Retaining our mangrove greenbelt:
Integrating mangroves and aquaculture

by Jurgenne Primavera

Introduction

For centuries, mangrove systems have contributed significantly to the well being of coastal communities through their provision of a wide array of goods from forestry (wood used for fuel, construction, and fishing poles, and forage for livestock, honey, and medicines) as well as from fisheries (higher-valued fish, crustaceans and molluscs) which they significantly fortify. But mangroves do not stop at being providers of essential goods; they also offer many ecosystem services including coastal protection provided by a buffer zone during typhoons and storm surges, reduction of shoreline and riverbank erosion, flood control, nutrient recycling and habitat for wildlife.

Mangroves cover around 18 million ha world-wide, of which 6.3 million ha, or a third, is found in Southeast Asia. The largest expanse of it, about 4.5 million ha, is found in Indonesia, where the earliest brackishwater culture ponds can be traced.

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Multilateral agencies, through their external development assistance to aquaculture, have long been promoting that mangroves, and other wetlands, are wastelands to be put into better use such as conversion to ponds. Although conversion to salt beds, agriculture, settlements, and overexploitation by coastal dwellers have caused mangrove decline, aquaculture remains the major causative factor, at least in Southeast Asia.

The high rates of mangrove loss in the region over the last three decades, ranging from 25 to 80% of total areas have coincided with the Shrimp Fever of the

1980s. Clearing of mangrove for shrimp farming have been reported throughout the region as the main cause for mangrove degradation. Given the ecological and socio-economic importance of the mangrove ecosystem, it has become clear that aquaculture needs to be more mangrove-friendly to be sustainable. Already, the culture of seaweeds, molluscs and fish in cages in subtidal mangroves is both compatible with mangroves and amenable to small-scale, family-level operations.

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But, there remains a need for Mangrove-Friendly Aquaculture (MFA) technology in the intertidal forest, or swamp, which does not require clearing of the trees. MFA may be defined on two levels:

1. Silvofisheries or aqua silviculture, where the low-density culture of crabs, shrimp and fish is integrated with mangroves, and
2. Mangrove filters where mangrove forests are used to absorb the excess nutrients in the effluents from high-density culture ponds.

This review aims to evaluate existing MFA practices belonging to the first category although pioneering research on the use of natural or constructed mangrove wetlands to treat pond effluents holds much promise towards making aquaculture sustainable. Discussion shall be on a country basis, moving from traditional systems in Indonesia, to the introduced technologies in Indonesia, Vietnam, the Philippines and Malaysia. It is hoped that such a review will be useful to scientists, aquaculturists, policy makers, and government/non-government organisations interested in making aquaculture more ecologically sound and socially responsible.

Mangrove-friendly aquaculture: a great regional variety

Among five Mangrove-Friendly Aquaculture (MFA) systems in four Southeast Asian countries, the traditional Indonesian tambak is decades to centuries-old technology, while the rest – silvofisheries in Indonesia, mixed shrimp-mangrove systems in Vietnam, and aquasilviculture ponds and mangrove pens in the Philippines and Malaysia – are more recent state-initiated projects. Indonesian traditional tambak and silvofisheries ponds as well as Vietnamese shrimp-mangrove farms are widespread over thousands of hectares whereas MFA systems in the Philippines and Malaysia are still at the verification and early dissemination stages.

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Both Indonesian silvofisheries and Vietnamese mixed systems were established by the state primarily to relieve land use conflict between forestry and fisheries, unlike the other MFA systems, which were developed to provide food and income through fish, shrimp and crab production, and to rehabilitate/ conserve mangroves.

Variety in designing…

Ponds are the predominant MFA system featuring gates, elevated dikes, and excavated channels which alter mangrove hydrology and ecosystem functions in the process. By contrast, pens in mangrove areas only require enclosures made of net or bamboo, and have minimal impact on mangrove hydrodynamics and vegetation.

The silvofisheries pond system itself has two models - with mangrove trees either growing inside (mixed), or separately from, the watered area (pond). The mixed system is difficult to manage because the mangrove trees and cultured fish may have conflicting requirements (e.g., shallow vs. deeper water). Management of the separated pond-mangrove system is easier, but it is more vulnerable to illegal pond expansion in the mangrove area.

Variety in operating…

Most MFA ponds rely on wild fish or shrimp fry that enter with the tide. Pond systems in Indonesia (traditional and silvofisheries), and in the Philippines, also depend on stocked seed of tilapia, milkfish and mud crab. Feasible with two-species combinations, polyculture becomes more difficult as species are added. Only mud crabs *Scylla spp*. are stocked in mangrove pens in the Philippines and Malaysia.

MFA systems with wild (tidal) fish/shrimp, and milkfish stocked at low densities rely on natural food; supplementary feeds (e.g., pellets and raw fish) are given to stocked omnivorous and carnivorous species like tilapia and mud crab. Aquaculture production of <500 kg/ha/yr, in ponds dependent on natural food, is characteristic of extensive systems; yields increase to 1-3 t/ha/yr when feeding is provided in the more intensive systems.

Apart from the unsustainable use of raw (trash) fish that may be consumed by local people, mud crab culture in pens is the most financially lucrative and environment-friendly among MFA systems, because of minimal impacts on the mangrove habitat. However, continued dependence on natural seedstock may impact negatively on wild crab fisheries.

Indonesia: the traditional tambak

The beginnings of brackishwater pond culture in Asia may be traced in East Java in Indonesia. As has been stated, Javanese law codified in 1400AD already described punishment for stealing fish from a tambak or saltwater pond. In Indonesia, extensive pond culture integrates mangroves in either the ages-old traditional system, or through the more recent government-initiated silvofisheries programs.

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A good example of the former can be found in the Solo-Brantas delta of East Java, and other regions in Indonesia, where tidal wetlands are formed by the complex of ponds which retain mangroves on dikes, as strips between ponds, or in remnant patches inside ponds. Individual ponds are usually 1- 4 ha in size, and ecologically similar to tidal lakes. This significant landscape has been reported to provide wildlife habitat, contribute aesthetic and amenity values, and enhance the living environment of human settlements.

Indonesia: introducing silvofisheries

While tambak are integrating mangroves into the system, their unregulated development could still negatively affect mangrove integrity. This became clear in the 1970s, when mangrove lands under the State Forestry Corporation (Perum Perhutani) have been progressively and illegally transformed into culture ponds. To reduce potential conflicts between excessive tambak development and mangrove conservation, the Corporation initiated a Social Forestry Program in 1976 that integrated fish production and forest management.

Indonesia's Tambak – Traditionally integrating mangrove and fish culture

Mangroves are planted on pond dikes and adjacent tidal flats to stabilise dikes, reclaim land for future tambak construction, provide green manure as fertiliser to stimulate natural food (plankton) production, and provide fuel for smoking fish and industrial use. Mangrove patches mainly of *Avicennia* are also left on islands inside ponds because of added costs for clearing.

The primary species of mangroves planted on dikes are *Avicennia marina* and *Rhizophora mucronata*, followed by *Excoecaria agallocha* and *Xylocalpus moluccensis*. Other plant species are grown for fruits (papaya, banana), fodder (*Leucaena*) and amenities (*Hibiscus*). Where green manure is wanted, *A. marina* is planted and harvested by cutting the lateral branches (for fuel wood) and using the leaves as green manure (preferred because they lack tannin, unlike *Rhizophora*), and allowed to regenerate for a few seasons. In other places, where building materials (e.g., tree poles) are more important, *R. mucronata* is planted, harvested when the trunks reach 5-10 cm in diameter, by cutting down the whole tree and replanted, since the species of the family *Rhizophoraceae* cannot regenerate branches.

Cost-benefit and other financial analysis have shown that a land-use pattern of 1 tambak to 1 mangrove ratio works well .The traditional ponds may be managed by the tambak operator himself, or by a hired supervisor/ employee. During final harvest, the mberi (a customary system of dividing wealth) is practised, whereby neighbouring communities participate, and also receive production shares from the harvest.

Silvofisheries in Indonesia: future directions to explore

Further research is needed on rates of litter production and decomposition of different mangrove species to support maximum pond productivity, and on stocking strategies for compatibility of aquatic species for polyculture. Pond design needs to be evaluated in terms of mangrove to water area ratio, water area to dike length ratio (reflecting potential production relative to construction costs), gate width (for entry of wild fry and flushing out mangrove debris), tidal flushing rate, etc. Finally, empang parit, or mixed silvofisheries projects, have been mostly successful on community or government-owned land, where capital costs for dike and gate construction have been subsidised by the state). Some farmers living on government land cannot avail of bank credit for improvements, and are therefore reluctant to maintain the trees. The separate, or alternate, mangrove/pond silvofisheries model is best suited to privately-owned land, because of superior management control and potential production; there would be little incentive for the land owner to plant back mangroves, as required in the mixed model.

The terms tambak tumpang sari (alternative purpose ponds), tambak empang parit (mixed-farming crop ponds), hutan tambak (forest canal pond system) and silvofisheries have been applied to this new system. But regardless of the terminology, there are two basic silvofisheries models defined, depending on whether mangroves are inside or separate from the ponds. Research, demonstration and promotion of these models have been undertaken by universities and national programs in the Ministry of Forestry and Directorate-General of Fisheries, exploring different ratios of mangrove to watered area and its impact on shrimp, crab and fish culture in terms of production and net profitability.

The benefits from silvofisheries include mangrove conservation, increased incomes from fish products, and food security. Nevertheless, when compared to open ponds, they are reported to be more difficult to manage, more expensive to construct, and have less efficient water circulation. Unless thinned properly, growing mangrove trees can also provide habitat for predatory birds and snakes, and shade out plankton and benthic algae, leading to decreased fish production. Moreover, tannic acid in *Rhizophora* leaves is potentially toxic to aquatic organisms – shrimp silvofisheries operations are even reported not to be profitable if *Rhizophora* are planted inside ponds, because of low survival of black tiger shrimp under these conditions. The preference of the State Forestry Corp. for the genus *Rhizophora* (due to convenience in planting and resistance to inundation inside fishponds) may be a source of tension with local people who prefer *Avicennia*. The branches of the latter can be harvested (for firewood) without disturbing fish inside the ponds while the leaves can increase pond fertility, and regulate pH during the rainy season.

Without its protective mangrove belt, the coast is open typhoons, storm surges, or to riverbank erosion such as here in Aklan, Philippines

Some also observe that conservation and biodiversity are not enhanced in silvofisheries, because of monoculture mangrove planting, and the effects on wildlife of pesticide used to eradicate unwanted fish. Moreover, mangroves planted high in the intertidal or landward zone, beyond the reach of ordinary high tides, also show abnormal growth and high mortality.

Vietnam: integrated shrimp-mangrove farming systems

In the late 1980s, illegal mass migration to build shrimp ponds in the southern provinces in Vietnam, such as in Minh Hai, which resulted in the destruction of many mangrove areas. To relieve the ensuing land use conflict, the State Fishery and Forestry Enterprises (SFFE) promoted integrated shrimp-mangrove farming systems that would allow shrimp culture as food and cash crop while rehabilitating mangroves. Each household was allocated an area of 4-8 ha, of which 70% is reserved for mangrove forest, 20% for ponds, and 10% for housing. The SFFE provides capital for felling of miscellaneous trees and planting of *Rhizophora* while the farmer contributes labour and money for excavating canals and building dikes. *Rhizophora* are initially densely planted and are subsequently thinned by 20-30% every 5 years, until completely harvested after 20 years. Economic analysis of ponds with different levels of mangrove forest gave the highest returns with medium mangroves density (30-50%) and the lowest returns when all mangroves were cleared. Nevertheless, many farms have expanded the shrimp ponds up to 80% of total farm area, because of higher financial returns from shrimp in the short term.

In another province, Ca Mau, two kinds of farms are known: mixed and separated. In both systems, individual ponds consist of long (250-800 m), narrow (3-4 m), and shallow (about half a meter) channels parallel to each other. These farms culture shrimp on a very extensive manner, stocking low density of wild larvae and having low production yields. In mixed farms, these channels are dug through the mangroves so that dikes or levees are vegetated, but often the excavated soil from the canals is dumped onto the vegetated flats, resulting in poor growth of mangroves due to their increased elevation and less tidal flushing. In separated systems, the mangroves are usually grown on an area next to the pond and the levees are bare of vegetation. Nowadays, production in these farms is often reported to be too low, sometime due to too dense mangrove cover, but often linked with issues of poor pond design or inadequate management of the tidal flow.

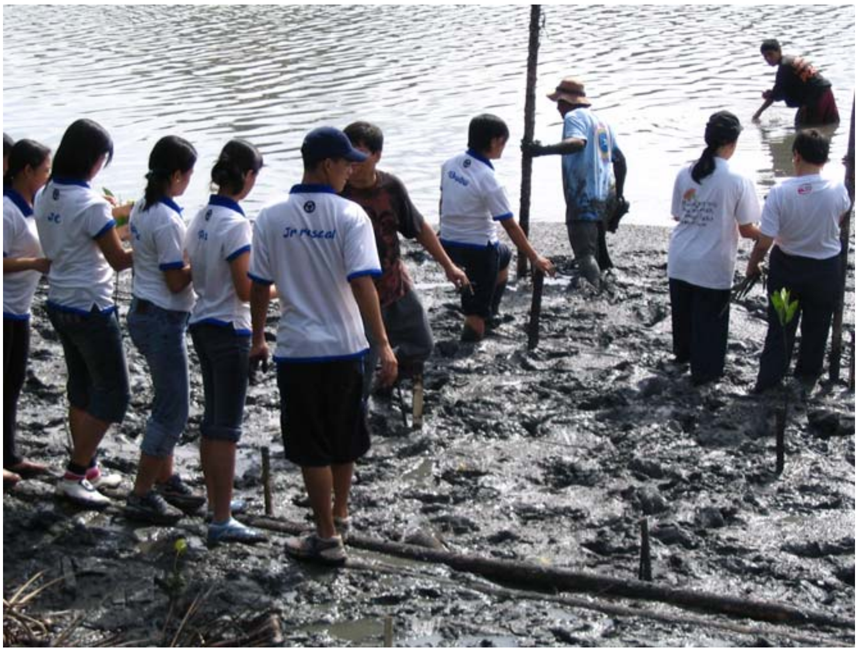
Philippines: aquasiviculture

In the Philippines, mangrove-friendly aquaculture has not gone beyond the verification and demonstration of integrated mangrove ponds, and pens for fish and crabs. These include projects of the Bureau of Fisheries and Aquatic Resources (BFAR), the Ecosystems Research Development Bureau of the Department of Environment, and the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC AQD) in the provinces of Quezon, Mindoro Oriental, Palawan, Bohol and Aklan.

Established in 1987, and patterned after Indonesian silvofisheries, the BFAR project in Ubay, Bohol, features 1.6 to 2.6 ha ponds, with 80% area planted to *Rhizophora* mangroves. In the first five years, stocked milkfish were harvested at 1 t/ha/yr. Subsequently there has been free entry of wild fish (siganids, mullets, tilapia, tenpounder, tarpon, snappers, groupers, barracuda), crustaceans (shrimps, blue crabs), and molluscs (oyster, clams, snails). Wild ducks, and other birds, also use the area as a sanctuary. Problems encountered include difficulty in assessing and harvesting fish stocks due to the mangrove prop roots, death of mangroves caused by prolonged flooding, and overgrowth of filamentous algae killing fish.

In Puerto Galera, Mindoro Oriental, a mangrove area was converted to one ha aquasilviculture ponds with the central portion (80% of total pond area) planted with nipa palm, *Nypa fruticans*, because of its higher economic value as a source of shingles for housing material. Fish production in the canals was high, at a rate above 3 t/ha/yr for both tilapia and milkfish, giving when combined with nipa shingles, good returns. Fruit crops (banana, pineapple, and jackfruit) and vegetables (tomato, beans) planted along the dikes even further added to income.

AQD has initiated research and verification trials on mud crab *Scylla spp*. culture in mangrove pens and ponds in Aklan and Palawan. Mangrove pens range from 200 m^2 to one ha in size with 20-30% of the pen area occupied by half a meter deep canals to retain water during low tide. Mud crab production and profitability are good and gives a 60-90% return on investment according to the pen size, with smaller pen showing more profitable. Nevertheless, tree damage from prolonged inundation of *Avicennia pneumatophores*, due to altered hydrology and unintentional cutting of roots, has been observed. The feeding of raw (trash) fish to crabs is also problematic, because some local people consume such fish, which therefore could be put into a better use.



Replanting mangroves trees, here in Iloilo, Philippines

Malaysia: mudcrab pen culture

In 1992, pen culture of the mud crab species *Scylla olivacea* and *S. tranquebarica* was introduced by the Inland Fisheries Division of the Department of Agriculture to logged-over mangrove areas in Sematan, Sarawak, and to increase the income of artisanal fishermen. Small pens of less than 200m^2 were constructed using trunks of the nibong palm *Oncosperma tigillarum*; a 2.4 m high fence keeps predators out, and cultured crabs in. Small perimeter drains or canals are always filled with water. Existing mangroves in the pens are left intact and bare areas are planted, mainly to *Rhizophora*. Crabs are stocked at relatively low densities to avoid high mortality and are fed raw fish, yielding enough to ensure acceptable revenue to the farmers. Following the success of the initial experiments, the number of pens rapidly increased in Sematan, and other districts in Sarawak .The high proportion of young crabs caught in the Sematan mangroves, despite the large number used for stocking suggests that considerable recruitment is contributed by the pens. However, problems of shortage of crab seed and non-availability of feed (low-value fish) during the rainy season have been reported.

Conclusions

The "mangrove-friendliness" of different MFA systems can be evaluated in terms of how they affect the basic resource and regulatory functions of the mangrove ecosystem. Usually, species diversity of both mangrove flora and fauna is lower inside mangrove ponds compared to adjacent natural mangroves and open waters. However, high mangrove species diversity can be retained in pens.

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MFA systems have lower plant and animal species diversity, because focus has been shifted to the production of selected species (shrimp, milkfish, *Rhizophora*), at the expense of natural food webs and the onsite and offshore fisheries productivity they support. Natural mangrove vegetation is only fully retained in traditional systems such as the Indonesian tambak, but mangrove seedlings are planted in Indonesian silvofisheries ponds and in the shrimp-mangrove farms in Vietnam.

The regulatory functions of coastal protection, erosion control, flood regulation, and nutrient recycling are not jeopardised by this loss of diversity, so long as an adequate mangrove greenbelt is retained along shorelines and riverbanks.

This underlines a need for further research on appropriate mangrove and fish species for stocking and on an adequate mangrove to pond ratio, but also on an improved pond design and management to refine the major MFA systems which in the region have been mostly state-, rather than technology-driven.

About the author

J. H. Primavera, Ph.D., is a mangrove specialist and a researcher in the Southeast Asian Fisheries Development Center in the Philippines. Her work demonstrates that protecting mangroves can save lives and property from destructive typhoons, filter out silt runoff that kills coral reefs, provide nurseries to juvenile fish and shrimp, and renew fisheries catches. She has been awarded a Pew Fellowships in Marine Conservation for 2005 based on her outstanding work on mangroves.