MANGROVES AND THEIR UTILIZATION FOR AQUACULTURE*

DR. HERMINIO R. RABANAL
FAO/UNDP South China Sea Fisheries Development
and Coordinating Programme
Manila, Philippines

INTRODUCTION

In general, coastal aquaculture projects established within the circumtropical zones between 35°N latitude and 35°S latitude have either been built out of mangroves, were previous mangrove site, or areas that developed into mangroves. Available statistics which are rough estimates and likely to be incomplete show that about ½ of the world area now devoted to aquaculture or about one million ha (Table 1) producing about one million metric tons of fishery products annually are at present being derived from these projects. These consist of various species of finfish, crustaceans, mollusks and seaweeds. Some of the more prominent species include: *Chanos chanos* (milkfish), *Mugil cephalus* (mullet), *Siganus* spp. (rabbit fish), *Lates calcarifer* (sea bass), *Epinephelus* spp. (groupers), *Oxyeleotris marmoratus* (marble goby), *Tilapia* spp., *Penaeus* spp. (shrimps), *Scylla serrata* (mangrove crab), *Crassostrea* spp. (oysters), *Meretrix* spp. (clams), *Anadara granosa* (cockles), *Mytilus* spp. (mussels), and *Porphyra* sp., *Undaria* sp., *Gracilaria* sp. and *Eucheuma* spp., (seaweeds). These various species are raised in impoundments or ponds, net enclosures or cages, and/or managed open spaces of tidal flats.

The potential for increased production of high quality human food from this type of environment is still very high. The available but incomplete estimate on the extent of worldwide mangrove areas show an aggregate area of about 7.5 million ha (Table 1). If these were added to the area of tidal flats, the aggregate can exceed 10 million. These are mainly in the Indo-Pacific region but extensive areas also

---

* Presented at the National Workshop on Mangrove Ecology held at Phuket, Thailand, 10-16 January 1976.

occur in the African countries and the islands of the Pacific. Some percentage of these areas estimated at 30-50 percent or equivalent to one to five million ha may be suitable and available for development as sites for aquaculture production; and their development may augment production by two to 10 million metric tons of valuable fishery products.

This paper will examine the existing methods used for this type of development; their possible ecological impact to the environment, and find ways of adopting the techniques so that existing ecological balance could be preserved thus, avoiding detrimental environmental consequences. The following discussions will deal mainly on aquaculture utilizing ponds.

ECOLOGICAL CONSIDERATIONS IN SELECTING SITES FOR DEVELOPMENT

Proper selection of sites suitable for aquaculture production in mangrove areas determines to a large degree the future success of these projects. In making this choice, the ecological characteristics of a particular site should be fully considered. These include the water supply, soil, land elevation, vegetation, extent and nature of watershed and climatic and hydrological factors.

Water Supply

Continued year-round availability of water supply with the right quality is basic to the success of an aquaculture project in mangroves. In this case, projects depend mainly on the water brought in and drained by tidal fluctuation in a particular site. Although this supply should be adequate, its amount should not fluctuate radically nor at a very high range to avoid flooding. It should also be free from excessive turbidities and/or sources of possible pollution.

In general, mangrove sites are affected by both the saline sea water and land-based fresh water draining through a tidal stream or river and are therefore usually brackish. Though fluctuations of salinity is tolerable for most cultivable species, such fluctuations should not be too wide or abrupt to enable the cultivated species to adapt to changing conditions.

1. Importance of tide

Coastal tidal areas vary in their tidal characteristics both in magnitude and frequency of fluctuations. Sites with very narrow tidal range or those with one to two m annual absolute range and normal daily range of less than one meter would offer an unfavorable situation for water control and management of impounded aquaculture projects. In this case, flooding or draining the project when needed would be difficult unless water pumps are used and this would increase the expenses required for operation. The northwest coast of Luzon (Philippines), east coast of Madagascar, southeast coast of Thailand, northeast coast of Irian Jaya, northwest coast of Java, and South Sulawesi (Indonesia) are of this tidal characteristic. Likewise, many areas in the Caribbean also have daily tides that are less than ½ meter. This latter place also has the problem that the mean tide level in October is 30 cm above that in March. On the other hand, there are certain areas with very high tidal fluctuations of four to five m annual absolute range and three to four m normal daily range. Sites built under this situation would run the danger of overflooding with very deep water during high tide or complete drainage during low tide and massive leak-proof dikes would be required to fend off this possible flooding or drying. Areas with this tidal characteristics include the southeastern coast of Irian Jaya, Riau and southern part of North Sumatra provinces (Indonesia) and northwest coast of Madagascar.

Present technological experience indicates that areas with moderate tidal characteristics or those with absolute annual range of two to three m and normal daily range of one to two m would be ideal and conducive to desirable water management for aquaculture projects. Fortunately many coastal mangrove areas possess this type of tidal characteristic (Figure 1).

2. Water quality

Water supply brought in by incoming tide and the normal drainage from tidal rivers are generally of good quality. These are clean, clear and devoid of noxious substances. Some peculiar nature of the water sources or man-made changes of the environment may however result in radical changes of water quality for aquaculture in these areas. Heavy population pressure resulting in domestic pollution from sewage, modification of the watershed through public development works (road construction; harbor works, etc.) or building of industrial plants in the area may result in poor water quality and eventual abandonment of such areas for aquaculture projects. The abandonment of some 200 ha ponds specialized for milkfish nurseries in Malabon and Navotas towns, Rizal province, Luzon island, Philippines, due to effluents from small industries, population pressure, and silting is a case in point.

Land elevation and topography

Mangrove lands vary in elevation and topography. These may vary from elevations that are continually below water level at all tides to those that are usually dry land except during extreme high tides of the year or during a combined high tide water and floods resulting from heavy precipitation in the watershed. For a mangrove of good tidal fluctuation (two-three m) the ideal elevation of the land suitable for development for aquaculture should be those sites that are above the lower low tides but below the higher tides of the year (Figure 1).

Mangroves are usually level tidal flats but in some cases uneven topography may be encountered. In the latter case some levelling will be required. Due to the expense involved and the possible effect of using less fertile subsurface soil due to excavations during levelling, flatlands of suitable elevation would be preferable sites for aquaculture development.

Soil

Mangroves with predominantly clayey, clay, sandy clay, sandy clay-loam soils can be suitable sites for aquaculture. Those that are sandy or predominantly sandy or rocky soils are objectionable for use. Soil examination of sites, to be truly diagnostic should include both surface and sub-surface soil down to about one meter in depth.

Certain mangrove soils with very heavy deposits of organic matter consisting mainly of barks and roots of dead trees have been encountered. These are also difficult sites for aquaculture purpose. However, if the detritus were mainly from leaves, fertility seems to be enhanced (Mathias, 1974).

Vegetation

Areas heavily forested with big trees are difficult to develop. However, if the soil is good and the land elevation and tidal characteristics are favorable, such areas can gradually be developed for aquaculture projects.

Relatively clean areas or those with smaller mangrove trees would be easier to convert to aquaculture production.

Watershed and flooding

Before developing a mangrove area for aquaculture, the extent and nature of watershed areas should be investigated. Very extensive upland watersheds using the lower mangroves as drainage basin will likely cause frequent flooding of developed projects specially if the prevailing climatic condition in the region is characterized by heavy annual rainfall. However, if the drainage basin is sufficiently extensive, appropriate allowance to permit drainage of flood waters during the rainy period can be provided in the development of the project.

CLIMATOLOGICAL AND HYDROLOGICAL CONSIDERATIONS

Rainfall and temperature are important factors to consider. Rainfall characteristics vary in different areas. Moderate to heavy annual rainfall (1.5 to 5 m) may be distributed into rainy and dry period during a year. In some cases low annual precipitation (0.5-1.5 m) equally distributed throughout the year may prevail. In the first case, seasonal activities of drying and allowing the pond to fallow for growing fish food organisms and harvesting the fish stock have to be scheduled. In the latter case continuing management possibly utilizing pumps may be required.

Temperature extremes are usually not limiting in tropical aquaculture areas. In the extreme northern and southern ranges of mangrove areas however, protection of aquaculture species should be provided during the winter period. Cold weather affects certain species even in the tropics such as the postlarvae of the giant freshwater prawn which are affected by temperatures below 15°C.

Hydrology, salinity and pH may be important considerations. It is suspected that abrupt fluctuation of salinity during the heavy rainy period determine the survival of certain cultivated penaeid shrimps in ponds built along tidal streams affected by freshwater, but ponds that depend for their supply directly from seawater maintain high survival rates. Verification research on optimum levels of salinity for cultivable penaeid species will be needed.

The pH of water supply and the soil may be important in food growing, better use of fertilizer inputs and normal existence of the cultivated species. Slightly basic conditions are considered ideal but if low pH prevails in an area remedial management procedures, such as liming, may be required.

THE DESIGN AND MANAGEMENT OF AQUACULTURE PROJECTS

Design

It is best that aquafarms built from mangroves are constructed with the least possible disturbance on the natural state of the site. The existing tidal rivers or streams should be preserved and although some amount of straightening of their courses may be advantageous, liberal allowance of not less than 10 m should be made from the river bank to the main dikes. This is an arbitrary minimum which should be wider if the site is a flood drainage basin. The existing mangrove vegetation should be preserved in this buffer zone and no excavations should be made if the area is already of low elevation. Additional planting of the appropriate mangrove species should also be made. In this way the river or stream edge is conserved or even improved and should henceforth be managed to preserve or improve its ecological condition.

The same management practice should be done with regard to the buffer zones towards the seashore. In this case however, the allowance should be larger; 50 to 100 m is suggested. The administrative requirement of not less than 400 m in Indonesia is deemed too big for this purpose. By having this large allowance, there is a tendency to have the pond site at higher and unfavorable elevation of the mangrove area where the project is constructed. It has been the experience in the Philippines during the earlier period of pond development that very liberal allowance was also being made from the stream bank and seashore. Subsequently, with the need for more areas for expansion, the permanent structures like concrete gates or pipes were left as ugly structures behind the new dikes.

It would also be advisable to follow the general configuration of the river bank or seashore in building the perimeter dikes. In this case the maximum area which can be enclosed for ponds can be used. A practical pattern of layout planning and construction can be developed in the countries where brackish water fish farm industry has been developed. These countries are Indonesia, Philippines, and Taiwan.

First a site is selected, marked, and the path of the dikes fully cleaned and cleared. The main water control gates are built appropriate to the size of the farm. Then the enclosing or perimeter dikes which should be big and firm for the purpose should be built. Initially, the whole site enclosure is flooded with water of one-half to one meter deep, if possible. If this is not possible, attempt should at least be made to completely cover the whole area with water. By having a condition of stagnation for an extended period of one to three months or more, the leaves, fruits and small twigs of the mangrove trees will fall off.

The internal construction of the pond system may start after the trees have shed their leaves. Soil for diking can come from inside the pond system if the elevation of the site can still permit some excavation; otherwise such diking material should be transported from suitable places in the vicinity of the site. Internal diking can start first with the construction of the required water supply canals for the system. Such a canal should be treated like an external stream retaining the mangrove vegetation in it or putting additional plantings if necessary. In this way a line of trees which can serve as wind and wave brakes in case of large farm areas will be available within the farm. In large farms or those with total area of 100 ha or more (some units are as big as 2,000 ha) lines of suitable mangrove species may even be advisable at some strategic portion within the pond system for the above-stated purposes. Routine water management and pond operations in the pond system after the construction would allow growth and survival of mangrove trees inside the fish farm.

The water control structures (main, secondary, tertiary gates, and culverts and pipes) are very important features of coastal farm ponds. Firm, well-constructed main gates are usually of reinforced concrete with narrow opening (1.0-1.2 m wide) and with bottom down to as low as the lowest low tide in the area. From experience it has been found that one gate can service 10 ha so that if a farm is big, multiple opening gate at one strategic point in the farm or a number of gates at selected points along the perimeter dikes should be constructed.

The secondary water control structures can be of reinforced concrete, wooden sluice gates, culverts, or pipes.

In excavating pond soil within the farm site for diking or levelling during construction, attempt should be made to preserve or keep in the area the surface detritus-rich soil of the site. This will keep and enhance the inherent fertility of the area once construction is completed (Jamandre and Rabanal, 1975).

Complete clearing of individual pond compartments of trees including stumps and roots is considered advisable. If this cannot be done all at once, it is suggested that this be done in phases. Unsupervised partial or incomplete clearing often turns out to be very disadvantageous in future farm operation.

Management

Certain aspects of fish farm management which have ecological implication need mentioning.

Management of the water supply is an important aspect of brackishwater pond management. It is assumed that the layout and construction of the ponds allow independent and controllable water supply in the different pond compartments. Depth of water determine the type of natural food that will grow in the pond and the type of species to be reared (*Chanos* or *Penaeus,* etc.).

For intensive management, fertilization of the ponds and supplementary feeding of the cultivated stock can enhance production. Under certain conditions, liming may be required. Both inorganic fertilization and organic fertilization can prove advantageous depending on the soil and water conditions of the site. Management by maintaining a dynamic balance between the cultivated stock and the fertilizer and feed inputs can be learned through extended experience. Limited knowledge is at present available and more research will be needed on this subject.

Another factor for further study is pest control. Predators and competitors of the farmed species occur in brackishwater farms; diseases and parasites appear to be rare under present extensively managed farms, but these may increase with intensified operations. Pesticides are now being used to control snails and other bottom pests.

The stocking of brackishwater farm ponds, being greatly dependent on natural fertility of site are relatively low with subsequent

low production, about 300-400 kg/ha/year. Intensive farming operation using higher stocking rates, polyculture utilizing two or more species, and stock manipulation using different size groups for one cultivated species, have resulted in much higher production. This should of course be supported by additional inputs in fertilizers and feed and greater management effort. More research to standardize culture techniques will be required.

A management practice that is often neglected although it is necessary, involves the periodic draining and drying of farm ponds. This eradicates the predators and competitors and hastens the decomposition of bottom organic matter. Besides, a hard bottom is often essential for proper pond management and is needed during harvesting of the crop.

AQUACULTURE: A RATIONAL USE OF MANGROVES

There are many alternative uses of mangroves. Compared with other development uses, however, aquaculture appears to be the type of utilization that best preserves the ecological conditions of mangroves as a biologically-balanced environment. Properly designed and constructed aquaculture projects provide conserved buffer zones of say 10-30 percent of an entire site as untouched or even improved mangrove area. The provision of adequate drainage basin to prevent destructive floods may be accomplished if appropriate background data are utilized in the farm design.

An essential element in the rational use of mangroves through aquaculture is the proper selection of sites suitable for this purpose. It has been the experience in centers of coastal aquafarm development that a great proportion of existing mangrove areas are actually not suitable for this purpose for reasons of tide, land elevation, soil, etc. If only suitable sites were used, wide areas of mangroves will be spared from development into aquafarms. On the other hand, the development into aquafarms of unsuitable sites is destructive utilization and can result in failure.

Fertility of the environment and subsequently productivity and the production of the economic product, the object of culture, can be enhanced by proper aquafarm management. In this way the species of characteristic fauna and flora in mangrove areas are conserved.

Furthermore, if hatchery work is initiated as an added activity of the farm for the cultivated species, possible extinction of species due to other radical changes (pollution, land reclamation, etc.) can be prevented. Hatchery methods for mullet (*Mugil cephalus*) and penaeid shrimps have already been developed while studies on other aquaculture species are underway.

The production of an economic food crop from mangrove developed as aquaculture projects can be increased above natural production. This can be brought about through management and introduction of inputs. With ecologically-oriented farm design and proper management, aquafarms from mangroves can therefore be highly economic propositions (Lawas, *et al*, 1974). For instance, while natural fishery production from a natural mangrove area can vary from 200-400 kg/ha/year (enclosed mangrove area, no inputs), managed farm ponds (with fertilizers, feeds, other inputs) can produce 1,000 to 2,000 kg or a 500 to 1000 per cent increase in production.

BIBLIOGRAPHY

INDRAMBARYA, B. and N. SRIPLANG
1976 Distribution of littoral mudflats interpreted from the Earth Resources Technology Satellite imagery and their correlation with mangrove areas. Workshop on Mangrove Ecology, Phuket, Thailand

JAMANDRE, T.J., JR. and H.R. RABANAL
1975 Engineering aspects of brackish water aquaculture in the South China Sea region. Manila, FAO/UNDP SCSP/75/WP/16: 96 17 annexes

KIENER, A.
1972 Ecologie, biologie et possibilites de mise en valeur does mangroves malgaches. Ext. d. Bull. d. Madagascar, (308): 84

LAWAS, J.M. et al
1974 Economic study on alternative uses of mangrove swamps: bakawan production or fishponds. FAO/IPFC Proc. 15(II): 65-69

LING, S.W.
1973 Status, potential and development of coastal aquaculture in the countries bordering the South China Sea. Rome, FAO/UNDP/SCS/DEV/73/5: 51

MACNAE, W.
1974 Mangrove forests and fisheries. Rome, FAO/UNDP IOFC/DEV/74/34: 35

MATHIAS, J.A.
1974 The possible significance of leaf fall and decomposition in Malaysian mangrove swamps. MS submitted for IBP Synthesis Meeting. Kuala Lumpur, 12-18 August 1974. 12p

PILLAY, T.V.R.
1965 Investigations of the possibility of brackish water fish culture in the Niger delta. Rome, FAO/UNDP TA Rep. (1973): 55

PILLAY, T.V.R.
1973 The role of aquaculture in fishery development and management. J. Fish. Res. Board Canada. 30 (12): 2202-17

RABANAL, H.R.
1974 The potentials of aquaculture development in the Indo-Pacific region. South China Sea Fish. Dev. Coord. Prog., SCS/74/WP/1: 34

VIBULSRESTH, and C. KIETRUANGROJ
1976 Distribution of mangrove forests as revealed by the Earth Resources Technology Satellite (ERTS-1) imagery. Workshop on Mangrove Ecology, Phuket, Thailand

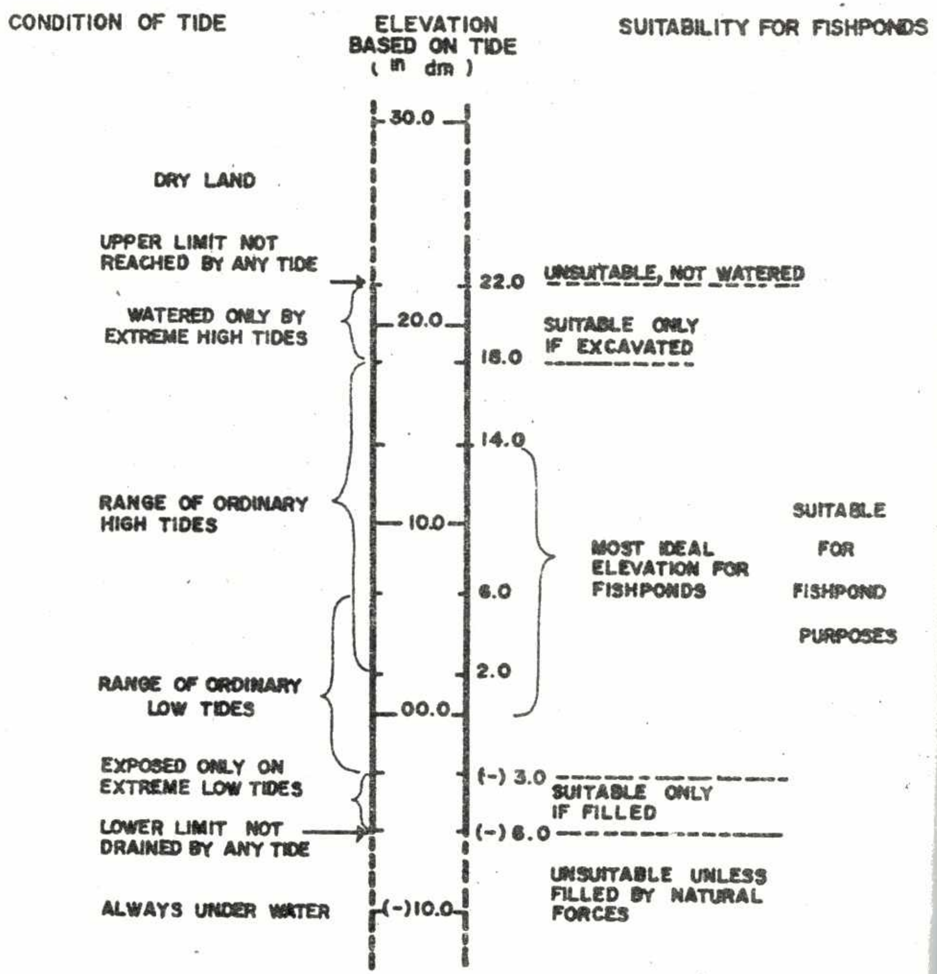

FIGURE 1

Determination of Suitability of Proposed Fishponds Sites Based on Tidal Water Supply as Affected by Elevation of the Area. (Applicable Under Philippine Conditions)

WORLD-WIDE ESTIMATE OF MANGROVES AND MANGROVE/TIDAL FLATS DEVELOPED AND POTENTIAL FOR AQUACULTURE a/

COUNTRY OR REGION	DEVELOPED AREAS (HA)	POTENTIAL (ESTIMATED AREAS OF MANGROVE AND TIDAL FLATS) (HA)	SOURCE OF INFORMATION
Andamans (part of India)	*	39 000	MacNae, 1974
Bangladesh	30 780	598 000	MacNae, 1974
Burma	2 920	520 000	Pillay, 1974
Hong Kong	3 000	6 500	Ling, 1973
India	607 915	2 000 000	Pillay, 1974
Indonesia	184 000	1 000 000	Ling, 1973
Kenya	*	58 700	MacNae, 1974
Khmer	*	50 000	Ling, 1974
Korea, Republic of	74 300	191 700	Rabanal, 1974
Malagasy Republic	*	325 500	Kiener, 1972
Malaysia	4 500 1/	300 000 2/	1/ Ling, 1973 2/ MacNae, 1974
Mozambique	*	85 000	MacNae, 1974
Nigeria	*	738 700	Pillay, 1965
Philippines	175 500	550 000	Ling, 1973
Singapore	465	2 800	Ling, 1973
Sri Lanka	10 000	140 000	Pillay, 1974
Taiwan, China	39 200	53 800	Ling, 1973
Tanzania	*	50 000	MacNae, 1974
Thailand	10 000 1/	313 000 2/	1/ Ling, 1973 2/ Vibulsresth & Kietruangroj, 1976 and Indrambarya & Sriplang, 1976
Vietnam	50 000	600 000	Ling, 1973
TOTAL	1 192 580	7 622 700	

* No available data

1/ Mangroves also occur in South Africa, Pakistan, Papua and New Guinea, Australia, and New Zealand and many islands of the tropical Pacific but there are no available data from these areas.