilization*			
Water management			
• *frequency*			

	Practicing country		
	Brunei Darussalam	Malaysia	Thailand
• *volume*		100% if possible by arranging cage in two layers	
Stocking			
• *monoculture or polyculture*	monoculture	monoculture	monoculture
• *species*	seabass, carangids, snapper, grouper *(E. suillus)*	seabass, snapper, grouper	seabass, grouper *(E. malabaricus),* red snapper
• *stocking density*	10/m²	15-25/m² reduced to 10/m² (seabass, grouper)	
• *stocking size*	1.5-3.0 inches	2-3" seabass; 1-2" snapper; 3-4" grouper	
• *source of seed*	hatchery	seabass hatchery, imported egg and hatchery-nursed snapper, wild grouper	seabass hatchery, wild and hatchery grouper, wild snapper
Feeding			
• *type of feed*	trashfish and pellets	90% trash fish, feed pellets	trashfish
• *source of feed*	trawlers and imports	trawler by-catch	natural
• *feeding rate*	3 times	once or twice a day	5-10%/day
• *preparation*	chopping	hand chopping, machine grinding	mincing, cutting
• *method of feeding*	by hand	by hand	
Monitoring			
• *physico-chemical*	D.O., salinity, temperature, nitrate/nitrite	check net fouling	
• *security*			
• *stock sampling*	once a week	stock grading every 2 weeks	
Harvest and postharvest			
• *method of harvesting*	selective	total/cage	selective (live fish)
• *harvest size*	600-800 g	500-800 g	0.6 - 1.2 kg

	Practicing country		
	Brunei Darussalam	Malaysia	Thailand
• *gear*	scoop net, container		net
• *packing and transport*	boat to shore, cold ice	by boat	contain in small box with aeration
• *live vs. dead*	both (live and dead)	live	both (live and dead)
Marketing and economics			
• *consumption (home or local, export market)*	local market		70% local, 30% export
• *production cost*	$9.00		RM 8.00
• *capital outlay*	$60,000		depending on size (e.g., at 150 cages costs US$120,000)
• *net profit*	$1,000-2,000 a month		
• *return-on-investment*	33%		
• *yield*			

Workshop recommendations

I. For problems associated with mangroves

MORE RESEARCH WORK ON THESE AREAS:

- biodiversity: biomass, mangrovetum / gardening, mortality, tree density for optimal detrital production, cost-benefit analysis or valuation
- zonation of mangroves: carrying capacity studies
- silviculture practices: pruning and thinning, appropriate spacing between trees
- management for sustainability

FOR POLICY ENFORCEMENT:

- reversion of abandoned/underdeveloped ponds for aquasilviculture
- rehabilitation: financial / technical guidelines and support

II. For problems associated with aquaculture practices

MORE RESEARCH WORK, SCIENTIFIC EXCHANGE ON:

- shortage of seed supply from the wild, spawner quality, fry quality
- management aspects: optimum stocking density for crab culture in canals in mangrove areas, feeds and feeding, water quality management (drainage and sedimentation), diseases and disease outbreaks (fast diagnostic tests), farm pollution
- engineering aspects: farm layout, design and construction
- refinement of appropriate / promising technologies for possible funding / loans from banks
- ecological footprint or the support area needed for mangrove-friendly aquaculture

MORE TRAINING AND EXTENSION PROGRAMS, COLLABORATIVE WORK WITH NON-GOVERNMENT ORGANIZATIONS, AND INFORMATION DISSEMINATION ON:

- economic viability of mangrove-friendly aquaculture practices
- non-acceptance of technology, lack of awareness and knowledge, if not misinformation

III. For socio-economic and cultural issues

FOR POLICY ENFORCEMENT:

- property rights: ownership, informal use rights, access, tenurial rights, equal opportunity use, conflict over potential areas for aquaculture, financial constraints, poaching, tree farm leasehold
- other legal issues

CO-MANAGEMENT REGIMES / COMMUNITY-BASED APPROACH / COMPLEMENTARY LIVELIHOOD /

- integrated / overall development of an area must include all sectors
- gender issues

SCIENTIFIC EXCHANGE

- regional cooperation, institutional development

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The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 to promote fisheries development in the region. Its Member Countries are Japan. Malaysia, the Philippines, Singapore. Thailand. Brunei Darussalam, and the Socialist Republic of Viet Nam. Representing the Member Countries is the Council of Directors, the policy-making body of SEAFDEC. The chief administrator of SEAFDEC is the Secretary-General whose office, the Secretariat, is based in Bangkok, Thailand.

Created to develop fishery potentials in the region in response to the global food crises, SEAFDEC undertakes research on appropriate fishery technologies, trains fisheries and aquaculture technicians, and disseminates fisheries and aquaculture information. Four departments were established to pursue the objectives of SEAFDEC.

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- The **Aquaculture Department** (AQD) in Tigbauan, Iloilo. Philippines, established in July 1973 for aquaculture research and development
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