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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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Aquaculture as a Use of the Coastal Zone: Environmental and Economic Aspects, Giant Clam Farming as a Development

ABSTRACT

There is increasing competition for the use of the coastal zone as economic development proceeds. This has resulted in the recent release of a Green Paper by the Queensland Premier's Department on coastal zone management. Economic development and conservation appear rarely, if ever, to be completely compatible, and the use of the coastal area for the development of aquaculture can have some adverse environmental effects. In Australia, aquaculture is relatively underdeveloped and the McKinnon Report sees scope for its expansion. A recent report prepared for the United Nations is also optimistic about the prospects of expanding supplies of fishery products by means of aquaculture. But environmental constraints on and production sustainability problems for mariculture are largely ignored in such reports. Giant Clam farming is a new mariculture possibility and has been developed as a response to dwindling wild stocks of giant clams. Most species of giant clams are now listed in the Convention on International Trade in Endangered Species (CITES). While giant clam farming has a number of desirable environmental features and self-sustaining properties compared to other forms of mariculture, it is not without some adverse environmental consequences. But in certain situations the economic benefit from farming giant clams can be expected to outweigh adverse environmental consequences. It pointed out that the environmental impact of mariculture of giant clams varies with the techniques adopted for their cultivation.

Keywords: Coastal Zone Management, Giant clam farming, CITES

JEL Classification: Q57, Q31

Aquaculture as a Use of the Coastal Zone: Environmental and Economic Aspects, Giant Clam Farming as a Development

1. Introduction

The coastal zone involves considerable social conflict about its use and this conflict has intensified with economic growth. The costs in terms of opportunities forgone of one development rather than other possible developments or of no development at all, have become greater. This has happened throughout the whole world as levels of population and incomes have risen, as new technology has expanded the number of possible uses for the coastal zone and provided improved access to it, e.g. via better transport. In addition, utilization of the coast for recreational purposes has become increasingly popular (an historical change of taste) and individuals now have more leisure and income to take advantage of its recreational opportunities. In Australia, as in many other countries, increasing demand to employ the coastal zone for outdoor recreation (and as a venue for indoor recreation too) comes not only from local inhabitants but from foreign tourists as well. Proposals for the use of the coastal zone for aquaculture including new forms of aquaculture such as Pacific Giant Clam mariculture need to be assessed against this background.

The Queensland Government has recognized Coastal Management as an area requiring greater and more efficient government attention and has suggested in its Green Paper, *Review of estuarine and coastal management procedures in Queensland* (Premier's Department, July, 1989) new administrative procedures for coastal and estuarine management. It suggests that in the past, demands to use the coastal area could be settled independently. But this is no longer workable: "Increasing population, growing economic activity and greater recreational opportunities now mean that in some coastal areas, close to major population centres there is a high level of competition for available resources (Premier's Department, July, 1989, p. 4).

Views differ about the extent to which mariculture (aquaculture in marine or brackish waters) is compatible with the conservation of nature, with the protection of the environment, and with alternative uses of the coastal area. Virtually no economic development is compatible with leaving Nature undisturbed. To that extent economic development and conservation of

the natural environment are incompatible, and it is nonsense (or at the very best wishful thinking) to suggest otherwise. But some forms of economic development including some forms of mariculture are more conducive to conservation and environmental goals than others, as will become apparent from the discussion below. Also it should be noted that conservation as a goal is not a straightforward goal. For example, some environmental changes may favour some species but be detrimental to others. Then one has to evaluate whether there is a satisfactory change overall in nature preservation or not, taking into account the relative value of species favoured and of those disadvantaged. The answer may not be clear-cut because of the difficulties of valuation and differences in valuation by different members of the community.

2. Development of Mariculture in Australia and in Queensland

Aquaculture is relatively underdeveloped in Australia compared to other regions of the world. By far the greatest producer of aquaculture products in the world is Asia, followed by Europe and then North America (Nash, 1988). It is estimated that approximately 40 per cent of world aquaculture production by weight is accounted for by marine products (UN Food and Agriculture Organisation, 1987). But in Australia possibly more than 90 per cent of all aquaculture production is from mariculture. In part, this is a reflection of the relative lack of freshwater in Australia compared to those continents in which aquaculture production is concentrated.

In addition, in Australia there is a relative lack of freshwater environments compared to the availability of marine environments. Note that "mariculture refers specifically to organisms cultivated in marine or brackish (for example estuarine) environments for part or all of their life-cycle" whereas aquaculture is the more general term and includes organisms farmed only in freshwater (Department of Industry, Technology and Commerce, p. 21).

In order of estimated value of production at the farm gate, the estimated relative importance of mariculture industries in Australia in 1987-88 were

(1) Pearl oysters ($53 M),

(2) Table oysters ($39.6 M),

(3) Salmon and trout ($6.7 M),

(4) Microalgae ($2.8 M),

(5) Prawns (shrimp) ($1.0 M),

(6) Barramundi ($0.8 M),

(7) Mussels ($0.8),

(8) Crabs ($0.4 M),

(9) Brine shrimp ($0.1 M),

(10) Macroalgae (seaweed) (negligible) and

(11) Other molluscs (negligible),

(Source: Department of Industry, Technology and Commerce, 1989, p. 25). Considerable expansion in the short term has been predicted for the value of Australian mariculture production, with expansion being especially rapid in production of prawns, barramundi, salmon and trout. One study (Garland, 1989) predicted a doubling of the value of mariculture production in Australia in a period of two years compared to production in 1987-88, with approximately a ten-fold expansion in prawn production, an eight-fold rise in salmon and trout output and five-fold growth in the value of barramundi production. Such an expansion will undoubtedly mean that those in the Australian mariculture industry will want to make greater use of coastal and estuarine areas for aquaculture. While expansion in salmon and trout farming will, on the whole, be confined to Tasmania, much of the expansion in prawn production, barramundi farming and production of other molluscs, such as giant clams, is likely to be concentrated in Queensland and require land and water space. In particular Queensland will need to give continuing attention to the environmental impact and economic consequences of mariculture of crustaceans in the State since Queensland accounts for about 80 per cent of Australian commercial activity concerned with aquacultured crustaceans (principa1ly *penaeid* prawns) (Department of Industry, Technology and Commerce, 1989, p. 27) and an extremely large expansion in activity is predicted.

While the recent McKinnon Report (Department of Science, Industry and Technology, 1989) on wealth from Australia's ocean resources was enthusiastic about the prospects for expanding mariculture in Australia, it also pointed to a number of difficulties:

- “overseas competitors have many years of experience, which is lacking in Australia
- a relatively small database of basic biological data about species which could be cultured [especially native species]
- use conflicts, when operators and/or government attempt to alienate space for aquaculture operations
- the over-complex regulatory environment in Australian government agencies, not yet adjusted to the needs of aquaculture; and
- the low level of awareness of international market factors" (Department of Industry, Technology and Commerce, 1989, p. 29).

Although the Report brings attention to the conflict problem over coastal space and suggests the need for action by the States to ease complexity of regulations adverse to aquaculture, as well as the need for governments to take positive action to promote the development of aquaculture, it says little about the possible environmental impact of maricu1ture and appropriate methods for resolving conflict about use of coastal space.

3. Aquaculture and Global Conservation Goals

Given worldwide concern about the environment, especially the environmental future and the sustainability of economic development, the General Assembly of the United Nations established the World Commission on Environment and Development to, amongst other things, propose long-term environmenta1 strategies for achieving sustainable development and to consider ways and means by which the internationa1 community can deal more effectively with environmental concerns. The recommendations of this Commission were published in *Our Common Future* (World Commission on Environment and Development, 1987).

One of its recommendations is that in order to improve food security, "the expansion of aquaculture should be given high priority in developing and developed countries", (p. 138). It argues that the capture fisheries will be unable to meet increasing demand. Supply from marine fisheries by early next century is likely to be well short of expected demand and most of the naturally available freshwater fish stocks are already fully exploited or damaged by

pollution. Therefore, there is a gap to be filled by aquaculture.

At the present time about 10 per cent of all the world's fisheries products are supplied by aquaculture. Approximately 7 per cent of fresh fish supplies, 75 per cent of mollusc production and 75 per cent of seaweed supplies are obtained from aquaculture (Nash, 1987). Asia is the main producer of fish products by aquaculture and within Asia, China and Japan stand out as being major producers, but other Asian countries are also substantial producers.

While there may be scope for substantially expanding the world's supply of living aquatic products through aquaculture, especially mariculture, it is surprising that *Our Common Future* does not bring attention to the environmental difficulties of doing this and in certain circumstances, the adverse consequences of aquaculture development for food supplies, conservation and the sustainability of production as well as the distribution of income. The consequences depend upon the type of product grown by aquaculture, the techniques used to grow it and the location in which it is grown. Different techniques are liable to have different environmental spillovers. Economic or conservation opportunities forgone as a result of the development can be expected to vary according to the location in which aquaculture is placed. Some types of mariculture developments, such as those associated with particular types of prawn (shrimp) production, involve low labour-intensities and high capital plus land ratios, and tend to increase inequality of income, at least initially, in communities in less developed countries. Furthermore, they can have serious adverse effects on conservation, the environment and on the sustainability of production.

4. Comments On Some Environmental and Sustainability Effects of Mariculture

In discussing the environmental impact of Third World aquaculture systems, Pullin (1989) divides these into three sets:

(1) *Extensive*. Those requiring no feed or fertilizer inputs.

(2) *Semi-intensive*. Having some feed and/or fertilizer inputs but not mainly reliant on these.

(3) *Intensive*. Mainly reliant on external food inputs

In this respect, it might be noted that at present most of Australia's mariculture production is

based upon extensive techniques (e.g. pearl and table oysters) but more intensive forms of mariculture such as salmon, prawn and barramundi production are developing.

Coastal and/or brackish water ponds for shrimp and prawns and for fish production e.g. mullet, sea bass or barramundi can have the following adverse environmental impacts: first, destruction of natural ecosystems, especially mangroves; second, salinization/acidification of soils/aquifers and third, the release of effluents/drainage high in biological oxygen demand (BOD) and suspended solids. Mariculture using sticks, rafts, pens, cages, etc., e.g. oysters, seaweed, some fish species, may present (a) a navigational hazard, (b) be incompatible with use of the area for recreational purposes and for fishing, (c) have an adverse visual impact, and (d) exclude wild species or lead to destruction of wild species because of habitat change e.g. seaweed culture which occupies pristine coral reefs.

Brackish water ponds in estuarine areas generally result in destruction of native habitat and a loss of breeding and hatchery areas for natural fish stocks, and may result in the destruction of mangroves which are valuable timber resources in many developing countries and loss of detritus and natural food sources for wild fish stocks. In some developing countries the 'seed' for mariculture is captured from the wild, but as mariculture expands it can reduce the availability of wild seed. This for example has happened in Ecuador. The construction of new ponds for shrimp not only demands more postlarvae but reduces their availability from the wild. Despite an approximate doubling of effort to catch postlarvae in the wild to satisfy the increased demand for seed as a result of expansion of the area of cultivation of shrimps, the number of semilla (postlarvae) caught has barely risen (Meltzoff and LiPuma, 1986).

Furthermore inequality in incomes may rise as a result of pond culture in estuarine or coastal areas. Areas which were previously common property become alienated and villagers are likely to be denied free access to them. Furthermore, areas alienated in some countries may be distributed according to privilege as appears to be the case in Ecuador (Meltzoff and LiPuma, 1986). Again, those reliant on fishing resources downstream of estuaries and along the coast near the estuarine outlets may find that their available wild supplies of fish species are reduced both due to lower availability of food for these species and less recruitment of stock. So the income of coasta1 fishermen and gatherers can be reduced severely. Such growing income inequality as a result of mariculture development was apparent to me when I visited Los Negros island in the Philippines in 1987. This is not to argue that common property (*res nullius*) is necessarily the best form of property for coastal resources but to

emphasize that where private property (de jure or de facto) is created environmental spillovers and income distributional consequences must be carefully considered.

There can be no hard and fast rule about the optimal form of property ownership from an economic viewpoint. We cannot, for instance, show from a conservation and sustainable development point of view that private ownership is always superior to common property. Where there are few spillovers from mariculture, as in the case of oyster production, private property may be more conducive to sustainability of production and the preservation of oysters than common access. But in other cases, such as pond culture in estuarine areas, common property may be more supportive of **overall** production because of its favourable conservation impact. This may be so for common property which involves common access (*res nullius*) or for that which involves communal management (*res communis*).

Sometimes mariculture is seen as a means of preserving a particular species. This, for example, has been claimed to be a benefit of turtle farming (Tisdell, 1986) and also of giant clam farming. However, some conservationists argue that farming leads to an expansion in demand for the product and increases harvesting pressure on wild stocks (see Tisdell, 1986), so reducing their numbers. Nevertheless, economically viable farming provides a strong incentive mechanism for the preservation of the farmed stock of the species. Still, farming does tend to result in a reduction in genetic diversity, that is in the number of species and varieties.

Another environmental aspect of aquaculture which needs to be considered is its susceptibility to water pollution. Filter feeders in particular are very susceptible to water pollution. This makes it difficult to sustain viable production from molluscs in areas where industrial pollution or pollution from other sources is increasing with economic growth. Indeed, some molluscs, such as oysters, are even susceptible to releases from anti-fouling paints used on the hulls of some boats. Let us consider the farming of a mollusc which has recently become available for mariculture.

5. Giant Clam Farming as a New Mariculture Development

Pacific giant clams, sometimes called killer' clams, belong to the family *Tridacnidae* and differ from several other marine molluscs which are also called clams. They are confined in their natural distribution to tropical and semi-tropical waters of the Indian Ocean and the

western side of the Pacific Ocean but not all species occur throughout that range. Indeed most species are only naturally present in a limited band fanning out from Southeast Asia to the Solomon Islands, Papua New Guinea and northern Australia. All currently recognised species, except *Hippopus porcellanus*, occur in northern Australia. The habitats of northern Queensland in particular seem to be very suitable for them (Cf. Lucas, 1988). The family is especially well adapted to tropical coral environments, requires warm water, good penetration of light of the water and an absence of disturbance by freshwater. They therefore tend to thrive on tropical coral atolls.

Populations of giant clams have been greatly depleted throughout their natural range (with the possible exception of Australia) as a result of harvesting by man. This is a consequence of greater demand as a result of human population increase and of new technologies which have made it easier to harvest the species and transport products from it over longer distances for consumers. In particular, Taiwanese operators have taken advantage of these technological developments but so too have some Australian operators in the Pacific islands. Technological developments include improved diving equipment, better ocean vessels, refrigeration and in some cases freeze-drying techniques. But apart from increased pressure on giant clams for commercial markets, greater harvesting pressure has also come from gathering of clams for subsistence food by indigenous peoples. As a result most species of clams are considered to be endangered and many have become locally extinct and the area in which they have become extinct is increasing. Hence, giant clams have been listed under CITES, the Convention on International Trade in Endangered Species (Lyster, 1985). The aim of such a listing is to reduce the possibilities for international trade which draws on natural stocks, lower the demand for their harvest and so help to maintain natural stock. However, not all countries are signatories to CITES, some (such as Japan) excluded a number of items listed under CITES and there are a number of loopholes and 'dishonest' practices that may be used to circumvent CITES restrictions on international trade in products from endangered species.

Possibly a more effective way for the conservation of giant clams has been discovered. Methods to breed them in captivity and to farm them have been developed in recent years. All species of giant clams have now been bred in captivity. The most recent species to be bred in captivity is *Hippopus porcellanus*, the China Clam, which is the rarest clam of all and very much sought after for the shell trade.

Techniques for the mariculture of giant clams have been developed mainly at two centres: (1)

The Micronesian Mariculture Demonstration Center (MMDC) at Palau with a considerable amount of financial assistance from the United States and (2) James Cook University (Department of Zoology) with the financial support of the Australian Centre for International Agricultural Research (ACIAR). But techniques are also being developed elsewhere e.g. in the Philippines, Fiji, Solomon Islands (ICLARM) and Papua New Guinea.

Basically three phases are involved in the mariculture of giant clams: (1) the hatchery phase, (2) ocean nursery phase and (3) grow-out phase. In the hatchery, which is typically located on the ocean foreshore, clams are bred and their progeny reared in saltwater tanks. At about 9 months of age, the seed clams are then transferred to a position in the ocean where they are protected by some type of covering (e.g. plastic mesh) from predators. This is the ocean nursery phase. At about 3 years of age (at this time *Tridacna gigas* are about 20 cm across) the clams can be moved to an unprotected ocean situation to commence their grow-out phase.

It is not possible here to assess all the environmental and conservation impacts of giant clam culture. However, the culture appears in many respects to be less environmentally damaging than many other forms of mariculture and it has appealing self-sustainability properties. Giant clams do not require to be fed or fertilized (indeed, much of the clam's food is manufactured by an algae which lives in its mantle and which provides the animal with its brilliant colours). Using the classification suggested by Pullin, mentioned earlier, the cultivation of giant clams is extensive rather than intensive. Closed breeding cycles have been established for the species which has been reared in captivity for the longest, namely *Tridacna derasa* and it appears likely that closed breeding cycles will be established for all species. Thus clam farming does not require continuing capture of broodstock from the wild or the taking of seed from the wild.

However, hatcheries do compete for scarce space when located on the foreshores of coastal areas, and ocean nurseries and grow-outs located on intertidal areas such as rock shelfs can have unfavourable visual impacts and crowd out coral and other species. While nurseries and grow-out areas located in the intertidal zone may be more economic than those located in subtidal benthic areas, subtidal benthic locations have the advantage of resulting in less adverse visual impact and may have a smaller adverse impact on other species. Rack culture is also a possibility. Clams are raised off the sea floor by the racks. The suspension of clams from floating rafts is a fourth possibility. Both of the last mentioned forms of cultivation may interfere with navigation. All types of clam cultivation may interfere with the use of the

ocean for recreation e.g. swimming and walking, except subtidal benthic cultivation. **In protected areas** however, it seems that at present intertidal ocean-nursery culture is more economic than subtidal benthic. At least at Orpheus Island near Townsville, available evidence indicates that intertidal culture involves easier construction of covers, easier maintenance; less fouling of covers and better growth and survival rates for giant clams than alternative methods (Lucas, Braley, Crawford, Nash, 1988, p. 130). But in exposed situations, damage may occur to protective covers and growth and survival rates of clams may be smaller. One can at least envisage circumstances in which the more economic methods for giant clam cultivation are those which are not so satisfactory from an environmental point of view. The question then arises of the extent to which environmental values should be forgone for economic gain.

Economists have argued that environmental protection or conservation is not an absolute good in itself (Tisdell, 1990, forthcoming). They suggest that the economic benefits of a development have to be compared to its environmental costs. A development is, according to this point of view, justified if the net economic benefits from it outweigh its estimated environmental costs. Furthermore, the socially optimal technique to use is that which gives the highest returns after an allowance for environmenta1 costs are subtracted from private returns. Thus, even if intertidal culture of giant clams involves greater environmental damage than the alternative of subtidal, intertidal culture may still be justified in economic terms in some localities, if it is sufficiently more profitable. This is not to deny that there may be difficulties in measuring environmental costs and we also need to be aware that partial evaluation can lead us to overlook global problems (Tisdell and Broadus, 1989). In the case of giant clam mariculture, much more research will be needed before economic benefits and environmental costs can be quantified with accuracy.

6. Concluding Comments

For many, the oceans are our last frontier for development. Man has conquered the land and has subdued Nature upon it, and is cultivating and husbanding a major portion of it. Man's domestication of sea creatures and plants and man's control over ocean resources lags far behind his control overland, which is probably a reflection of the fact that man is a terrestrial animal. While some international bodies (World Commission on the Environment and Development, 1987) and national bodies (McKinnon Report, Department of Science,

Industry and Technology, 1989), see great potential for the economic development of ocean resources to support economic growth, such development will not be without environmental costs and ill-considered ocean development may well be unsustainable.

On the other hand, there is scope for beneficial development of ocean resources including expansion of mariculture, both in the world as a whole and in Australia in particular. Unnecessary government impediments to such development need to be pruned away since they will restrict business enterprise **some** of which may be in the general interest. However, the problem is complex. Some government control must remain since the environmental impacts of ocean developments have to be taken into account and the competing demands of others to use the coast must be considered in dedicating any part to a particular use.

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1. "Market for Giant Clam Shells: Report on a Survey of Retailers and Wholesalers in Southeast Queensland, Australia." Clem Tisdell with the assistance of Rene Wittenberg, November, 1989.
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