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Working Paper No. 21

ACIAR-Supported Research on The Culture of Giant Clams (Tridacnae): A Multi-Faceted Economic Assessment of Research Benefits (Draft Appraisal)

by

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April 1991

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Research for the project *Economics of Giant Clam Mariculture* (Project 8823) is sponsored by the Australian Centre for International Agricultural Research (ACIAR), G.P.O. Box 1571, Canberra, A.C.T. 2601, Australia. The following is a brief outline of the Project:

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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ACIAR-Supported Research on the Culture of Giant Clams (Tridacnae): A Multi-Faceted Economic Assessment of Research Benefits (Draft Appraisal)

ABSTRACT

ACIAR has been funding research into giant clam mariculture since 1983/84. By the time this research terminates in 1991, ACIAR will have provided $3.2m in research funds. The benefits of this ACIAR-sponsored research are assessed from several different points of view applying diverse types of project appraisal. Market-related cost-benefit analysis (CBA) similar to that used by Davis, Oram and Ryan (1987) is applied to estimate benefit-cost ratios. A benefit-cost ratio of at least 4.8 on ACIAR's research expenditure is estimated, when a zero rate of discount is applied. But even when a positive rate of discount is applied, the benefit-cost ratio can be expected to exceed unity. Conway's agroecosystem approach to project appraisal is also applied. The development of giant clam mariculture is found to be meritorious in terms of *sustainability*, to have good *stability* properties and potentially favourable *income distribution* effects. The level of returns from giant clam mariculture are still uncertain but there are prospects of above normal returns, even though financial returns are not immediate. Thus the development seems to rate positively applying Conway's approach. This is also true for extended CBA and sustainability supplemented CBA. Evolutionary-type appraisal of the ACIAR-supported research is favourable in terms of the diversity of research approaches tried, the diversity of possible economic developments based on the mariculture, the scope for small scale production and the appropriateness of technologies developed. A range of benefits have been or can be expected from this project for Australia and for less developed countries, and these are listed. The; project will not only yield tangible direct contributions to economic production but indirect non-materialistic (non-consumptive) benefits, e.g. conservation benefits in terms of existence, option and b quest values. Conservation benefits are a major advantage of this project, but even without these it would be justified in economic terms.

Keywords: ACIAR research, Giant Clam Culture, cost-benefit analysis, R & D,

JEL Classification: Q57, Q31

ACIAR-Supported Research on the Culture of Giant Clams (Tridacnae): A Multi-Faceted Economic Assessment of Research Benefits (Draft Appraisal)

1. Background

ACIAR has been funding research into giant clam mariculture since 1983/84. By the time this research terminates in 1991, ACIAR will have provided almost $3.2m in research funds for the project, making this one of the largest projects supported by ACIAR. Currently ACIAR is undertaking an economic assessment of research projects which it has funded, to provide guidance on the economic benefits received in relation to its outlays. These will form part of the assessment of ACIAR and will provide information to the Australian Government for its decision on whether to extend the life of ACIAR and/or what reforms to make in its purpose, organisation, etc. When ACIAR was established it was subject to a sunset clause. The consequence of this is that it will go out of existence unless the Australian Government makes a positive decision to extend its life.

The economic assessment of the ACIAR-sponsored giant clam project is more difficult than for most ACIAR projects because of the nature and range of benefits involved, some of which, although real, such as conservation benefits, are intangible or non-consumptive in type and since a new industry is virtually being established or re-established the degree of uncertainty involved, especially about the prospective market is considerable. Because of this, it is important to assess the project using different methods of appraisal and in particular to supplement narrow cost-benefit analysis. Four appraisal approaches will be applied:

1. social cost-benefit analysis,
2. Conway's agroecosystems criteria,
3. extended cost-benefit analysis, including an extension to allow for sustainability and
4. ‘evolutionary-type’ assessments.

Each of these will be applied in turn. But let us consider in more detail the special nature of this ACIAR project which necessitates economic assessment from diverse viewpoints before summarising the results of the application of these.

2. Special Nature of this ACIAR Project (Nos. 8332 Plus 8733) and Difficulties in Evaluating its Economic Benefits

The nature of this ACIAR project for culture of giant clams differs from most other ACIAR projects in two important respects:

1. It is pioneering means to establish virtually a new industry - that is, to establish a new product(s) based on giant clams in the market place.
2. It is also providing methods and means that have saved or are likely to save species of giant clams from extinction and to re-establish them in areas where they have already become locally extinct. Thus conservation of species is an important benefit from the research.
3. In addition the research is providing means whereby subsistence and semi-subsistence coastal dwellers in tropical and subtropical countries can cultivate giant clams or restock their reef areas with clams thereby increasing locally available supplies of high protein food for their diet.
4. Furthermore giant clam production involves important properties of *sustainability* from a production point of view.
5. Also much of the research which has been undertaken is of a cost-reducing nature and productivity enhancing as far as methods of giant clam culture are concerned. But, unlike most other ACIAR projects, the latter aspect can be regarded as a secondary or flow-on aspect.

Most ACIAR projects have been concerned with the development of methods to reduce the costs of production of commodities already in existence, for example the development of methods to control pests. The net effect of such research is an increase in agricultural productivity and a decline in per unit cost of production. Well-developed economic techniques exist for measuring the economic benefits from such changes (Davis, Oram and Ryan, 1987) even though in practice they only provide partial measurement.

Because the giant clam culture project has been so innovative and the applications of its results continue to evolve and develop, both the eventual size of the market and demand factors as well as cost of production factors still remain uncertain. This makes it dangerous to rely on any precise quantification of economic benefits. Nevertheless substantial economic benefits can be identified and up to a point some indicative quantification of potential

benefits is possible.

It is clear that the application of a variety of approaches to economic assessment are likely to provide the most satisfactory appraisal of this project. It is useful to summarise the results obtained by applying the four approaches to appraisal mentioned above.

3. Returns On R & D Using Market-Based Cost-Benefit Analysis

Market-based assessment of returns on R & D expenditure using social cost-benefit analysis was pioneered in the 1970s and extended in the 1980s (Davis, Oram and Ryan, 1987). Basically, it uses increases in producers' surplus (increased profits or benefits to producers) plus increases in consumers' surplus (benefits to consumers, for example, achieved as a result of price reduction brought about by the research results) to measure social benefits.

Industry supply and demand curves for farmed giant clam products are not as yet firmly established so any indication using this method will be subject to some speculation. However, using data obtained from surveys in Australia and New Zealand it is estimated that the size of the potential Australian market for giant clam meat is at least 3,000t per year at a retail price per kg of $10 - $12 (Tisdell and Wittenberg, 1990a,b). Assuming that clam meat sells for $5 per kg *in situ* or at the farm-gate, it is estimated that a standard ocean-based clam farm putting down 100,000 clam seed per annum can earn an internal rate of return of 19.5% per annum on its investment assuming that it buys clam seed at 75c each. This amounts to a steady amount of profit of $155,299 per annum when it is fully established (Tisdell, Tacconi, Barker, Lucas, 1991) and assuming Australian costs and other conditions.

It seems that the Australian and New Zealand market would support approximately 15 clam farms of standard size. When established they would earn a total profit annually of about $2.329m or an above-average profit of about $1.2m per annum.

In addition, however, profits from land-based nurseries must be taken into account. A fully established industry supplying the potential Australian and New Zealand market would need 1.5 million seed clams per year. Three nurseries turning out 500,000 seed clams per year could supply this market. The cost of producing clam seed inclusive of interest on capital has been estimated for nurseries of this size to be 41 - 45 cents per seed clam (Tisdell, Lucas, Thomas, 1990). In round terms assume 50 cents (which might include delivery cost). If clam

seed sell for 75c, on the sale of 1.5 million clam seed a year this would amount to a surplus profit in aggregate of approximately $0.375m. Over a 10 year period this adds up to $3.75 million. Therefore the undiscounted benefit to cost ratio considering only profit on the supply of nursery seed would be at least 3.75/3.2 = 1.17. Of course, over a 20-year period the ratio would be twice as large.

If the pure profit from supply of clam seed and from supply of clam meat for the Australian and New Zealand market are added together this amounts to $11.65m + $3.75m = $15.4m. Dividing this sum by the ACIAR research outlay on giant clam research, the undiscounted cost benefit ratio is 15.4/3.2 = 4.8. This ratio would be higher (at least 9:1) if all profit, not just pure profit, is counted.

However, it should be emphasised that this ratio is indicative rather than precise. Considerable **uncertainty** is involved in predictions for a virtually new and embryonic industry. Also there can be argument about the appropriate cost figure for the research to use because collaborating institutions have also provided some funding, albeit the minority share. Furthermore, how should R & D expenditure funded outside Australia be counted? Just how much of the progress is due to ACIAR- sponsored research and how much to that of other bodies such as MMDC and ICLARM? The benefits of the research to LDCs have not been counted nor have all the spillover benefits in Australia been included. Nevertheless, the weight of evidence clearly indicates an expected benefit to cost ratio for this ACIAR-sponsored clam research exceeds unity[1].

4. Conway's Multiple-Objectives Approach

Cost benefit analysis tends to be single dimensional in that it aims to reduce all benefits and costs to monetary values and then select the strategy giving the greatest net benefit. It is, therefore, possible for CBA not to capture important elements involved in economic choice. Conway (1985, 1987) has suggested that four characteristics need to be taken into account specifically when assessing productive techniques or systems. These are consequences of the techniques for

[1] Note that consumers' surplus is not taken into account in the above assessment. If it were, total benefit using this method would be even greater. The other matter which is not addressed is the rate of phasing in of clam farms. The above estimations assume simultaneous phase-in of all the ‘required’ farms and nurseries. This will be modified in subsequent analysis.

1. the level of economic returns, production, or income,
2. the sustainability of the above,
3. the degree of instability (fluctuation or variability) in returns or incomes, and
4. the degree of inequality in the distribution of income.

Other things equal, Conway suggests that techniques or economic activities are to be preferred which exhibit greater economic returns, show greater sustainability of returns and less variability of returns and promote greater equality in the distribution of income. But it is rarely the case that a single economic activity is superior to all others in every respect. That being the case, priorities or trade-offs need to be established. While Conway is not specific about priorities or trade- offs, it is clear from his published works that he personally places a high priority on sustainability. However, traditional cost-benefit analysis places no value on sustainability as such. Suggested characteristics of giant clam culture in terms of Conway's variables for social choice are listed in Table 3.

Table 3: Characteristics of Giant Clam Mariculture in Terms of Conway's Multiple-Objectives and 'Ratings'

Level of Returns (Satisfactory but uncertain)

- In Australia, the potential level of returns seems to be above average but uncertain.
- In LDCs, it is doubtful if returns are as high as for seaweed cultivation - commercial returns likely to vary with country location - comparative productivity of giant clam mariculture for subsistence purposes yet to be assessed.

Sustainability (Excellent)

- Ecologically sustainable because a closed breeding cycle has been established and farming need not be environmentally degrading - environmentally more friendly than many other forms of mariculture.
- Economically sustainable in that not dependent to any great extent on imported inputs. In LDCs, clam meat can be consumed locally if not exported. Meat is high in protein.
- Ocean stages of mariculture are technically relatively simple. This is the stage in which villages in LDCs are most 1ikely to be involved in this form of mariculture. This simplicity favours transfer of skills and makes for sustainability.
- Within village communities, this form of farming seems to be socially sustainable given adequate communication with and support from village leaders. Local marine property-rights and social structures need to be taken into account to achieve sustainability (Fairbairn, 1990 a,b,c,: 1991a).

Stability of Returns or of Level of Production (Good/Very Good)

- Clam production is subject to possible losses from tropical cyclones but severity of loss likely to be less than with land-based crops such as coconuts. Disease and related risks are still being assessed.

- Have advantage that they can be stored in situ and therefore are not subject to forced selling or consumption as with perishable crops. Period and timing of harvest is flexible.

Income Distribution (Potentially excellent in LDCs)

- In many LDCs, due to overfishing and other forms of natural resource overexploitation coastal dwellers including fishermen are extremely poor. Since this form of mariculture can be practised on a small scale it gives coastal dwellers a chance to supplement their diets and their incomes.

- However, unlike for seaweed which is easily propagated from cuttings from existing seaweed beds, most villagers at least initially would need to purchase clam seed (Firdausy and Tisdell, 1989, 1990). This could be a problem for poorer members of the community unless seed is made available at subsidised prices through foreign aid.

- Large commercial undertakings for clam farming in LDCs could have adverse distributional consequences. Whether this would be so would depend on institutional arrangements, e.g. whether local villagers are excluded from operations or from clam beds. Whether or not clam farming has favourable or unfavourable distributional consequences will depend on the institutional arrangements adopted Cf. Fairbairn, 1991b).

Examination of Table 3 indicates that giant clam mariculture would be rated very high from the point of view of its sustainability characteristics, high from stability point of view once established, and high from a distributional point of view if appropriate institutional arrangements are adopted. In relation to level of returns and productivity, it is too early to be definite. However, the available evidence indicates that above average returns are possible and that giant clam farming could be a very productive means of supplementing protein in diets in many LDCs, especially Pacific atoll countries which have few opportunities for adding to local production (Bertram, 1986; Tisdell, 1990a, Ch. 10; McKee and Tisdell, 1990 Pt. III). In terms of production of edible protein (meat), the productivity of giant clam mariculture seems high (Munro, 1988).

5. Extended CBA And Sustainability-Supplemented CBA

Extended cost-benefit analysis usually refers to extensions to CBA to allow for environmental spillovers or externalities from projects. Where possible the impact of environmental externalities are expressed in monetary terms, favourable externalities being a

positive addition to benefits and unfavourable externalities being a deduction from the benefits of the project when assessed narrowly. However, in practice economic assessment of externalities is not a straightforward matter.

Take, for example, a project involving an unfavourable externality. The economic effect on those adversely affected could be measured in two different ways: (1) By the amount they need to be paid (willingness to accept compensation) just to be as well off as without the externality. (2) The minimum amount which they would be willing to pay to avoid the externality. These measures may give different values. As Mishan (1981) points out, choice of the socially appropriate measure has more to do with morality rather than economics. Furthermore, even in cases where externalities are taken into account, compensation may remain purely hypothetical because the Kaldor-Hicks criterion or **potential** Paretian improvement test is used: if gainers **could** compensate losers from a change then it is considered to be socially desirable.

Giant clam-farming, unlike prawn or shrimp farming, appears to have few if any unfavourable externalities, even though in some cases it could conflict with recreational or tourist use of inshore areas (Tisdell 1991b).

Pearce et al. (1989) have proposed that cost-benefit analysis be extended to take account of sustainability. They argue that it is desirable to maintain the present stock of natural-resource capital even though they permit trade-off against man-made capital in some cases. They suggest that some projects cause depreciation in natural capital stock but others augment it. What is important is that for an appropriate set of projects the depreciation of natural capital stock be zero, that is that sustainability effects be required to balance out.

This approach, which is akin to Natural Resource Accounting, is not without difficulties (Tisdell, 1991d; Tacconi and Tisdell, 1991) e.g. in relation to measurement, but it does mean that sustainability issues are not entirely overlooked in project evaluation.

Giant clam culture would appear to make a large positive contribution to sustainability of natural stocks. It seems to have saved a number of clam species from possible extinction and it provides a means to add to natural clam stocks by reseeding reefs which have been depleted of wild clams. The research has, apart from its more materialistic benefits, helped to maintain existence values e.g. by saving the China Clam, *H. porcellanus* from almost certain extinction and it has kept options open for future use of giant clam species. In addition, it is

helping to satisfy bequest values for example, islanders in the Lau Group, Fiji, expressed interest in giant clam farming so that their children could enjoy clams as a part of village life (Vuki et al., 1991).

On the other hand, farming can also bring with it some dangers to sustainability of species (see Tisdell, 1991) and risks are involved in translocation of species which not only include accidental spreading of pests and disease but possible adverse impacts on ecosystems and genetic diversity. Nevertheless, on balance the ecological sustainability benefits of giant clam culture seem to be overwhelmingly positive.

6. Evolutionary-Type Approaches To Assessing R & D

Evolutionary-type theories tend to view the human situation rather differently to traditional optimising models of human behaviour. Uncertainty is seen as being very important and much of human behaviour is seen as being experimental. It is characterised by (inescapable) bounded rationality (in the sense used by Simon, 1955), by trial-and-error and by learning-by-doing rather than by optimising *ab initio*. Behaviour, or much of it, involves dynamic interaction with the 'rest of the world' rather than static optimising.

Given uncertainty, diversity in approaches to problem solving is seen as an advantage (Metcalfe et al., 1990). In research and development (R & D) diversity of approaches is seen as more likely to advance knowledge than uniformity or to advance it at a faster rate. While some research approaches will inevitably fail or prove to be inferior, which ones these will be can rarely be known in advance or at least the set of all these can rarely if ever by known with certainty. If we had such knowledge, R & D itself would virtually be superfluous.

From the point of view of being diverse, research into giant clam culture worldwide appears to pass the test. Different countries tended to concentrate on the culture of different species of giant clams. For example, MMDC concentrated on *T. derasa*, the Japanese on *T. crocea* and ACIAR-sponsored research at James Cook University mainly on *T. gigas*. Furthermore, different methods or techniques for culture have been explored by the different research groups e.g. James Cook explored high-tech hatchery techniques whereas MMDC concentrated on low-tech extensive techniques, e.g. micro-encapsulated diets for clams in the veliger stage were explored by James Cook. Because of the species involved, ocean culture at James Cook tended to be intertidal, rather than sub-tidal as at MMDC. One could easily add

to the list of diversity in R & D in this area. It is normal practice in the development of new techniques for diverse ‘prototypes’ to be developed and then, as a result of learning, for some of these to be discarded in favour of superior ones in the set. ‘Failures' are in a sense as important for progress as 'successes' because there can be very little progress in knowledge without some failures.

Research into giant clam culture offers diversity in another respect. Potentially it can result in a diversity of end-products as well as a diversity of techniques, some of which may be most appropriate to less developed countries. Collaborators in ACIAR research from the Philippines, Fiji and other areas have been adapting clam culture techniques to local environments and conditions (PCAMRD; ACIAR, 1989). ICLARM sponsored research in the Solomon Islands has, as part of its mission to develop appropriate technologies for mariculture in the South Pacific, taken into account the availability of local resources. Overall it is recognised that giant clam cultivation techniques that might be applicable in Australia (or Japan for that matter) may not be most appropriate or may require adaptation for application in less developed countries.

Some members of the 'evolutionary-school' argue that small is not only 'beautiful' but socially optimal. Small-scale productive arrangements are to be preferred and techniques which preserve local (small) communities are to be preferred (Schumacher, 1973) both on environmental grounds and on the basis of human welfare. While I do not intend to debate the merit of these arguments here, it might be observed that ocean growout of giant clams can be on a small scale. No particular economies of scale seem to exist and it is well adapted to preservation of local communities in LDCs. This is a positive point in its favour.

On the other hand, land-based production of clam seed seems to involve substantial economies of scale when the techniques developed at James Cook University are applied. The technique would seem to suggest that central hatcheries supplying seed clams would be most economic (Cf. Tisdell, Lucas, Thomas, 1990). Central hatcheries may also make less demand on natural stocks of clams for brooders since they are more likely to establish closed breeding cycles for clams. Nevertheless, there has been some experimentation e.g. in the Philippines, with hatchery techniques appropriate to the village level.

Thus, in terms of diversity, possibilities of small scale operations and development of appropriate technologies research which has been done into giant clam culture would appear

to merit a high rating from an evolutionary-type viewpoint. This qualitative assessment is summarised in Table 4.

Table 4: Characteristics of Research and Development in Giant Clam Culture and Rating from an 'Evolutionary' perspective.

Characteristic	Further Details	Rating
Diversity	- diversity of research approaches	+
	- diversity of techniques	+
	- diversity of potential products	+
Small-scale production	- possible for ocean phase	+
	- possible but likely to be less economic and practical for first nursery stage	-?
Appropriate technology	- different production techniques have or are being developed for 'advanced' economies and for less developed countries	+
Simplicity	- ocean phase simple	+

7. Benefits of ACIAR-Sponsored Giant Clam Research to Australia.

It is usually expected that research funded by ACIAR will bring benefits to less developed countries as well as to Australia. It may therefore be useful to list some of these perceived benefits even though they cannot all be quantified.

From Australia's point of view the following benefits have been received or can be expected:

1. Development of local expertise on mariculture, particularly clam culture, which has enabled advice and practical assistance to be given to commercial giant clam farms in Australia.
2. Information and demonstrations of techniques assist establishment of commercial farms in Australia. The profit obtained by these farms form part of the economic benefit as discussed in section 3.2. In addition, benefits or surpluses are likely to be obtained by Australian consumers of giant clam products.
3. Although these are more difficult to measure from an economic viewpoint, development of giant clam farming techniques should assist economic development in Northern Australia. In the past, this has been a priority for some Australian governments. Giant clam farms are ecologically most suited to tropical waters.

4. Some aboriginal communities, such as those on Palm Island and in the Torres Strait Islands, may be able to benefit economically from the farming of giant clams. Palm Islanders already have established giant clam farming activities.
5. The industry will add to employment opportunities in the North of Australia both directly and indirectly and help to diversify the economy in this area. But one should not expect large increases in employment in the Australian environment. Possibly nurseries and giant clam farms (assuming around 15) could employ directly at the most 60 people. But with processing, packing, and indirect employment the number would be higher, e.g. of the order of 250.
6. While one might question whether export income should be given special value, it is often seen as having particular merit. The research will have assisted in the development of an Australian industry with good prospects for exports and earning of foreign exchange. This can occur through (a) export of clam meat, e.g. to New Zealand and Japan, clam seeds and specimens for aquariums; (b) export of equipment needed for giant clam farming and (c) sale of consulting services and expertise.
7. Development of skills and knowledge by Australians in this form of aquaculture has added to local expertise in mariculture, to the general advancement of knowledge. While a substantial part of the advances has been in applied science, there have also been advances in pure and curiosity science e.g. the identification of a new species of clam.
8. The research has promoted a spirit of co-operation and understanding between Australian researchers and those in Southeast Asia and the Pacific. It has been beneficial from the point of view of international relations, and provides tangible evidence of Australia's concern for its less developed Pacific neighbours.
9. Academic outputs from the project have included learned and practical publications and training of university students. Many of the benefits from these are likely to come in the form of future and indirect benefits.
10. In this area of research, Australian researchers are now recognised as being amongst the world leaders. This is largely (almost wholly) due to ACIAR's support of this research.

Thus Australia has received a substantial range of benefits from this research project. While these cannot all be quantified, they are nevertheless important and the range of them would seem to compare more than favourably with those from other ACIAR-sponsored projects.

8. Benefits Of ACIAR-Sponsored Clam Research For Less Developed Countries

Less developed countries often differ in their socio-economic characteristics and economic situation. For example, there are clearly major significant differences between the Philippines' economy and that of Kiribati or Tuvalu in terms of market size, degree of industrialisation and commercialisation, available natural resources, locational advantages and disadvantages and, in this case, experience with and development of mariculture. We must, therefore, be careful about treating all less developed economies as if they have virtually the same characteristics. For example, the benefits to the Philippines of giant clam farming may be mainly for commercial development, whereas in Tuvalu and Kiribati local subsistence development may be relatively more important. Despite these differences a number of general benefits of giant clam culture can be listed for less developed countries.

These include:

1. The possibility of supplementing subsistence diets or incomes by stocking or restocking reefs or other suitable habitats with giant clams. In this respect it is pertinent to emphasise that giant clam meat is high in protein, and protein deficiency exists in some rural coastal communities. Poverty amongst coast-dwellers is common in southeast Asia, partially because of overfishing and overexploitation of the coastal zone, and would be more common in the Pacific Islands in the absence of foreign aid.
2. Giant clams also have advantages for **local** consumption because they are easily storable *in situ*, in 'clam gardens' or in ocean areas close to villages. Because of this storage characteristic, clam stocks can easily be drawn on when seasonal food shortages occur, or when the weather is too inclement for fishing to take place, or the fishing catch is below expectation.
3. In some Pacific villages, clams are eaten on special occasions or for feasts. Preservation of clam stocks will, therefore, assist in preserving traditional customs. Interviews in the Lau Group, Fiji, revealed that many villagers were interested in giant clam culture to ensure that supplies would be available for future generations, thereby helping to preserve traditional culture (Vuki et al., 1991). This may be regarded as a bequest value.
4. Clam mariculture can also provide opportunities for villagers to earn supplementary cash income. In the Pacific Islands, clams have been sold at local markets for cash when they have been available e.g. in Suva and Nausori, Fiji. At one stage, frozen clam meat was

also sold in ‘blister packs' in supermarkets in Suva, and if adequate supply happened to be available the market could presumably be re-established (Tisdell, 1986). The importance of local markets should not be underestimated. In the case of the Pacific Islands, local supplies for example can substituted to some extent for imports of tinned fish and other meat, and in some cases, could lower the amount of foreign aid required to supplement local incomes.

5. There are also prospects for exports of giant clam products from LDCs but not all LDCs are likely to be equally well placed from the point of view of achieving substantial export sales. For example, distance from export markets, poor international transport links, and in some cases stringent health or quarantine regulations imposed by importing countries can seriously limit a country's export markets for giant clam meat. However, it is possible that product developments, such as suitable smoking techniques for clam meat or innovations in transport such as suitable aquarium type containers for transporting live clams by ship could overcome some of these limitations. At the present time, it seems quite possible for the Philippines and possibly Fiji to develop an export trade in maricultured clam meat but prospects for Tuvalu and Kiribati in this respect do not seem to be bright, even though giant clam culture for them would be valuable for subsistence and supply of local markets, e.g. Funafuti and Tarawa.
6. James Cook University has assisted with the setting up of giant clam nurseries in LDCs e.g. in Fiji and the Cook Islands and have sent *T. gigas* clams to LDCs e.g. to Fiji and Philippines for rearing and providing future broodstock of these species. By supporting hatchery and research facilities in LDCs, ACIAR-sponsorship is enabling clam production techniques to be adapted to local conditions, helping to save or reintroduce species such as *T. gigas* which have become locally extinct and ensuring that adequate experimentation and trials take place under local conditions before widespread clam farming commences. This would seem to be a rational procedure in an uncertain world. It is dangerous to apply blindly results obtained in Australia for example without seeing first of all whether they are applicable in a different socio-economic and environmental setting.
7. ACIAR sponsorship has resulted in the development of local skills and growth of knowledge in LDCs about mariculture and giant clam mariculture particularly at government- and university-level in LDCs. This means that expertise has been created which can be used to assess giant clam farming developments or proposed developments e.g. applications by commercial companies or organisations to commercial clam farming

and to give advice and back-up to those involved in clam development, e.g. at the village level. In most cases, plans exist or already have been implemented for extension and official co-operation at the village level, e.g. in Fiji and the Philippines.

8. Local employment opportunities are few in the rural areas of most LDCs and ‘underemployment' is widespread. This encourages a drift of the rural population to urban centres. By providing extra employment opportunities in rural coastal areas, giant clam farming should make a small contribution to stemming this flow.
9. For LDCs giant clam mariculture has a number of sustainability properties that increase its attractiveness. It will allow diversification of income sources, but more importantly, it is not dependent upon continuing inputs of raw materials. This is because giant clams feed naturally by utilising principally sunlight and minerals in the water via their symbiosis with zooenthellae in their mantle. This contrasts, for example, with prawn (shrimp) and eel farming. This requires the supply of animal-based protein for the feeding of the stock. Very often this has to be imported. For example, in Shenzhen, China, ‘fishmeal' for feeding eels is imported from the USA at considerable cost (Tisdell, 1990b, p. 47). This is justified since reared eels are exported but it is risky since (meal' prices can vary suddenly and enterprises can lose money because retail prices of eels do not rise sufficiently or quickly enough.

Of course, it would be incorrect to give the impression that giant clam mariculture in LDCs can only have benefits. Some of its present drawbacks are as follows:

1. Problems involved in transportation and preservation of giant clams are greater than, for example, the case for seaweed but not, say, in comparison with prawns and shrimps.
2. A comparatively long period of growing-out is likely to be optimal in many LDCs, most likely about ten years. Initial financial returns are therefore slow in coming (as with coconut), and if cash investment is required, 1iquidity or cash flow problems could be encountered initially (Tisdell, Barker, et al., 1991). Investment in seaweed in suitable localities appears to give a much faster payback (Firdausy and Tisdell, 1991).
3. Export markets and channels of distribution for giant clam meat are not yet fully established or re-established. Uncertainties still exist about the market for giant clam products especially the potential international market in more developed countries, However, uncertainty is to be expected because a major innovation is involved.

9. Concluding Comments

Narrow economic assessment of the value of R & D is rarely if ever adequate in itself, and as Pigou (1932) has pointed, out welfare economics can only provide us with a partial indicator of welfare. Furthermore, there are a number of different possible economic approaches to assessing projects, each of which sheds light on different facets of its economic value. Thus a holistic rather than a single approach such as CBA is needed. A holistic approach requires that one assesses a project from different angles and then, in all humility, recognises that some facets may have been missed or overlooked. I have adopted this holistic approach in my socio-economic assessment of ACIAR-sponsored research into giant clam mariculture.

For the various economic approaches to assessment considered here the ACIAR-sponsored giant clam project appears to have a positive net economic value. Cost- benefit analysis indicates that the anticipated rate of return on the project exceeds the rate of interest and the benefit to cost ratio is likely to be substantially in excess of unity. But cost-benefit analysis does not capture the full economic value of the project, especially from an economic development point of view. The wider approach used here to supplement cost-benefit analysis helps to rectify this for this innovative research and development project which has been supported by ACIAR.

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