# PART II. SELECTED ASPECTS OF COASTAL AQUACULTURE DEVELOPMENT/ASPECTS CHOISIS DU DEVELOPPEMENT DE L'AQUACULTURE COTIERE (continue)

## 14. Marine Cage Culture System in the Tropics: Technology and Potential

by

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## ABSTRACT

This paper reviews the existing technology of cage culture of fish with special reference to tropical marine environment. The success of aquaculture practices heavily rely on the suitability of site chosen. Basic consideration on water quality, environmental hazards, pollution, communications, socio-economic status of the surroundings, legislation and conflicts with navigation, fisheries, recreational and conservational activities is important in choosing a site for marine cage culture. The cage design and construction should take into consideration the ecological characteristics and the surrounding socio-economic patterns. Proper management of the farm requires familiarization of the culture biology of the species and the operational functions of the culture system. Present trends of marine cage farming is described using experience in the tropical conditions. The potential of marine cage culture as a suitable and productive aquafarming system has been established although major technical constraints especially in seed and feed supplies have yet to be solved.

## INTRODUCTION

The enclosure method of fish farming using cages or pens is a productive aquafarming system. A fish cage is usually made up of nettings with opening at the surface to facilitate feeding. A fishpen, on the other hand, constructed at the culture site is made up of closely arranged wooden or bamboo poles and may be further reinforced by nylon netting, galvanized wire mesh or bamboo screen. There is no horizontal netting at the bottom.

Cage culture utilizes little physical facilities and space. A floating cage consists of a floating unit from which a single cage or a battery of net-cages is suspended (Fig. 1, B, C). A stationary cage is fastened to fixed bamboo or wooden poles at their corners (Fig. 1, A). Floating cages are popularly used for fish rearing in both fresh and coastal waters.

Fish farming in cages is a traditional practice in Cambodia for raising freshwater fishes (Pantulu, 1979). The technology was later introduced to Vietnam, Thailand,

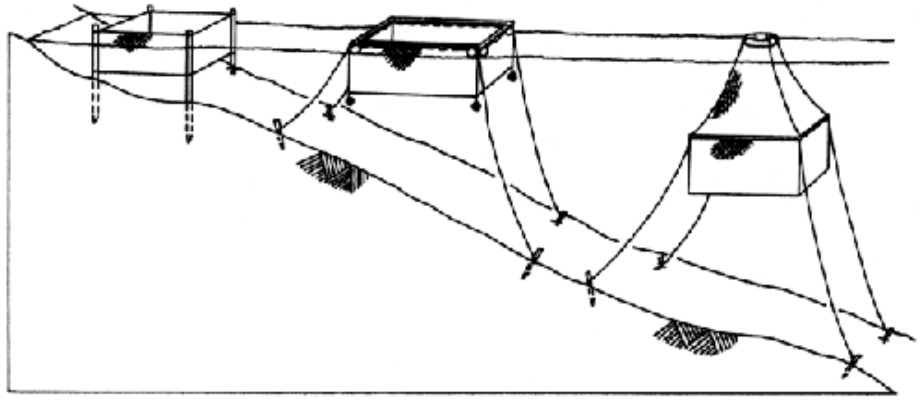


Fig. 1. Schematic diagram of various arrangements of marine cages.

> A - Stationary cage tied to fixed poles; B - Floating cage suspended at surface and C - Floating cage suspended at below water surface in rough sea conditions.

Indonesia and Philippines where large areas of inland waters were utilized for cage culture. Commercial marine cage culture, however, is a relatively recent practice initiated in Japan in the early sixties in sheltered coastal water and lagoons. Success of marine cage culture and its commercial viability have contributed significantly to large scale development of this aquaculture system in many countries. The centers of greatest commercial activity in marine cage farming are Japan, mainly for raising yellowtail and red sea breams; Hong Kong, for raising serranids, lutjanids and sea breams and Norway, Great Britain and France for raising salmonids.

Finfish is the main group of organisms cultured in marine cages in commercial scale although several experimental trials had been attempted for invertebrates such as marine shrimps (Penaeus indicus and P. monodon) in India and Malaysia (Marichamy et al., 1979; Chia, personal communication), cuttlefish (Sepia pharaonis) in Thailand (Yodying et al., 1979) and mud crabs (Scylla serrata) in India (Marichamy et al., 1979). Among the finfish cultured, carnivorous species are more widely raised than herbivorous species probably due to market demand. The main species of finfish cultured in marine cages include the salmonids (Salmo gairdneri, S. salar, Onchorynchus kisutch, O. keta, O. nerka, and O. gorbuscha), the carrangids (Seriola quinqueradiata, Trachinotus carolinus, Carangoides spp., and Caranx spp.), the breams (Chrysophrys major, Sparus aurata, Pomadasys maculatus), the lutjanids (Lutjanus argenticulatus, Lutjanus spp.), the sea perch (Lates calcarifer), the serranids (Epinephelus akaara, E. awaora, E. tauvina, E. salmoides), the flatfish (Scophthalmus maximus, Solea solea, Hippoglossus hippoglussus), the filefish (Monocanthus cirrhifer), the puffer fish (Fugu rubripes), the horse mackerel (Trachurus japonicus), the threadfins (Polydactylus sexfilis, Eleutheronema tetradactylum) and the siganids (Siganus javus, S. oramin). However, large-scale commercial cage farming seems to concentrate on salmonids (mainly Onchorhynchus spp. and Salmo gairdneri) in Europe and North America, carangids (Seriola quinqeradiata) and red seabreams (Chrysophrys major) in Japan and serranids (Epinephelus spp.) and seabass (Lates calcarifer) in Southeast Asian countries.

Marine cage culture has obvious advantages over many other aquaculture systems. It has good water quality, constantly renewed by current flushing, less accumulation of metabolic waste and faecal matters, high yield, simple to operate, relative low capital inputs and high rate of economic returns. However, it also has limitations such as high risk, labour intensive and heavy dependence on supplementary feeds.

In view of the high productive characteristics of the cage culture system and the presence of large areas of sheltered coastal waters in many countries still not fully utilized, marine cage farming can play a significant role in fish production especially in those coastal countries in the subtropical and tropical belt whose climatic conditions are most favourable for growth.

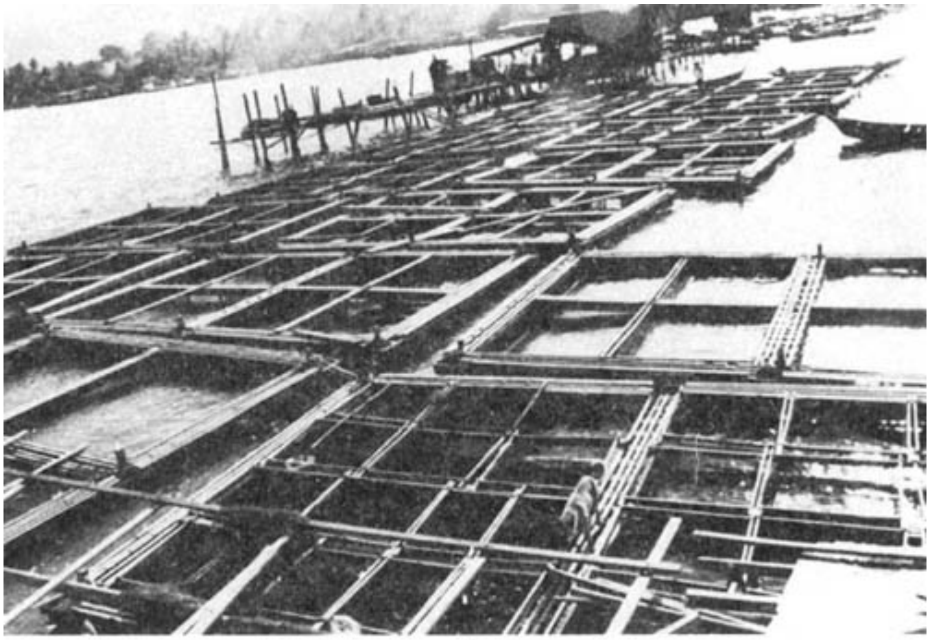
## 1. STRUCTURAL DESIGN AND CULTURE SITE

The design of the physical structure of a cage is determined by the oceanographic conditions of the culture site and the target species. Each design is site-specific and knowledge of the topography, wind force and direction, prevalence of storms or monsoons, wave loads, current velocity and water depths are important parameters for consideration.

Fish cages of various shapes and dimensions have been used. In general, square or rectangular cages are preferred because of easy construction and maintenance. Such cages are widely used for farming of yellowtail (Harada, 1970; Fujiya, 1979), salmonids (Møller, 1979; Kennedy, 1975) and groupers (Chua, 1979). Cylindrical cages are also used for marine or brackish water species such as milkfish (Yu et al., 1979) and rainbow trouts (Tatum, 1973). Cylindrical cages can be designed to rotate so as to delay change of nets due to bio-fouling (Caillouet, 1972). Other forms of cages such as orthogonal (Milne, 1979; Anon., 1976) and octagonal (Møller, 1979) in shape have been used for salmonid culture in United Kingdom, Norway and France.

The size of net-cages ranges from less than 1 $m^3$ to 50,000 $m^3$. Freshwater net-cages for tilapia culture in Indonesia and the Philippines are usually very large (exceeding 100 $m^3$) and are installed in calm shallow lakes. For marine cages, the dimensions of the cages are preferably smaller even in relatively calm waters because large nets are difficult to maintain especially with biofouling. Although large size cage reduces construction cost, the optimum size must be within the physical capability of the fish farmer to manage and maintain. For tropical condition where biofouling can be rapid and heavy, net cages are preferable to be between 20–50 $m^3$.

Most cage culture practices use surface floating cages for farming marine finfishes in protected bays and lagoons, sheltered coves and inland seas. The surface floating unit consists of floats, framework and cage proper. Most of the floating cages have rigid wooden or metal framework surrounded with cat-walk to facilitate operation and maintenance (Fig.2). For flotation various types of floating materials (metal drums, plastic drums or containers, PVC pipes, styrofoam or ferrocement blocks, rubber tires with polystyrene, bamboo and logs) have been used. Metal drums coated with tar or fiberglass are most widely utilized because they are cheap, however, they corrode easily in seawater and the life span ranges from half to three years (IDRC, 1979). Fiberglass drums or buoys are increasingly used by commercial fish farmers and can last for many years in seawater although the initial cost is comparatively higher. Styrofoam blocks, if ensheathed with polythene sheets, not only provide good buoyancy but also last as long as five years in tropical sea conditions. Ferrocement floats which have shown promise in tropical sea conditions require some skill in construction and are not widely employed. Though bamboo and logs have been widely used for brackish and marine cages, they are easily attacked by fouling organisms and wood borers. Their life span in seawater conditions is relatively short (1–2 years, at most).



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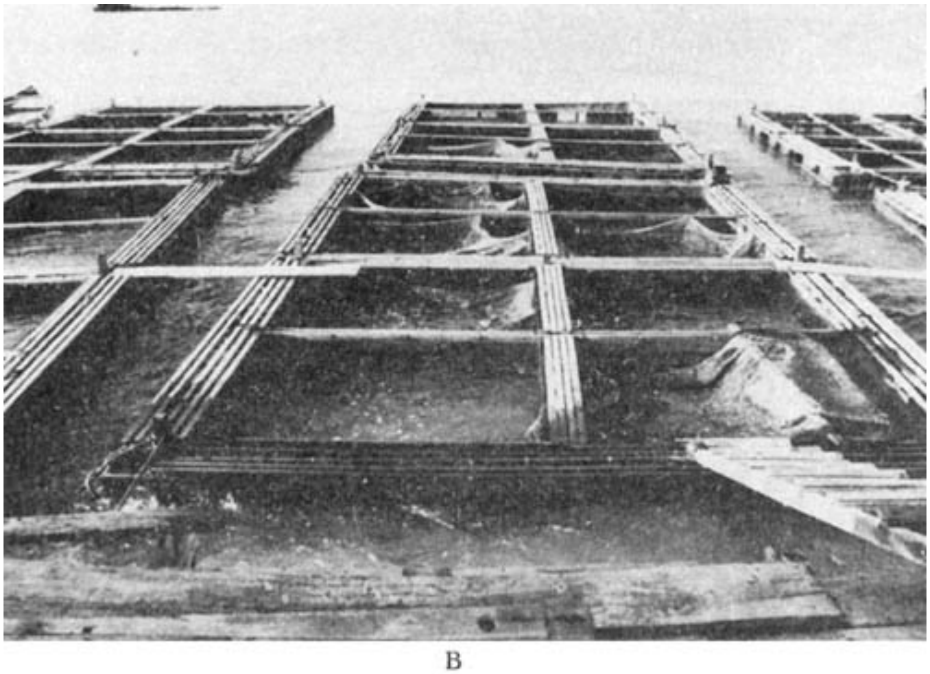


Fig. 2: A marine cage farm at Jelutong, Penang, Malaysia. A - Part of the farm proper producing 100 tons of estuary groupers per hectare in 6–8 months. B - Close-up of the cages showing net arrangement.

For cages designed with catwalk, the framework from which a single net or a battery of cages suspended is normally large so that it provides a stable and rigid platform for the workers to work. Some marine cages do not have catwalks and the surface floating unit consists of floats from which each cage is suspended.

The cage proper can be made up of synthetic netting of nylon or polyethylene fibres reinforced at the corners with polyethylene ropes. These cages are flexible and are kept stretched vertically with weights at the bottom of the cage or fastened by rope to the framework (Kennedy, 1975). The net can also be stretched with rectangular, round or square steel or PVC pipes depending on the shape of the cage. Rigid cage made of metal netting (galvanized mesh, copper-nickel mesh or vinyl-coated mesh) mounted on rigid metal or wooden framework are also popularly used for sea cage farming (Powell, 1976; Milne, 1979; and Swingle, 1971). The relative merits of flexible and rigid cages were discussed in Huguenin and Ansuini (1978) but the choice of the types of cages used is the question of economics. Flexible cages are more widely used in less developed countries in view of the relatively lower initial cost.

The mesh size used is determined by the size of the stocked fish. However, small mesh netting is rapidly clogged with fouling organisms especially in tropical seas (Chua, 1979). Cages with fine mesh are easily damaged by floating objects, increased drag force and hence affect the mooring loads of the cages. As the fish grow in size, larger mesh cages should be used.

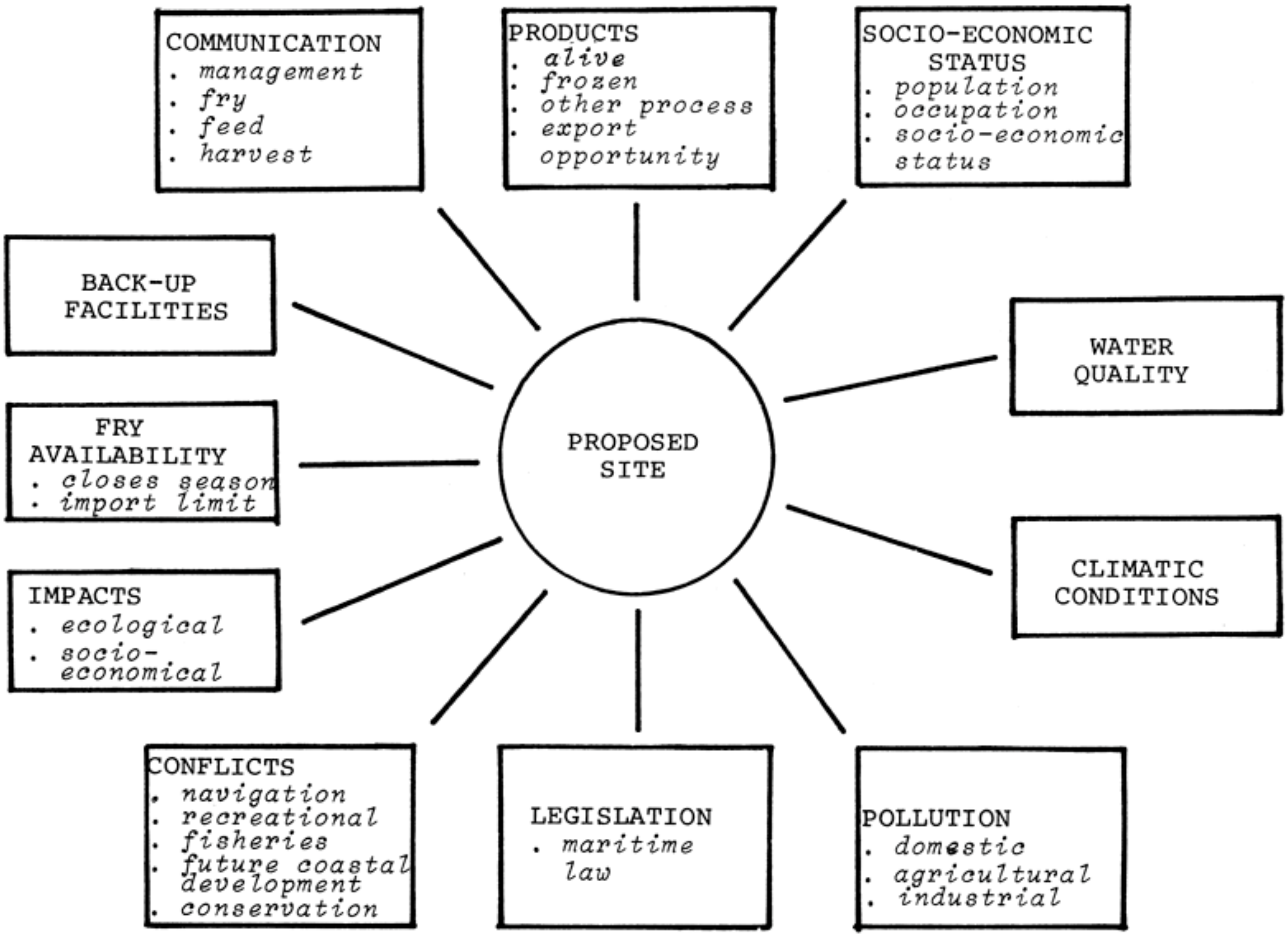
Right choice of site contributes significantly in the success of a marine cage farm. Ample considerations of all the factors either directly or indirectly affecting the culture operation or management should be examined and evaluated. Cursory site inspection may save money and minimize delay in aquaculture venture but very often it also pays poor dividends. It may cost a lot more in corrective measures.

The quality of water of the culture site is of course one of the most important factors meriting detailed investigation together with other considerations on water movement, environmental hazards, pollution from industrial, domestic and agriculture activities; on conflicts of usage for navigation, recreation, fisheries, conservation and other present or future coastal developments; on availability of fry from hatchery production, wild collection or import; on existing legislation on closed season, conservation and maritime law; on accessibility of culture site by road, air or sea; for transportation of fry or juveniles and harvested products; on the marketing possibility of live, frozen, processed products and export opportunity; on the socio-economic status of the locality at which the site is proposed and on the availability and quality of labour (Fig. 3). These detailed information are needed for the aquaculturist to plan the scale of his venture, design of cages, assessment of carrying capacity of nets for stocking, decision on feeding strategy and for other operational and management purposes.

## 2. CULTURE BIOLOGY

Knowledge of the culture biology of each species is crucial in optimizing production from cages. The species chosen for culture is usually based on a number of biological (omnivorous, hardy, fast growth, good food conversion, seed availability) and economical criteria (marketability and demand). Each species chosen is also dependent on the prevailing conditions of the culture site. The environmental requirements of each species such as salinity, temperature, dissolved oxygen, pH, determine the selection of the species for the culture system.

Fig. 3 : Principal considerations for site selection for cage culture farm



### 2.1 Stocking

The number of fish to be stocked depends on the carrying capacity of the cages. Optimal stocking density varies with species and size of fish stocked (Brown, 1946; Chua & Teng, 1979). As stocking density directly influences the growth rate of the cultured species (Stickney et al., 1972; Allen, 1974 and Kilambi et al., 1977) determination of the optimal stocking rate becomes an important part of cage culture practices. High stocking rate may create group effects and may also result in higher mortality as observed by Chua & Teng (1978) on estuary grouper, Epinephelus salmoides. Optimal stocking rate ensures optimum yield at the end of the culture period as food conversion, survival rate, and condition of the cultured fish are closely related.

### 2.2 Feeding

Feeding is a vital operational function and may include many biological, climatical, water quality, and economic considerations. The direct influence on growth rate in terms of feeding intensity, feeding time, food rations are important economic considerations a farm operator has to make. The feeding characteristics of each species vary in maximum food intake, digestivity, feeding frequency and conversion efficiency. These in turn have direct effects on the net-yield, survival rates, size of harvestable fish and the overall production of the cage.

For most marine cage culture, supplementary feeding is usually given to the cultured fish. Trash fish is usually the main feed used for yellowtail, groupers, breams, snappers and other carnivorous species. The supply of trash fish as feeds have already posed serious problems in some countries like Thailand where large scale development of catfish farming have resulted in heavy decrease in trash fish supply. The shortage of trash fish and fish meals will be future problems of concern and should be fully investigated to catch up with the development of aquaculture.

However, the full dependence of feeds from trash fish will anyhow not be possible in view of the increasing demands. Supplementary feeds incorporating the basic necessary dietary requirements such as protein, fat, carbohydrates and minerals have to be added to the fish diet.

## 3. MANAGEMENT

Like any aquaculture system, management of cage culture to optimizing production at a minimum cost rests on the competency and experience of the farm operator or farm manager. He plays a vital role in ensuring the cultured fish grow at an expected rate through suitable regulatory measures on their feeding and stocking, minimizing losses due to diseases and predators, monitoring of environmental parameters and maintaining the efficiency of the technical facilities.

### 3.1 Biofouling

Almost all marine cages are faced with the serious problem of biofouling. In tropical waters, the rate of fouling is very much faster than in subtropical or temperate regions. The net walls as well as the firm structures such as the floats can be covered with biofoulers which serve as excellent habitats formed by the sedimentation of silt particles, for smaller organisms such as amphipods, shrimps, isopods, polychoates, etc. Such biofouling may eventually clog the mesh of the net walls, hence reducing the exchange of water. This may cause unnecessary stress on the cultured fish due to deprived oxygen and accumulated wastes. A fouled net may increase drag and attain heavy weight; in serious conditions this may result in the loss of the net and fish (Milne, 1970). Barnacles (Balanus spp.) green mussels (Perna spp.), oysters (Crassostrea spp.), algae and compound tunicates are some common fouling organisms on the net walls of cages. Boring organisms such as Martesia are frequently found to damage the wooden structures of the cage unit (Milne, 1970; Chua, 1979).

The rate of fouling depends on the mesh size of the nets, temperature of the water and productivity of the site. Smaller mesh (0.64–1.27 cm) can be easily fouled within 7–14 days whilst large mesh (2.54–3.81 cm) is fouled in about 1–2 months (Cheah & Chua, 1979). In tropical waters, the net-cage has to be replaced at least once a month. In designing the cages, it is therefore important to take into consideration the rate of biofouling and the species composition.

Mechanical cleaning of fouled net-cages is still the most efficient and cheaper method of removing the biofouling organisms. Antifouling paints and use of copper-nickel alloy, though they delay the onset of biofoulers, do not fully prevent fouling. In recent years, rotating net-cages have been suggested. However, their applicability in rich tropical waters has yet to be tested. Biological treatment using herbivorous fish such as rabbit fish (Siganus sp.), the pearl spots (Etroplus) and the scat (Scatophagus argus) would help to control biofoulers. Their feasibility in large commercial farms have, however, yet to be demonstrated.

### 3.2 Regulation of growth and production

The growth and consequently the net-production can be regulated through proper management and manipulation of the operational functions such as stocking density and feeding. It is sometimes necessary to regulate fish growth in the cage so as to attain the desired size for the targeted seasons. It was shown in estuary grouper that at water temperature between 29–30°C and feeding to satiation daily, a fingerling of 15–16g will attain marketable size of 500g in about 7–8 months at stocking densities of 15 fish/$m^3$, 8–9 months at stocking densities of 30–60 fish/m$^3$ and 11–12 months at stocking densities of 90–120 fish/m$^3$ (Chua & Teng, 1979).

Optimal stocking rate varies with species, feeding, behavior and environmental characteristics. Sound management to regulate these characteristics will help to maximize production. In many studies, maximum production of fish was attained by optimal stocking rate (Backiel and Le Cren, 1967; Coche, 1979; Hull and Edwards, 1979; Pantulu, 1979). The optimal stocking rate in marine cages can be further increased through proper understanding of the behavior characteristics. Teng and Chua (1979) have shown that by providing artificial hides in the form of used car tires, the optimal stocking density of estuary grouper, Epinephelus salmoides, can be increased from 60 fish/m$^3$ to 156 fish/m$^3$ and the production of fish could be increased by 230% over that of the stocking rate without artificial hides.

Grading is sometimes necessary to maintain uniform size so as to reduce the effect of size hierarchy (Brown, 1957). Greater size uniformity improves feed conversion rates and overall growth. However, the requirement for grading is determined by the marketing and processing constraints (Huguenin and Ansuini, 1978). Frequency of grading depends on individual species and size requirement at harvest (Aquacop, 1975; Fujiya, 1979). In estuary grouper, grading is done once a fortnight for the juveniles and once every two months during the grow out phase.

Whilst grading is essential for optimizing production, it often results in high mortality due to handling. It is therefore important to determine the needs for each species and to leave the fish undisturbed as much as possible.

Fish in marine cages are also subjected to disease infection, however, compared to freshwater aquaculture, the frequency of diseases are less severe. One of the main diseases in marine cage culture is the ‘red-boil’ disease (Vibriosis) caused by Vibrio parahaemolyticus. The symptom of this disease is very much the same as that caused by the temperate species Vibrio anguillarium found to infect salmon and trouts. The main cause of this disease is poor water quality, malhandling and weakening of fish. Vibriosis is common when cages are suspended in water rich in organic matter. Whilst treatments with antibiotics, sulfur drugs or immunications are essential, prevention is still the best management.

Constant monitoring of water quality becomes part and parcel of marine cage culture so that prior arrangement could be made if the site is threatened by pollution or in anticipation of the development of red-tides common in sub-tropical and tropical coastal waters.

In ensuring maximum production, predation by birds, otters and predacious fish should be prevented by proper selection of sites. Prevention measures such as extra outer net-enclosure, keeping of watch dogs and night guards, etc., will also be useful.

### 3.3 Harvesting

Harvesting in a cage culture system is a simple process. For flexible cages the net can be lifted and the cultured fish collected by means of a simple scoop net. For rigid cages, the cage has to be lifted to facilitate harvesting. No sophisticated harvesting technology is required. In most marine cage culture practices, the harvested fish are kept alive such as yellowtail, breams, snappers and groupers and transported immediately to the markets or restaurants. Preservation and processing of cultured fish will be an essential part of the culture industry when aquaculture is further developed.

### 3.4 Transportation

Transportation of both fish fry and the harvested products is an important aspect of all aquaculture systems. Transportation of young fish or fry from the wild or hatcheries to the culture site could encounter severe mortality due to bad handling and packing techniques. In the transportation of fry, the fish are usually kept in oxygenated water in polythene bags and packed in paper boxes. For long duration, such packing technique may cause severe stress in the fish if the surrounding environmental conditions become unfavorable such as high temperature and excessive shaking. Sytrofoam boxes are now increasingly used for fry transportation in which the water temperature could be decreased and maintained low by ice.

There are considerable improvements needed in fry transportation especially at the level of wild collections. Transportation of live marketable fish poses more problems than fry transportation. Not only are the larger fish subject to the same stress as that of the fry stage during transportation caused by temperature fluctuation, physical disturbance, accumulation of metabolic waste, etc., but also in increased cost per fish. High mortality is usually encountered in the transportation of marine fish for long distance. Hence, to minimize economic losses due to transportation, there is urgent need to develop effective and efficient technology for live fish transportation.

## 4. ECONOMICS

Cage culture is one of the intensive methods of aquafarming, however, it involves less costs than raceway or enclosure methods (Collins & Delmendo, 1979). The capital involvement consists of floats, platform, mooring facilities, a motor boat and at most, a floating hut. It is usually less than 10% of the total operational costs. The nets and the physical facilities are usually given a life span of four years in view of the marine conditions especially in tropical environment.

The main expenses in marine cage farming are cost of feeds (30–50%) and seeds (30–35%), which usually make up 60–85% of the total operational cost (Solar Arroyo, 1973; Collins & Delmendo, 1979 and Chua & Teng, 1980). The high expenditure on feeds is due to the exclusive dependence on external source for food supply and hence the quantity taken is in accordance with the feed conversion efficiency. Trash fish is still popularly utilized as feeds for carnivorous fish although formulated feeds are increasingly popular. Despite the fact that formulated feeds yield very good conversion ratios, their high cost have raised the production cost of fish considerably.

Table 1 compares the economics of yellowtail and grouper farming in floating net-cages for raising 500g size fish. The production cost for yellowtail and grouper differs only about 5%. In both cases, fish feeds and seeds account for 62.7–65.2% of the total operational costs. Due to shortages of seed supply, the cost of seeds is on the increasing trend and the price will even accelerate when aquaculture practices become fully established. Wild collection is still the most effective way of supplying the large quantities of fry needed for aquaculture development. Hatchery development for large scale seed supply is only a recent innovation, and it would take considerable amount of time before sufficient seeds could be produced that way to meet the growing demand. Unless collection of seeds from the wild is properly controlled and regulated, this only source of seed supply may soon be depleted and the price of fish seeds will then soar upwards. Amongst other expenses, labor cost, cost of fuel, repairs and maintenance, bird netting, netting for predators and general depreciation play a significant role in the economics of cage culture.

Table 1

Comparison of the economics of producing a 500 g grouper and a 500 g yellowtail in floating net-cages.

| | Grouper[1] | | Yellowtail[2] | |
|---|---|---|---|---|
| | Cost (US$) | Per cent | Cost (US$) | Per cent |
| Seeds | 0.36 | 31.3 | 0.35 | 28.9 |
| Feeds | 0.39 | 33.9 | 0.53 | 43.8 |
| Fuel | 0.01 | 0.9 | 0.03 | 2.5 |
| Labour | 0.09 | 7.8 | 0.08 | 6.6 |
| Depreciation | 0.17 | 14.7 | 0.12 | 9.9 |
| Miscellaneous Expenses | 0.13 | 11.3 | 0.10 | 8.3 |
| | 1.15 | | 1.21 | |

[1] Calculated from Chua & Teng (1980).
[2] Calculated from Fujiya (1979).

The optimal cage size depends on the economics of operation, types of species cultured and the environmental conditions. It was shown by Huguenin and Ansuini (1978) that large nets (above 50 $m^3$) are more economical to operate than the smaller cages.

Huguenin and Ansuini (op. cit.) have also demonstrated that the return from marine cages for yellowtail and salmonids varies from 46 to 86%. Such profit margin is, however, considered to be extremely lucrative.

## 5. PROBLEMS AND CONSTRAINTS

Although cage culture technology has now been developed and marine cage culture has been widely practiced throughout the world, there are still problems and constraints that limit its rapid commercial scale development.

One of the main problems in marine cage culture is the uncertainties in seed supply. Many commercial farmings such as milkfish in Philippines, Taiwan and Indonesia, the yellowtail in Japan and groupers and sea perch in Malaysia, Thailand, Hong Kong and Singapore, are largely dependent on wild stocks for seed supply. However, the fish farmers are often confronted with shortage of seeds. Undoubtedly, it is essential to maintain a dependable source of seeds. Hatchery developments are only intensified recently and it is envisaged that not for another decade or so can fish seeds be easily available at a reasonable price. However, the advantage of controlled breeding and genetical selection and hybridization should receive increased interest in scientists and governments.

The fish farmers are also faced with the problem of feed supply. Generally trash fish is the common feed given to carnivorous farm fish. Due to low conversion ratio, the quantity of trash fish required is 3–8 times the weight of the farm fish. In addition, a substantial quantity of trash fish is being processed into fish meals. In countries such as Thailand, Malaysia, Singapore and Hong Kong where the supply of trash fish is limited due to overfishing in the coastal waters, ample supply of trash fish as feeds to meet the growing demand may not be possible. The only solution to meet the demand is full development of formulated feeds at which other sources of animal protein have to be sought. Formulated feed pellets have been well developed for many species of fish such as eels, channel catfish and yellowtail, yielding good feed conversion ratios. Attempts to formulate feeds for specific species should be encouraged and the nutritional requirement for each species should be fully investigated. Unbalanced or poorly prepared feeds often result in heavy loss of food, low food conversion efficiencies and even increased mortality.

Marine cage culture is a high risk farming venture and in spite of scientific innovation, there is no way to control the onset of natural environmental hazards such as typhoons, monsoonal storms, hurricane, or the occurrence of red-tides. Marine cage culturists must be prepared to face such environmental hazards although a good farm operator will be able to avoid most of these through careful site selection and proper cage design to cope with the expected extreme environmental conditions.

Like all coastal aquaculture practices, marine cage culture also faces the problem of site acquisition. It may be difficult to acquire rights on the use of the seabed and the water above it. There is obvious possibility of a clash of interests on navigation, mooring, inshore fishing and pleasure boating. Therefore, in countries where fish is the main source of animal proteins and increased fish supply is the national objective, aquaculture development should be given top priority.

Uncertainty in seed and feed supply, high risk involved in the venture and ignorance of its commercial viability have restricted bank loans and other financial aids to marine cage operators in many cases. Although an increasing number of private enterprises have ventured into this emerging business, commercial operations are still limited to a number of big companies which also maintain large research capabilities.

## 6. POTENTIAL FOR DEVELOPMENT

Although aquaculture is not new, marine cage culture systems are relatively new to many countries. The potential for development is large although the problems and constraints outlined above have yet to be resolved and overcome. Compared with many other aquaculture systems, marine cage culture has added an advantage in using the natural environment as the medium for fish growth. The continuous movement of water through the cage generated by tides or coastal currents ensure high productivity of the culture system provided the food supply is adequate. Although there are risks encountered in such culture systems, they can be minimized through careful site selection, skillful operation and management. The rapid development of such culture techniques in many countries of the world today since this method was successfully implemented in Japan in the early 60's clearly demonstrates its technical and economic potential as an effective aquaculture system for fish production.

Apart from the technical and economic significance, cage culture system can play an important sociological role in providing alternative employment to the inshore fishermen of many countries who are facing serious overfishing problems and low economic returns. Like the cage farmers in Cambodia, Vietnam and Indonesia who operate few cages on a family level (Pantulu, 1979; Bardach et al., 1972), marine cages can be operated by small fish farmers in estuaries, lagoons, bays and protected coast. Although the initial capital input in marine cage culture is higher than fresh-water cages, the economic returns from marine cages are also higher. Many small cage farmers in

Singapore, Hong Kong, Thailand and Malaysia have contributed significantly not only in fish production but also have generated employment. In Malaysia, cage culture is being developed at family, cooperative as well as company levels. With the subsidy from the government, many inshore fishermen in Malaysia are gradually turned into full-time small cage farmers operating few marine cages or part-time cage farmers using the surplus manpower from the family (children, wife, unemployed members) to maintain and manage the farm whilst the trash fish from the catch is converted into fish feeds. This family unit system of cage farming is being encouraged in Malaysia (Chua & Teng, 1978a). Whilst there is an increased activity in incorporating cage farming in improving the rural economy, the impact of cage farming on the socio-economics of the rural community has yet to be investigated.

## CONCLUSION

Aquaculture has demonstrated its full potential as a viable system of animal husbandry to increasing fish supply and improving rural economy. The development of aquaculture is the result of the interaction of economic pressures, scientific endeavour and advanced technology, and cage culture technology is developed as a result of such interactions.

Whilst cage culture system has demonstrated its production efficiency, economic viability and sociological significance, the development is confronted with shortage of fish seeds and supplementary feeds. Until a major breakthrough in these aspects ensuring consistent supply of the desired seeds and supplementary feeds at reasonable market price, cage culture as well as any other marine farming will continue to face with developmental uncertainty. Sufficient financial and technical inputs from both international and national bodies are essential to develop this new, but important emerging food industry.

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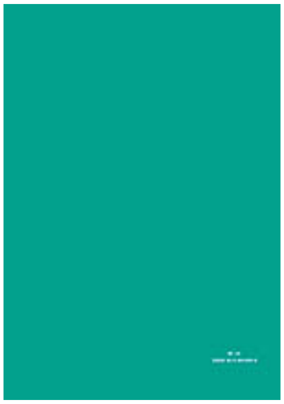

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