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Assessing Species for Mariculture in Developing Countries: A Review of Economic Considerations

by

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Carunia Firdausy and Clem Tisdell[2]

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The technical feasibility of culturing giant clams for food and for restocking tropical reefs was established in an earlier ACIAR project. This project is studying the economics of giant clam mariculture, to determine the potential for an industry. Researchers will evaluate international trade statistics on giant clams, establish whether there is a substantial market for them and where the major overseas markets would be. They will determine the industry prospects for Australia, New Zealand and South Pacific countries, and which countries have property right factors that are most favourable for commercial-scale giant clam mariculture. Estimates will be made of production/cost functions intrinsic in both the nursery and growth phases of clam mariculture, with special attention to such factors as economies of scale and sensitivity of production levels to market prices.

Commissioned Organization: University of Queensland.

Collaborators: James Cook University, Townsville, Queensland; South Pacific Trade Commission, Australia; Ministry of Primary Industries, Fiji; Ministry of Natural Resources and Development, Kiribati; Silliman University, Philippines; Ministry of Agriculture, Fisheries and Forests, Tonga; Forum Fisheries Agency, South Pacific; ICLARM, Manila, Philippines.

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ABSTRACT

The economic importance of mariculture in less developed countries (LDCs) and their development plans are discussed. The basic processes involved in mariculture are outlined and some of the species maricultured in LDCs are considered. Factors which are important in assessing the suitability of a species for mariculture in developing countries are highlighted. These include consumer acceptance, biology, environmental, technological and economic factors. The economic success or otherwise of a species for mariculture depends upon all the factors as well as others.

Keywords: Giant clam mariculture in developing countries, supply and demand of seafood, market requirements for seafoods, Indo-Pacific.

JEL Classifications: Q57, Q31

Assessing Species for Mariculture in Developing Countries: A Review of Economic Considerations

1. Introduction

Mariculture development is often a central policy objective in economic development in many developing countries. Through this policy, it is expected that (1) the rising food/protein needs of an expanding population can be mitigated; (2) employment opportunities will be created; (3) foreign exchange earnings can be increased; and (4) huge coastal areas of unproductive 'idle water' bodies can be utilised efficiently and effectively for food production (Bell and Canterbery, 1976; Chua, 1986; Ling, 1973).

However, mariculture in developing countries is still at a comparatively undeveloped stage. Intensive studies and research to investigate the socio-economic feasibility of mariculture development are still being undertaken (Allen et al., 1984; Ismail, 1977).

The likely success of mariculture development in LDCs appears to be fundamentally related to the suitability of the species chosen. Many authors such as Bell and Canterbery (1976), and Tisdell (1986) have already suggested factors which need to be considered in assessing species for mariculture in developing countries, but those factors are not easily integrated and some factors have not been taken into account. Therefore, the purpose of this paper is to unify their suggestions into a single, simple standard assessment of species for mariculture in developing countries.

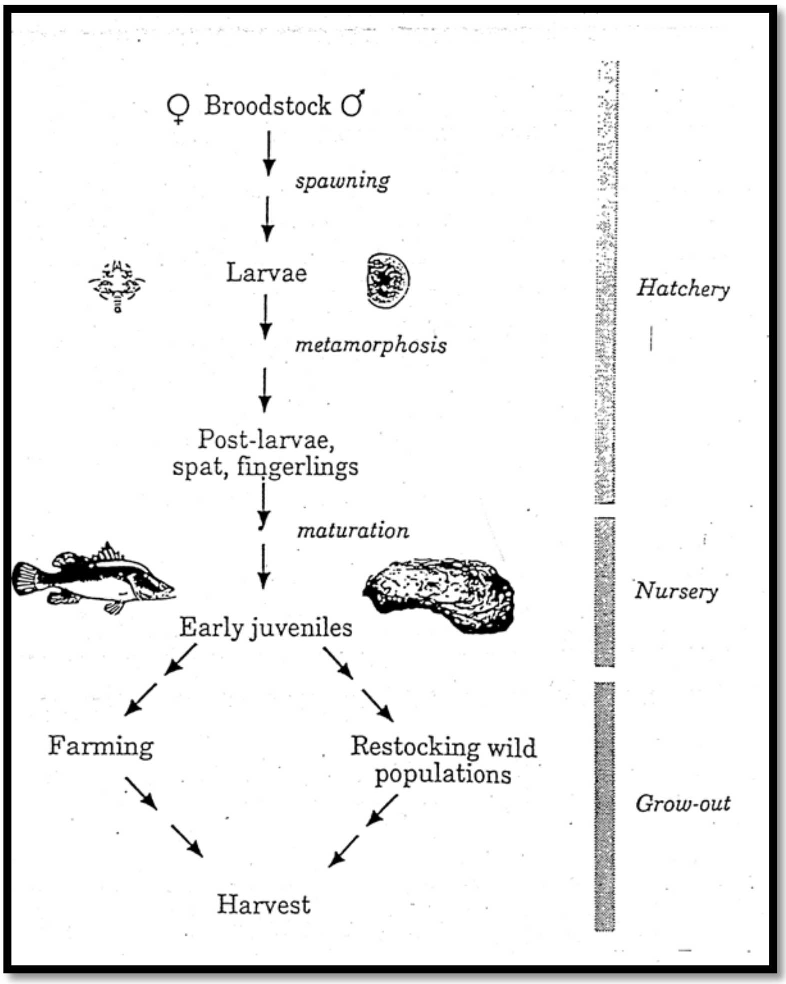
The scheme of this paper is as follows. In Section 2 the nature of mariculture activity and some examples of species being reared in developing areas are described. This is followed by an outline of some characteristics of developing countries and the development of mariculture activity in these countries. Section 4 discusses factors that need to be taken into account in assessing species for mariculture. Finally, Section 5 presents concluding remarks to put some suggestions in perspective.

2. Mariculture Operations and Species Being Reared in Developing Countries

2.1 The Nature of Mariculture Operations

Mariculture can be defined as the culture and husbandry of marine organisms (animal and plants) in marine and/or brackish-water. It involves as a rule the high density rearing of marine animals (or plants) of commercial importance.

The operation of mariculture can be divided, as a rule, into three stages - hatchery, nursery and grow-out (see Figure 1).



Source: After Garland 1988, pp. 5

Figure 1. Production Stages in Typical Mariculture Operations

The hatchery has a critical role. It aims to rear hundreds of thousands or millions of larvae by providing them with artificial optimal growing conditions. These include a plentiful supply of food, and strict control of temperature, oxygen, Ph, waste products, and hygiene. The larvae change (metamorphose) into juveniles usually after a few weeks and are on grown in a nursery where the conditions of culture are more like the natural environment (Garland 1988, pp. 4).

After several more weeks, young sturdy juveniles are ready for the many different sites where they will develop fully. The animals can be farmed in oyster trays, prawn ponds, fish cages or other confined vessels. They may be fed intensively, such as by pellets, or extensively, in which case they rely on naturally present food. On reaching the marketable size, the crop is harvested. Alternatively, the juveniles may be used for restocking natural waterways depleted by overfishing, pollution, or other causes. Then, commercial operators can harvest wild animals of legal size.

These stages of production, of course, involve costs. The costs of erecting and equipping a modern hatchery, for example, vary enormously according to capacity, location, and the ingenuity of its designer. Published costs range from US $ 3600 to US $71,500 in the Philippines for hatcheries with larval tanks ranging less than 30 000 to about 100 000 litres capacity, and from US $ 40 000 to US $ 900 000 for hatcheries designed to produce 2 to 20 million post-larvae per month in Ecuador (Wickins 1986, pp. 54).

Other costs which may be involved in hatchery operations are the costs of providing brood-stock, labour, technical expertise, feeding costs and costs of preventing disease and pollution. The normal growth and development of larvae may be affected in hatcheries which exist near estuaries or in areas where water quality is periodically influenced by run-off or pollution. In addition, high mortality can occur. Thus, suitable site selection for hatcheries is a prerequisite of success of mariculture activity.

Similarly, at nursery and grow-out stages, the cost of feed, labour costs, expertise, and maintenance costs can be quite substantial. The costs of feed for certain species is usually the most important operating expenses and often is the greatest single item in a farm's running costs (Shang and Costa-Pierce 1983, pp. 524; Wickins 1986, pp. 58). Also, labour costs will make up relatively high proportions of total cost of operating hatcheries and nurseries (Munro 1985 cited in Tisdell, 1986, p. 22).

The costs of mariculture can be high, but it varies widely depending on species cultured and technology used. With regard to species, the operation of a prawn (shrimp) mariculture, for example, is likely to be more costly than giant clam culture. Prawn farmers have to manage the quality of the water and give intensive feeding to achieve higher yield. The types of prawn farming that depend solely on natural food will yield a lower production per unit area (Ling 1973, p. 17; Maguire and Allan 1988, pp. 5-6). Maricultured clams, however, do not need feeding (except during in the first week in the larvae stage) and it can be operated on low technology hatching and rearing methods (Lee 1988, pp. 29; Tisdell 1986, p. 87).

The possible high-cost of mariculture does not necessary mean that such culture can only be organised by large-scale enterprises. For some species, e.g. *Eucheuma cottonii* rural poor people in LDCs can organise this activity, .whether for small-scale commercial production, subsistence or semi-subsistence purposes. In this respect, however, adequate government attention and institutional as well as financial support to the rural poor may be required in establishing economical mariculture. Without government support, mariculture development in coastal rural areas in LDCs might only lead to small increment in the crop produced.

2.2 Some Examples of Maricultured Species in LDCs

Species for mariculture in developing countries can be classified into three major groups, molluscs, crustaceans, fish and algae. Ling (1973, p. 3-4) listed 20 species of fin-fish, 25 species of crustaceans, 20 molluscs and about 10 algae as being cultivated in the coastal areas of the Indo-Pacific region alone, with roughly one-third of these being cultured extensively.

Among the molluscs, oysters and mussels are now well established in culture. These species are cultured in Thailand, Philippines and Indonesia to name just a few countries. However, oyster farming in these countries faces many problems. Apart from technical problems, the danger of water pollution to oyster culture development is increasing rapidly. Production of spat has decreased, and in some places they are heavily contaminated and thus unfit for farming purposes. In other places, the mortality is high, growth rate low and quality so poor that they are often unacceptable for export or even for local market (Ismail 1977, pp. 107; Ling 1973, p. 19).

Other species cultured in LDCs are clams and cockles. However, apparently abalones, squids and scallops have not yet been cultured in LDCs. Cockles are cultured in temperate and tropical countries, particularly in Indonesia and Thailand. Cockle culture in Indonesia is conducted by a very simple method. Natural beds are divided by using bamboo fences. The production reaches 20-30 tons per hectare per culture season (May - December). The culture activity is not conducted every year and depends upon the availability of natural spat (Ismail 1977, pp. 104).

Giant clam mariculture in the South Pacific has the potential to add to local subsistence diets, add to local trade and provide extra export income. The integration of clam farming into existing social and economic structures would probably tend to maximise employment of family groups especially women. By contrast, in commercial large-scale enterprises, there appears to be a tendency for men to be employed in preference to women in the South Pacific (Tisdell 1986, p. 94).

Among the large penaeid (prawn), *Penaeus japonicus*, *P. orientalis* (Chinese prawn), *P. monodon* (Jumbo tiger prawn), *P. merguiensis* (Banana prawn) and *P. indicus* are farmed in many Asian countries such as China, Indonesia and Bangladesh (Wu Qin Se 1987, p. 12). In Bangladesh, it is observed that with traditional methods of prawn farming there is little possibility of increasing farm income. However, a shift to the improved technology in prawn culture in Bangladesh, supported by institutional credit, promises not only to yield higher net revenue for farms (even for small farms) but also is expected to create employment opportunities (Mahfuzuddin Ahmed 1986, p. 153).

Other cultured species include crabs and lobster. Experiments for rearing crabs from larval stages to juveniles have been conducted in Thailand, India, Sri Lanka and Philippines with varying degrees of success (Ling 1973, p. 18).

The most widely cultured fish in Asian marine water is the milkfish (*Chanos chanos*), Mullet (*Mugil cepalus* and *Mugil* spp), and Tilapias.

In Java (Indonesia) milkfish are cultured together with shrimp in brackish water-ponds (mixed-cultured). Most ponds are managed in the traditional way without the use of fertiliser, pesticides, or supplementary feeding. Production inputs into the ponds are mainly physical labour in stocking of the milkfish fry and maintaining and guarding the ponds. The shrimp, on the other hand, are usually stocked naturally rather than by the operator buying post-larval shrimp for stocking. Yields for this type of management are reported to be 200 to 400 kg of shrimp per ha per year (Collier 1981, p. 276).

Tilapiasare cultured in over 30 developing countries. In Philippines, the Tilapia ranks second only to milkfish in terms of production. These fish appear to be well suited for small-scale production because the initial capital investment especially for cage culture is not high, they can be bred easily and are hardy and high yielding (Smith et al. 1985, p. 1).

Finally, among the species of seaweeds cultured, the laver or "Nori" (*Porphyra*) is the most popular, followed by dulse (*Undaria*) and both are highly esteemed as food. In general, most of the algae cultured in the world are temperate water species and not suitable for tropical areas. However, some species of *Gracilaria* spp, *Eucheuma* spp and *Hypnea* spp do grow well in tropical waters such as in Bali, Central Mollucas (Indonesia) and the economic prospects for their further development seem good (Firdausy and Tisdell, forthcoming; Dwi Listyo Rahayu 1984, pp. 21).

Therefore, it is clear that the production of an extremely wide variety of fishes and other marine organism can be enhanced through mariculture in LDCs.

3. Characteristics of Developing Countries and Mariculture Activity

A major feature of the developing countries is their low per capita real income compared with developed countries. In other words, most LDCs exhibit a very low ratio of income to population. This low per capita real income is a reflection of low productivity, low saving and investment and backward technology.

Second, most LDCs are experiencing high population growth rates. As a result of this 'population explosion', the number of poor people living in rural areas is increasing and the unemployment rate is rising.

The unemployment problems in these countries are often serious due to the absence of job opportunities, either because of the low level of economic activity or because of the poor economic growth rate or both. Other contributing factors may be the choice of techniques which are capital rather than labour-intensive, education which is unrelated to economic needs and lack of investment.

Third, agriculture usually dominates the economies of most LDCs. It is characterised by high pressure on land, use of 'backward' technology, low saving and investment and hence poor productivity. The majority of the peasants live in poor conditions and the rate of literacy is also low.

As a consequence of those conditions, mariculture development as well as aquaculture in most LDCs is mainly conducted at subsistence-level and involves small-scale production. It is characterised by low material and management inputs, low level of technology, and hence low output (Madamba 1979, pp. 182).

Mariculture operations in LDCs are mostly based on historical tradition. Most mariculture operations in these countries are undertaken by small individual farms with either hired or family labour. Also, population pressure on rural land and the pattern of local demand often determine the extent and the type of species cultured (Bell and Canterbery 1976, p. 38).

There are three main types of mariculture operations in LDCs: (1) pond culture, (2) raft or cage culture and (3) for some seaweeds line culture. Production organization can take at least one of four different types (1) Government, (2) Private Co-operative, (3) Commercial, and (4) Family operated. Family operated organisations predominate in mariculture activity in most LDCs. They are managed by small-fish farmers whose knowledge of the ecosystem is limited, have limited capital and a low-level of managerial skills and hence low productivity. They often engage in other activities which are mainly agricultural so that mariculture is a sideline.

However, government, private co-operative and commercial organisations in mariculture are often large producers who regard mariculture as their sole means of income and view mariculture as 'big business'. They are not significantly constrained by capital availability and employ high managerial skills. Their products are mostly intended for domestic and export markets.

It is often strongly suggested that mariculture as well as aquaculture development in LDCs should be directed toward small-scale rural enterprise (FAO/UNDP 1978 cited in Madamba 1979, pp. 183). In this respect, of course, the success of a small-scale oriented production rests heavily on the provision of adequate services and support from government and concerned institutions, such as extension, production and distribution of inputs and marketing facilities. In practice, however, these services are rudimentary in many developing countries (Collier 1981, p. 279; Madamba 1979, pp. 184).

The production of mariculture in developing countries is usually included as part of aquaculture production. According to Allen et al., (1984, p. 2), in 1983 world aquaculture production represented about 10 per cent of the live-weight world aquatic food production from fisheries.

Asia still remains a centre of aquaculture activities. In terms of commodities, Asia leads the world production of seaweeds, finfish, crustaceans and molluscs. China and Japan produced 60 per cent of the Asian total supply. The developing nations such as Nepal, Sri Lanka, Indonesia, India, Bangladesh and Thailand produced 4.1 10^6 tons or close to 80 per cent of the remaining aquaculture production in Asia (Chua 1986, p. 4).

The number of persons employed full-time in aquaculture and fishing activities in Asia is more than 15 million. Perhaps twice as many working part-time rely substantially on nearby waters for their livelihood. The bulk of Asian fishermen/fish-farmers are from three major developing nations India (6.5 million), China (3.1 million) and Indonesia (2.2 million) and most of these are small-scale fishermen and fish farmers. The relative importance of fishery in Asian developing nations can be seen in Table 1.

Table 1. Relative Importance of Fisheries in Asian Developing Nations, 1984.

Country	Population (million)	Employment (fishermen/ fishfarmers)	Per capita fish consumption (kg/person/yr)	Contribution to DGP/GNP (%)
Bangladesh	99.6	-	7.3	6.2*
Burma	38.9	80,000	17.8	-
China (excluding Taiwan)	1,034.5	3,000,000	4.5	-
Indonesia	162.2	2,232,000	13.1	1.7**
India	746.4	6,500,000	3.0	-
Nepal	16.6	-	0.3	-
Pakistan	97.3	205,000	1.7	0.3**
Philippines	54.5	827,000	41.0	4.5*
Sri Lanka	16.1	70,000	14.0	3.0**
Thailand	51.7	500,000	18.8	1.6*

Note : * = GNP ; ** = GDP

Source : Chua 1986, p. 8.

It is worth noting that despite the increase in aquaculture production, most of the fish produced by this method for market are not within reach of the poorer section of the communities. High-priced commodities such as shrimps are generally limited to the upper classes and high production cost for this species has greatly limited the expansion of the domestic-markets. Culture of food fishes low in the food chain entails comparatively less operational cost than raising carnivorous species. However, the production costs of these species are still high and the retail price faces stiff competition with fish of similar quality from capture fisheries (Chua 19B6, p. 4).

Therefore, attempts to develop mariculture in developing countries orientated towards the welfare of rural people face many problems. Support services and financial provision may have to be instituted and re-oriented toward the small fish-farmers to encourage them to establish mariculture. Without purposive intervention from the government and concerned institutions, small fish-farmers may not be capable of getting into the mainstream of the mariculture development.

4. Factors in Assessing Species For Mariculture in Developing Countries

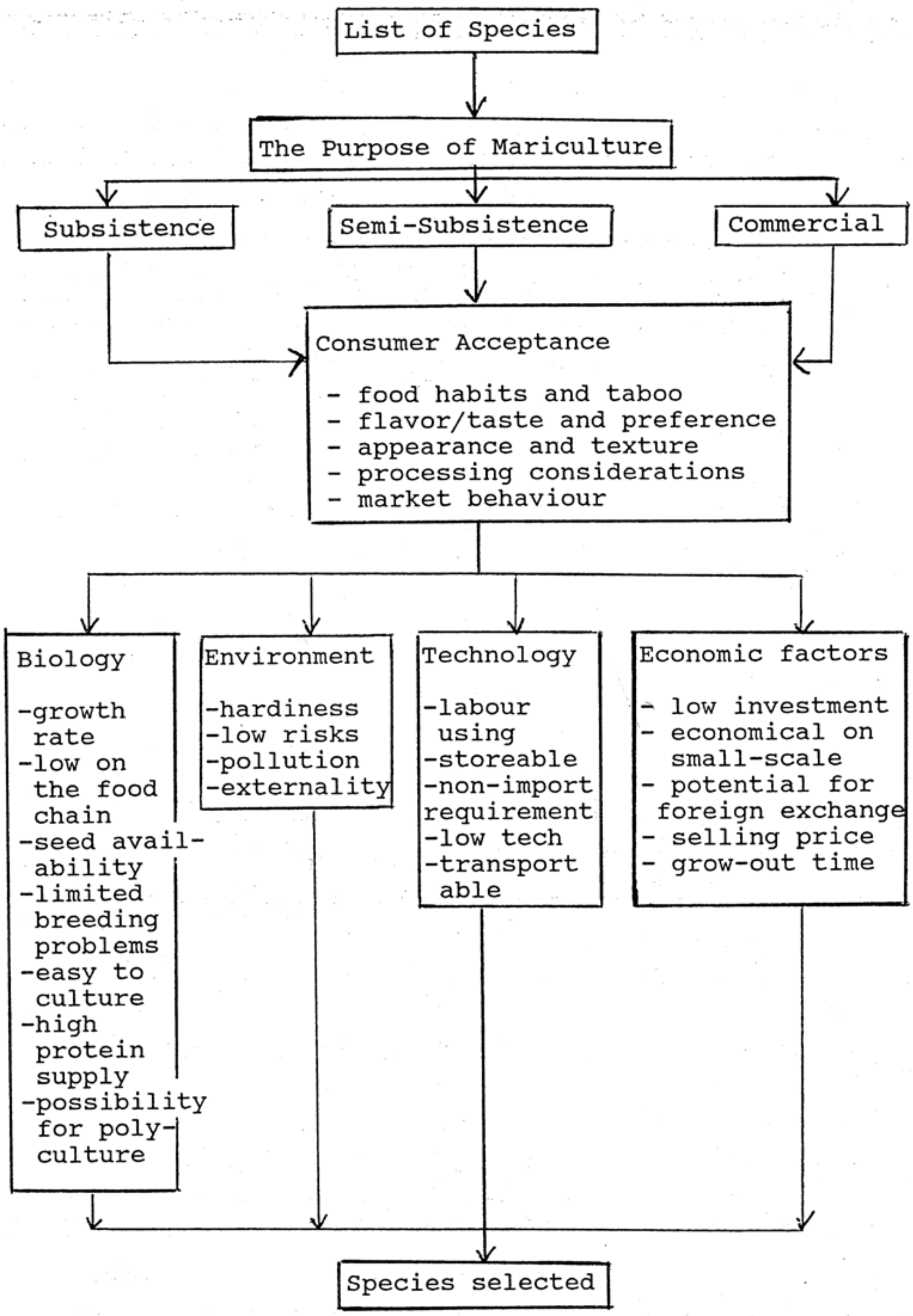
As indicated in the previous section, mariculture operations can involve considerable costs, both for labour and for capital. Unfortunately, in developing countries the availability of capital is very limited compared to developed countries. In assessing species for mariculture the characteristics of the country in question need to be taken into account. In other words, the species being considered for mariculture needs to be assessed on the basis of resource-availability in the country, local skills and management expertise. In particular consideration must be given to seed supply, feed and pesticide supply, and capital availability must also be taken into account.

In general, factors which have to be considered in assessing species for mariculture in developing countries can be divided into the following:

1. consumer or market-acceptance,
2. biological and environmental factors
3. technological factors
4. economic factors.

But possibly also a fifth factor, social and cultural considerations should be added because apart from affecting consumer or market-acceptance these factors may influence appropriate production techniques and arrangements and the likelihood of ,production being successfully sustained. The second and third factors determine production possibility, while economic factors determine profitability. All the factors need to be taken into account in assessing the suitability of a species for mariculture in an LDC (Figure 2).

Figure 2: Factors in Assessing Species for Mariculture in LDCs



It should be noted that the assessment of species in LDCs need to be distinguished depending upon the purpose of mariculture. Species designed for market/commercial purposes (local, domestic and export) need to be well known by many species in the market place, widely consumed by many people, and economically profitable. For subsistence and semi-subsistence purposes, however, the species chosen is usually for supplementing diets and does not involve profit maximisation.

Species selected for subsistence and semi-subsistence do not need to satisfy requirements in relation to foreign exchange earnings, marketability, transport and processing conditions which are usually important for commercial mariculture. Nevertheless they must still be acceptable to consumers and must be economic within a subsistence setting.

4.1 Consumer Acceptance

Of prime importance in assessing a species for mariculture is its consumer or market acceptance. People must want or be encouraged to want the marine food produced. Otherwise there is no justification for the considerable effort to domesticate and cultivate species.

Market acceptance of species can be gauged to some extent by knowing the food habits and taboos of different human cultures. Separate peoples have developed their own taste and food preferences.

In the Solomon Islands, for example, followers of the Seventh Day Adventists religion do not eat giant clams in the light of the injunctions of Leviticus. Leviticus 11 (9-11) says that "one may eat anything in the seas or rivers that has fins and scales but everything in the waters without these are not to be eaten and are an abomination." On this ground, clams and many other types of potential seafood are ruled out by followers of Leviticus (Tisdell 1986, p. 90). Thus, the cultural acceptability of species must be considered.

Other characteristics that serve as critical elements in evaluating consumer acceptance are flavours, appearance and texture. Certain species, such as those with barbels, spines and strange colour, are not favoured by some cultures. Liao and Smith (1984, pp. 446) found on the basis of their research that the consumer's reactions to species (prawn) as an aquafood product is related to the freshness, appearance, texture and taste.

All the factors noted above are important and must be factored into the decision regarding the choice of candidate species for the research and development programs that will lead to domestication and commercial mariculture.

Another group of market factors involves processing considerations. These relates to ease and cost of handling from harvesting to final packaging (selling) for local, domestic and export purposes. Species which have a rapid decomposition are most unlikely to be selected for export purposes. Also, the availability of transport processing and distribution facilities are important factors in commercial success. In this respect, it is suggested that preference be given to the selection of species for mariculture in LDCs which do not need sophisticated processing, transportation and distribution facilities since such facilities are likely to be in short supply in LDCs.

Finally, considerations about the size and structure of the market and the elasticities of demand and price for the products that can be grown need to be taken into account. An existing high price for a species in the market may not persist if the supply significantly increases. Therefore, such possibilities of market variation must be thoroughly understood, not only in the initial choice of a species for culture, but also in the conduct of the enterprise.

Having examined and characterized the market requirements for seafoods, we can now select a list of species that presumably will satisfy these requirements. The species selected need to fulfil cultural acceptability, high consumer acceptance, low decomposition rate and low requirements for processing and for distribution. In addition, we must be assured that they will command sufficient selling price in the market place, in conjunction with an appropriate production costs, to allow for an economically profitable venture.

4.2 Biological and Environmental Factors

A biologist could claim that in principle every species of plants or animals can be farmed, provided one is well informed about its biology, can offer the space required, the appropriate environmental conditions (climatological and hydrographical conditions), adequate food, and control of predators, parasites and disease. But mariculture which is technically possible may be economically impractical.

To determine whether a proposed mariculture venture is likely to be profitable, one of the first biological factors that must be considered is the growth rate of the species. Many of the most desirable seafoods in the market place are products from species that take several years in their native habitats to reach marketable size and condition.

For this reason, certain species may be relegated to secondary consideration as potential mariculture species. For example, several of the larger crustaceans, among them the lobster and crabs, fall into this slow growth rate category. Tilapias, on the other hand, can be bred easily and are hardy, high yielding, and reach marketable size quickly (Guerrero 1985, p. 3). Also, certain species of penaeid shrimps can reach marketable size in 100 days or less under appropriate grow-out conditions, stocking densities, feed quality, and feeding rate and with good farm management (Kenway 1987, p. 62).

Species requiring a short time for grow-out certainly are a more attractive prospect than others requiring two or more years of grow-out. Korringa (1979, pp. 27) suggests that commercially sound system of fish farming are based on rapid growing species which can be ready for the market in 10 months or less.

One reason is because species requiring a short grow-out period lend the venture greater versatility to respond to market variables and thus provide an opportunity to make profitable adjustment to demand for product size, form and volume. Also, net benefit will tend to be greater taking account of the interest discount factor. Benefit received now is worth more than the same amount received at some point of time in the future.

For species with long grow-out periods the cost and risks of maintaining high density population in confinement may be considerable. Compared to mariculture involving short periods, there well may be a considerable increase in risk due to price fluctuations, diseases, predation or pollution. Pollution is an important consideration in LDCs because usually in densely populated area there is considerable pollution of coastal waters, especially where industry prevails.

Growth rate alone however is not a sufficient measure of the appropriateness of species for mariculture. The costs of food necessary to achieve an acceptable growth rate must always be factored into the analysis before a judgement is made. The nature and amount of food needed to achieve a given level of growth may be the largest single item in the operating budget and it may well become the limiting factor in making choice about the suitability of a species for mariculture in LDCs.

Therefore, some authors have suggested that candidate species for mariculture could be assessed on the basis of their position in the food chain. Species which are low on the food chain (need little or no feed and/or fertiliser) are certainly more attractive than species which are high on the food chain. Species high on the food chain involve a high food cost, other things equal. For example, group of molluscs such as, clams (European), oyster, scallops and mussels are filter feeders living predominantly on live or dead microscopic plants. They therefore belong to the second link of the food chain and can be produced on a very large scale where the phytoplankton is rich enough (Korringa 1979, pp. 20). Giant clams are to a large extent phytotrophic and therefore can be regarded as being lower on the food chain than most molluscs.

The availability of seed production and breeding problems of species are also essential factors to be examined. Ling (1973, p. 23) and Korringa (1979, pp. 28) observed that a shortage of fry/seed supply is a serious bottleneck in many countries. For this reason, species which have high fecundity and fertility both in natural environment and under mariculture are important for commercial operations.

Hardiness or the immunity of species to environmental conditions (pollution, predation, and temperature) will reduce production costs as well as risks. The indigenous species are probably the best candidates to be considered for mariculture. This is because they are usually well adapted to the local environment.

Sometimes a species which can be cultured jointly with other species is advantageous, especially if complementarity in production occurs. In the latter case, polyculture can increase the return per unit of investment.

Additional considerations (not always readily appreciated by producers or funding agencies) include the environmental and social consequences of rapid movement into mariculture in tropical countries. One of the most frequently quoted examples concerns the denudation of large tracts of mangrove forest during the construction of coastal ponds. These are the natural nursery grounds of many cultivated or fished species of fish and crustaceans and the effects of their destruction could seriously affect the livelihood of many individuals. There is an urgent need for informed guidance on how much mangrove can be developed and how much should be left surrounding the farms to avoid ecological damage in the areas being developed. Therefore, species with few adverse externality effects should be favoured for mariculture.

4.3 Technological Factors

As indicated, subsistence-level and small-scale mariculture systems dominate mariculture in most developing countries. Material and management inputs are low and technology is primitive and generally traditional. Therefore, the success of production programs rests heavily on the species which can be developed given the limitations of technology and the level of management available. However, this does not necessarily mean that species which need imported technology and inputs cannot be successfully cultured from an economic viewpoint.

The technological factors which ought to be taken into account is the ability of the mariculture techniques for the species selected to create employment opportunities. Can the mariculture of the species selected add to employment of labour and improve income distribution? Does it involve a high labour/capital ratio?

Secondly, does the candidate species require import of technology and inputs? The species selected should desirably use inputs and technology available locally. Third, can the maricultured product be easily transported and stored? For example, oyster culture requires small financial inputs and uses simple technology. Processing and marketing can follow traditional methods and do not require sophisticated infrastructure and have little impact on the mangrove ecosystem (Angell et al., 1984, pp. 434). However transport and storage can pose difficulties.

From the above analysis, it is obvious that species selected for mariculture should fulfil appropriate requirements in relation to consumer acceptance, biological, environmental and technological criteria. Of course, these requirements vary widely between species and possibly there is no single species which can fulfil those criteria. Therefore, economic criteria are very important.

4.4 Economic Factors

Economic considerations must be taken into account in the assessment of the suitability of a species for mariculture. These are at least as important as the other factors discussed previously. The ultimate integrating criterion employed by most producers/investors is the return on the invested capital. Thus, it is useful for us to consider the economic components that influence return on investment.

With reference to marketing, the selling price that the species commands in the market place is clearly an important consideration for investors/producers. High value species are more likely to be chosen for culture than low value species since a high return on the investment is more likely to be realised other things equal. Low value species may however be justified if they have high productivity of marketable biomass per hectare per year, assuming that cost per hectare is similar to that for high valued species.

Similarly, the pattern of local and domestic demand as well as the economic potential for exports needs to be taken into account in determining the species chosen.

Grow-out time and its influence on cropping frequency is of great importance to the producers. These factors will affect the income received and determine the amount of investment required. A short grow-out species will not only generate cash flow, but will also reduce the degree of risk. This risk is a function of the cost of inventorying species, which are subject to disease, predation, market fluctuation, and social change. Such problems are most likely to occur in LDCs. In this regard, site selection is intimately related to species selection. The cost of land, energy and labour must also be weighted and entered into the cost effectiveness equation in which species is a central factor.

Labour and power cost requirements are operating budget items that must be considered when species selection is being made. In clam mariculture, for example, during the land-based nursery phase for juvenile clams, seawater has to be pumped or otherwise transported through the vessels holding them. To move large volumes of seawater by mechanical means can be costly and one needs some safeguards against pumping failure, if the water is being pumped. In this regard various technologies need to be evaluated from economic point of view (Tisdell 1986, p. 25).

The cost of feeding provides an important economic parameter for species selection. This consideration must be judged against a system where the animals are reared in ecosystems that can be managed as improved pasturage. That is, if the carrying capacity of a system can be increased by generating at least a portion of the nutrition required by the crop, then the cost of feeding can be materially reduced.

To examine the importance of grow-out time to producer benefit, let's consider a profit-maximising producer who has a cost-flow overtime, but sells his entire output at a single point in time. He purchases a brood-stock for I_0 dollars at $t = 0$. To grow the brood-stock, he has to spend the cost of G(t) dollars per year, and sells the product for R(T) dollar at t = T. This approach is taken from Henderson and Quandt (1971, p. 324-325). The present value of the entrepreneur's profit is:

$$D = R(T)\, e^{-iT} - I_0 - \int_0^T G\,(t)\, e^{-iT}\, dt \qquad (1)$$

Setting the derivative of D with respect to T equal to zero,

$$\frac{dD}{dT} = [R'(T) - iR(T) - G(T)]\, e^{-iT} = 0$$

Multiplying by e^{iT} and rearranging terms,

$$\frac{R'(T) - G(T)}{R(T)} = i \qquad (2)$$

The entrepreneur sells his product when his proportionate marginal rate of return with respect to time net of cultivation cost equals the rate of interest.

The second-order conditions requires that

$$\frac{d^2D}{dT^2} = [R''(T) - 2iR'(T) + i^2R(T) - G'(T) + iG(T)]\, e^{-iT} < 0$$

Multiplying by e^{iT} and rearranging terms,

$$[R''(T) - iR'(T) - G'(T)] - [iR'(T) - i^2R(T) - iG(T)] < 0$$

Substituting for iR(T) from (2) shows that the second bracketed term equal zero, and the second order condition may be written as

$$R''(T) - iR'(T) - G'(T) < 0 \qquad (3)$$

Substitute for i from (2) into (3) and multiply through by 1/R(T) > 0:

$$\frac{[R''(T) - G'(T)]\, R(T) - [R'(T) - G(T)]}{[R(T)]^2} < 0$$

which is the derivative of (2). The proportionate net marginal rate of return must be decreasing over time.

To determine the effect of an interest rate change on the growing period differentiate (2) totally and solve for dT/di:

$$\frac{dT}{di} = \frac{R(T)}{R''(T) - iR'(T) - G'(T)} < 0$$

Thus an increase in the interest rate will cause the entrepreneur to shorten his growing period, and a decrease will lead him to lengthen it. However, this simple model does not assume a shortage of available land (see Tisdell and De Silva; 1986).

Other considerations in selecting a species for mariculture are whether the species can be farmed as a sideline activity or a small part of a mixed production system or a full time production activity. The nature of productive activities has social and economic implications. Risks involve in full time specialised mariculture farming activity are greater than when it is a sideline activity.

Finally, since the bulk of fish-farmers in LDCs have little capital and poor technology, the species selected needs to be economical for small-scale production if it is to be widely adopted. This factor is important since it has implication for the smaller farmer and the income distribution.

5. CONCLUDING REMARKS

The assessment of species for mariculture in developing countries fall naturally into- five major categories, namely, consumer acceptance, biological, environmental, and technological criteria, and economics. But to these categories should be added social-cultural criteria, even though these overlap to some extent with some of the other categories. The economics depends amongst other things upon all these first mentioned factors as well as resource availability of the country in question.

Since mariculture in developing countries is still at undeveloped stage and it is dominated by small fish-farmers characterised by low material and management inputs, and low-level of technology, attempts to develop mariculture in LDCs orientated towards the welfare of coastal rural people need serious Government attention. Support services and financial provision may have to be instituted and re-oriented towards the small fish-farmers to encourage them to establish mariculture. Without purposive intervention from the Government and concerned institutions, small fish-farmers may not be capable of getting into the mainstream of the mariculture development.

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