

# **Malaysia: Mangrove-friendly aquaculture**

**CHOO POH SZE**

Aquatic Ecology Section  
Fisheries Research Institute  
11960 Batu Maung  
Penang, Malaysia  
[<chopol@dof.moa.my>](mailto:<chopol@dof.moa.my>)

and

**RAIHAN SH. HJ. AHMAD**

Department of Fisheries  
Jin. S. Salahuddin  
50628 Kuala Lumpur  
Malaysia  
[<raiahm01@dof.moa.my>](mailto:<raiahm01@dof.moa.my>)

## **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
<b>TOTAL</b>			<b>5,670</b>

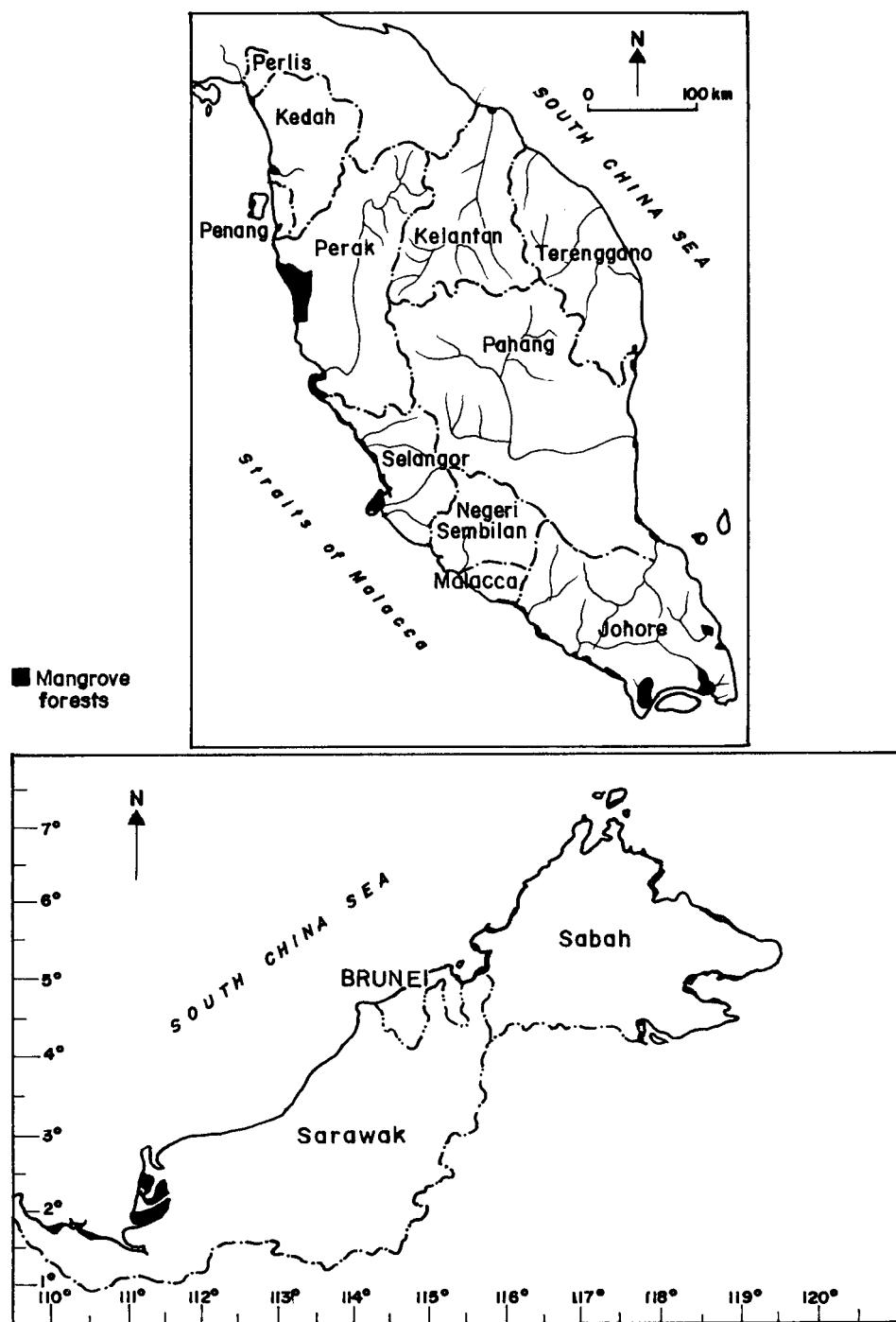


Figure 1. Distribution of mangrove areas in Malaysia

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
<b>Total</b>	<b>440,400</b>	<b>200,794</b>	<b>641,194</b>

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 (*Eonycteris 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 zibethinus*), and survive on the nectar of *Sonneratia* flowers when durian are not flowering. Reptiles reported include the crocodile (*Crocodylus porosus*), the pit vipers (*Trimeresurus pupureomaculatus* 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	-68.0
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 Foresty Act 1984 (amended 1993). Other relevant legislation 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<sup>2</sup>) 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 initiated 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<sup>2</sup>. The seaweed *Gracilaria changii* was cultured in racks. A total of 12 racks were spread over 10 m<sup>2</sup> of the pond area, and the seaweed was planted at a density of 1 kg/m<sup>2</sup>. 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 afforestation 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 inconsistencies 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

## References

- Annual Fisheries Statistics (1983-1995). Department of Fisheries, Ministry of Agriculture, Malaysia, Kuala Lumpur, Malaysia
- Chang WWS. 1997. Pen culture of mudcrabs in the mangrove ecosystems in Sarawak (East Malaysia). *Aquaculture Asia*, October-December 1997, p 3-5
- Chong VC. 1996. The prawn-mangrove connection - fact or fallacy? p 3-20. In: Suzuki M, Hayase S and Kawahara S (eds). 1996. Sustainable utilization of coastal ecosystems. Proceedings of the Seminar on sustainable utilization of coastal ecosystems for agriculture, forestry and fisheries in developing regions. JIRCAS Working Report No. 4, 87 p. JIRCAS, Ministry of Agriculture, Forestry and Fisheries
- Choo PS. 1996a. The utilization of mangrove areas for aquaculture - can it be sustainable? Bil. 196. Kertas Pengembangan Perikanan. Bahagian Pengembangan Jabatan Perikanan Malaysia, 50628 Kuala Lumpur
- Choo PS. 1996b. Aquaculture development in the mangrove, p 63-71. In: Suzuki M, Hayase S and Kawahara S (eds). 1996. Sustainable utilization of coastal ecosystems. Proceedings of the Seminar on sustainable utilization of coastal ecosystems for agriculture, forestry and fisheries in developing regions. JIRCAS Working Report No. 4, 87 p. JIRCAS, Ministry of Agriculture, Forestry and Fisheries
- Chua TE, James NP and Flodelizy YG. 1989. The environmental impact of aquaculture and the effects of pollution on coastal aquaculture development in Southeast Asia. *Marine Pollution Bulletin* 20 (7): 335-343
- Folke C and Kautsky N. 1989. The role of ecosystems for a sustainable development of aquaculture. *Ambio* 18: 234-243
- Folke C and Kautsky N. 1992. Aquaculture with its environment: Prospects for sustainability. *Ocean and Coastal Management* 17, p 5-24
- Gan BK. 1995. A working plan for the mangrove forest reserve Perak (Fourth Revision), p 214. The State Forestry Department of Perak Darul Ridzuan, Malaysia
- MCRST. 1992. The coastal resources management plan for South Johore, Malaysia. Malaysian coastal resources study team. Ministry of Science, Technology and the Environment, Malaysia. ICLARM Tech. Rep. 33, 291 p
- NATMANCOM. 1986. Guidelines on the use of the mangrove ecosystem for brackishwater aquaculture in Malaysia. Ministry of Science, Technology and the Environment, Kuala Lumpur, Malaysia
- NATMANCOM. 1996. Strategic paper for a national R&D programme on mangrove ecosystems in Malaysia. The working group to the Malaysian National Mangrove Committee and the National Council for Scientific Research and Development. Ministry of Science, Technology and the Environment, Kuala Lumpur, Malaysia
- Nisbet ICT. 1968. The utilization of mangroves by Malaysian birds. *Ibis* 110: 348-357
- Ong JE and Gong WK. 1991. Mangroves. In: Kiew R (ed). The state of nature conservation in Malaysia. Malayan Nature Society, 238 p
- Ong JE. 1995. The ecology of mangrove conservation and management. In: Wong YS and Tam NYF (eds). Asia-Pacific Symposium on Mangrove Ecosystems. *Hydrobiologia* 295: 343-351

- Robadue D Jr. (editor and translator). 1995. Eight years in Ecuador: the road to integrated coastal management. Coastal Resources Center, University of Rhode Island, 319 p
- Saenger PE, Hegerl J and Davie JDS. 1983. Global status of mangrove ecosystems. Commission on ecology papers no. 3. Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources Environmentalists 3: 1-88
- Salleh MN and Chan HT. 1988. Mangrove forest in Peninsular Malaysia: An unappreciated resources. Paper presented at the ENSEARCH seminar on marine environment: challenges and opportunities; March 31 - April 2, 1988; Kuala Lumpur
- Sasekumar A. 1980. The present state of mangrove ecosystems in Southeast Asia and the impact of pollution: Malaysia. SCS/80/WP/94b. South China Sea Fisheries Development and Coordinating Programme, Manila, Philippines
- Sasekumar A and Chong VC. 1987. Mangroves & prawns: further perspectives. Proceedings of the 10th Annual Seminar of the Malaysian Society of Marine Sciences, p 10-22
- Sasekumar A, Chong VC, Leh MU and d'Cruz R. 1992. Mangroves as a habitat for fish and prawns. *Hydrobiologia* 247: 195-207
- Sasekumar A, Chong VC, Lim KH and Singh HR. 1994. The fish community of Matang mangrove waters, Malaysia. In: Sudara SC, Wilkinson R and Chou LM (eds). Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2: Research Papers. Chulalongkorn University, Bangkok, Thailand