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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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Ocean Culture of Giant Clams (*Tridacna Gigas*): An Economic Analysis

ABSTRACT

The economics of growing *Tridacna gigas* giant clams inter-tidally is examined on the basis of experience with culture at Orpheus Island Research Station, James Cook University, Northern Australia. Even at a price as low as $3 per kg for clam meat on the farm, it is shown that profitable culture can be expected. At a real rate of interest of 10 per cent per year, the most profitable duration for growing clams for meat production is to 11 years of age. The farm is assumed to acquire 100,000 seed clams of approximately one-year each year. Analyses indicate that the real rate of return on funds used can be expected to exceed 10 per cent. Financial analysis of cash flows indicates that the payback period (for the finance needed) for a new farm being set up for giant clam culture is relatively long and initially the debt/asset ratio of the farm is likely to be high. The length of the payback period is significantly affected by the price of clam meat and the rate of interest. Assuming an annual real rate of interest of 10 per cent, payback is complete at the end of 12 years if clam meat sells for $7 per kg; at the end of 13 years if it sells for $5 per kg and at the end of 16 years if it sells for $3 per kg. While these payback periods may seem to be long, there are many types of commercial projects which have even longer payback periods.

Keywords: Giant clam farming, Tridacna Gigas, rate of return.

JEL Classifications: Q57, Q31

Ocean Culture of Giant Clams (Tridacna Gigas): An Economic Analysis

1. Introduction

Biological studies have shown the feasibility of culturing all species of giant clams. However, commercial farming will depend on the economic profitability of such enterprise. This paper evaluates the economic viability of a giant clam farm culturing *Tridacna gigas* in the intertidal zone. *T. gigas* has been extensively studied at Cook University and sufficient biological and economic data exist for such a preliminary evaluation.

T. gigas has a fast growth rate, compared with other Tridacnid species, "therefore, they are considered to have the greatest potential for mariculture by biologists" (Munro, 1988). Other factors such as consumers' preferences for the different giant clam species and ecological factors that might discourage the mariculture of a species -in a particular environment will have to be taken into account in the final decision about the species to be grown. The results of the present analysis should therefore be considered as a preliminary assessment of the economic viability of *T. gigas* farming.

Also, the results are to some extent specific to Australia. Firstly, biological data was derived for the first five years from the work undertaken at Orpheus Island Research Station (OIRS) and, therefore, might be subject to a certain degree of variation when clams are grown in different environmental conditions. For the following years, data has been derived from Munro (1989) and may need to be adjusted when further data from OIRS becomes available. Secondly, the cost structure is based on Australian prices (e.g. for labour) and might change if the farm is established in a Pacific Island state. Thirdly, the technology adopted might not be the most appropriate for other countries that have to import their inputs (e.g. plastic meshes) and have different labour skills.

This economic evaluation relates purely to a commercial farm. If giant clams are considered for re-stocking depleted reefs, other factors (certainly more difficult to assess) should be taken into account: for example, the importance of saving a species from extinction and the (probably unknown) benefits to the natural environment and to humans arising from that. In considering giant clam mariculture in subsistence economies, socio-economic factors such as the different roles of women and men in fishing and agricultural practices, land tenure, labour supply availability and specific local needs should be taken into account.

2. THE ECONOMICS OF CULTURE OF GIANT CLAMS

The mariculture of giant clams can be carried out in shore-based facilities (Munro, 1989) or initially onshore (hatchery and nursery phases) and then in the ocean (ocean-nursery and growout phases) (Crawford *et al*., 1988). The main factor affecting the choice of shore-based or ocean culture is the market targeted for the output. Two or three year-old clams from shore-based facilities could be sold to restaurants to be consumed fresh, directly in the shell. Clams of this size may be suitable, for example, for the Japanese sashimi or sushi markets. However, if clams are farmed in order to sell large quantities of meat, it is unlikely that shore-based facilities would be economically viable; the large size of the clams (it will be shown that they might be harvested between ten and fifteen years of age) would make onshore facilities unprofitable.

Given that the focus of this paper is on the production of large giant clams for their meat, the culture method is the only one considered.

2.1 GENERAL CONSIDERATIONS

The economic evaluation of the viability of giant clam mariculture is a fairly complicated exercise since giant clam mariculture is at an early stage and there are no established markets for cultured clams. The developmental phase of farming techniques requires the researcher to make some assumptions (here based on the practical experience arising from the work undertaken at OIRS) about capital requirements and operating costs.

The absence of established markets has several implications. Firstly, the potential size of the market is not yet known with certainty; therefore, there is uncertainty about the practical scale of operating a commercial farm. From marketing studies undertaken (see Tisdell and Wittenberg, 1990), it appears that the meat output of a farm of the size hypothesized in this study could be absorbed by the potential market.

Secondly, it is clear that production is likely to be economic when structured on a rotating basis (i.e. every year some clams will be harvested) rather than on a synchronized basis (i.e. all the clams are put down in the same year and subsequently harvested in the same year). Factors favouring production on a rotating basis are:

- in establishing a new market it is important to guarantee continuity of supply to the customer.
- the progressive establishment of the farm (i.e. adding one set of clams in each year) allows for a process of trial-and-error learning: e.g. size of lines and exclosures (Barker *et al*., 1988), positioning of the clams in the ocean, how to deal with pests and possible diseases.
- labour is distributed evenly over the years and a progressive setting up and continuous production would minimize labour requirements. In fact, a full time worker would be sufficient both to put in place the new seed clams arriving each year and to control the progress of the older clams (e.g. checking for predators and other sources of mortality, including theft).
- skilled labour could be difficult to find for the handling and packaging of the clams if the production is on a synchronized basis. This factor depends to a certain extent on the handling and packaging technology. Also, if specific machinery is required for the packaging its availability could be a constraint.
- the lines and the exclosures can be used for more than one year; therefore, if the farm is set up all at once, capital investment in lines and exclosures would be higher than in the progressive setting up case.

Thirdly, because an established market price for output does not exist, we consider a number of alternatives. Possible prices are chosen and sensitivity analysis of the results to different prices is carried out.

2.2 FARM SITE AND SIZE

The choice of a farm site will depend primarily on the presence of appropriate environmental conditions for the culture of clams. Once this precondition has been met, other elements come into play. A site close to markets would obviously be preferred to one in a remote area. Other things being equal, remoteness would decrease the profitability of clam production, given the higher costs of inputs and the lower (farm-gate) output prices (if the output price cannot be set by the mariculturalist) due to transportation costs. Other drawbacks of a remote area are the possible lack of suitable labour and supplies.

The choice of a farm site is related to the farm size. The larger the required farm size, the more difficult it is to find a suitable site. Environmental conditions are still a constraint, but possible conflicts with other activities may also arise; for example, a large clam farm could require the complete exclusion of tourism from the island where the farm is situated.

The size of the farm, defined by the number of clams in each period of time, depends on two factors: the output per year and the harvesting age chosen.

The desired output per year depends to a large extent on market demand for clams. If market demand is very large a single farm could not satisfy the market as reef availability would in the end become a constraint. It would seem from the evidence gathered by marketing studies (Tisdell and Wittenberg, 1990) that the Australian market could absorb the yearly output target of the enterprise hypothesized in the present study: an enterprise with a steady **stock** of clams around 500,000-600,000 when the farm is fully operational. An area of around 12-13 ha of reef should be sufficient to accommodate the above stock of clams. Harvesting age influences the size of the farm because a longer period before harvest implies a larger number of year-classes of clams held at any time on the farm. The optimal harvesting time for clams depends on the farmer's objective. For example, giant clams can be cultured for conservation purposes, for meat production in a subsistence economy or for meat production for commercial reasons. Watson and Heslinga (1988) have shown specifically for *Tridacna derasa* that if the objective of the farmer is maximum biomass production, as could be the case for a subsistence farmer, the optimal harvesting age depends on biological factors (i.e. growth rate and mortality rate). Watson and Heslinga estimated this to be about 6 years of age for maximising the weights of the meat (adductor muscle and soft tissue). However, when clams are cultured for commercial purposes, the objective of the clam farmer is the maximisation of the economic return. Thus, the optimal harvesting age depends not only on biological factors but also on economic elements such as value of the meat, costs of production and the real interest rate.

Adapting Tietenberg (1988), a simple harvesting model can be employed using biological factors influencing meat production (i.e., mortality rate, and growth rate) combined with the economic factors mentioned above. A first approximation to determining the optimal economic harvesting age for *T. gigas* clams grown out is one of the objectives of this paper. It concentrates on the optimal length of time to hold the first batch of clams put into the ocean using a modified single period model. A more complicated and realistic model of the optimal harvesting (and management of the farm) requires modelling the harvesting decision as part of a never-ending cycle in which interdependencies between periods cause the modified single period model to be incorrect. However, this issue will not be addressed as it is beyond the explorative scope of the present paper. The model used here following Tietenberg (1988), nevertheless, provides a useful first approximation. (See also Tisdell, 1991, Ch. 8; Bowes and Krutilla, 1985).

Note that the decision about the best harvesting age could also be influenced by the lack of knowledge about the size of the market. For an initial farm it could pay to progressively sell part of the output early in order to market and also to expand the public's knowledge about the size of the market. For an initial farm it could pay to progressively sell part of the output early in order to test the market and also to expand the public's knowledge of giant clam meat; that is, to enable learning by doing.

Another factor to be taken into account in harvesting is the quality of the meat. Older clams may have tougher meat than younger ones. Therefore the tastes of customers may influence the optimal age for harvesting giant clams. We have assumed that taste is not a factor in the culture modelis adopted that this is not a relevant factor, otherwise it would show up in a price variation in the value of clam flesh with age.

2.3 CULTIVATION METHOD

Seed clams are ready to be transferred from the hatchery to ocean-based nurseries at an age of about one year (Crawford *et al*., 1988). The seed clams cannot be placed in the ocean without protection because total mortality occurs if they are not protected for some years (Heslinga et al. 1986). Therefore, *T. gigas* clams are placed in 'lines' (see Fig. 1) for the first year of culture then transferred to 'exclosures' for the second year if the methods pioneered at OIRS are adopted. Observe that these methods are still at an experimental stage and possible changes, leading to a reduction in costs, are under study at the OIRS.

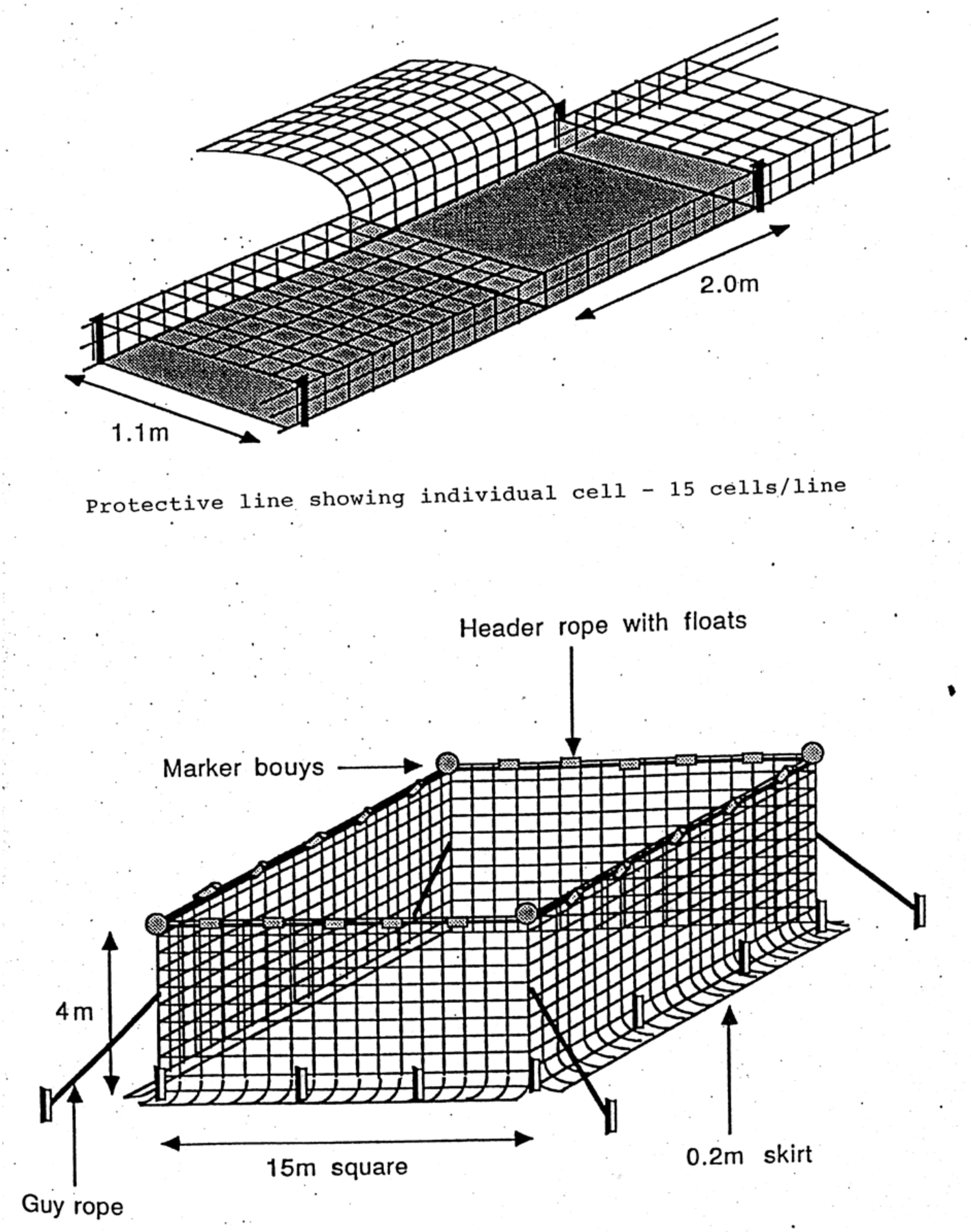

Figure 1: Exclosure for the protection of juvenile clams

At the end of the second year of ocean culture, clams (now three years old) are transferred to open ocean locations where they can be left, if appropriately spaced, until harvesting time (growout phase).

The biological data relating to the first twenty years of life of a set of 100,000 giant clams are presented in Table l. The growth rates are the average rates shown in Munro (1988). The flesh weight is proportional to total weight and for the first five years data are based on work undertaken at OIRS; for clams older than five years the figures are those reported by Munro (1989). The survival rates of clams shown in Table 1 are assumed to be realistic on the basis of OIRS experience.

TABLE 1 BIOLOGICAL DATA FOR T. GIGAS

Age BP	Lenght (CM) at BP	Weight (kg) per clam		Survival rate	No clam BP	Total flesh weight (kg) EP
		total	flesh			
1	6.8690526	0.0385755	0.00463	0.58	100000	6.2027002
2	14.158415	0.5092529	0.10694	0.82	58000	22.087695
3	20.721206	1.786221	0.46442	0.95	47560	37.906114
4	26.629848	3.9950711	0.83896	0.95	45182	50.358845
5	31.949544	7.1105429	1.17324	0.95	42923	74.175329
6	36.738996	11.024601	1.81906	0.95	40777	99.650211
7	41.051057	15.590427	2.57242	0.95	38738	125.39007
8	44.933311	20.649966	3.40724	0.95	36801	150.27315
9	48.4286	26.050375	4.29831	0.95	34961	173.46326
10	51.575495	31.653117	5.22276	0.95	33213	194.38769
11	54.408721	37.338264	6.16081	0.95	31552	212.69885
12	56.959544	43.005787	7.09595	0.95	29975	228.23114
13	59.256112	48.575028	8.01488	0.95	28476	240.95927
14	61.323769	53.983147	8.90722	0.95	27052	250.96118
15	63.185331	59.18307	9.76521	0.95	25700	258.38673
16	64.861342	64.141268	10.5833	0.95	24415	263.43239
17	66.370295	68.835569	11.3579	0.95	23194	266.32135
18	67.728842	73.253119	12.0868	0.95	22034	267.28847
19	68.951975	77.388557	12.7691	0.95	20932	266.56916
20	70.053193	81.242414	13.405	0.95	19886	264.39162

BP: Beginning of Period

EP: End of Period

2.4 CAPITAL COSTS

Provision of accommodation for worker(s) is probably required as the site for the farm is likely to be in an isolated area which limits the possibility of commuting; also, continuous surveillance will certainly be necessary. Accommodation cost will not vary much if two workers are required, instead of the one assumed in this paper.

A tractor will be needed to transport material required around the farm; also, a tractor is indispensable for hauling the clams which become quite heavy in later years. A utility truck may also be required.

It has already been noted that in order to contain the mortality rate of the clam seed clams in the first two years, it is necessary to put them in ‘lines’ and ‘exclosures’. Lines and exclosures have an average life of three and two years respectively; they can be considered a capital cost to be allocated to different sets of clams. The cost of lines and exclosures for 100,000 seed clams is presented in Table 2.

TABLE 2

DETAILS OF THE COSTS OF CONSTRUCTION OF THE LINES AND EXCLOSURES

Cost of materials for lines assuming double line.

1	2	3	4	...	15	Line 1
1	2	3	4	...	15	Line 2

Plastic mesh for base, 6 mm x 2 30 m roll @ $400 roll		= $800
Plastic mesh for top, 25 mm x 2 30 m roll @ $400 roll		= $800
Star pickets, 1800 mm halved	900 mm @ $4.05 ea x 33	= $134
Cable ties 2 packets of 100	@ $10 packet	= $ 20
Galvanised fencing wire 2 strands per side	180 m @ $0.1625 m	= $ 29
Granite chips (optional)	6 m³ @ $12.5 m³	= $ 75
Coral rubble (optional)	free	= $ 0

Labour for construction

45 person hours per dual line @ $10 hr = $300

TOTAL with granite chips = **$2129**
AVERAGE PER LINE = **$1065**

TOTAL with coral rubble = **$2054**
AVERAGE PER LINE = **$1027**

Cost of materials for exclosures assuming line of 6

1	2	...	6	Exclosure 1- 6

Plastic mesh for 4 m high walls, 570 m x 2 m x 25 mm	570 m @ $1 m	= $570
Star pickets, 1800 mm halved	900 mm @ $4.05 ea x 66	= $268
Cable ties 7 packets of 100	@ $10 packet	= $ 70
Galvanised fencing wire 590 m @ $0.165m		= $ 97
Incidental rope		= $ 14

Header float line

Buoys 209 150 mm round @ $2.50 ea	= $523
Buoys 24 300 mm round @ $10 ea	= $240
Rope 582 m inc 8 m guys @ $0.35m	= $204
Plastic spacers (poly pipe) 285 m @ $44 for 60 m	= $209

Labour for construction

200 person hours per 6 exclosures @ $10hr =$2000

TOTAL =**$4195**
AVERAGE PER EXCLOSURE =**$ 700**

In the case of lines and exclosures, the allocation of the cost to different sets of clams is quite straightforward as the lines last three years so that one set of clams will be allocated one third of the cost of the lines; the cost of the exclosures will be allocated between two sets of clams.

The allocation of capital costs relating to the tractor and the utility truck is based on the assumption that they have an average life of ten years. Given that one set of clams is acquired yearly, we can attribute one tenth of the capital cost of the tractor and of the utility to each set of clams. The cost of the worker accommodation is allocated on the basis of an expected life of forty years: each set of clams can be allocated 2.5% ($2,000) of the total capital cost of this accommodation.

Note, however, that if interest has to be paid or allowed for on the capital, the actual assignment of capital costs plus interest on batches put down later than the first batch will be higher at the time that they are put down. For instance, the capital cost plus interest on account of the worker accommodation for the second batch put down in the second year will be, at the time they are down, $2,000 plus $200 in interest, if a 10 per cent real interest rate applies. Thus, capital costs plus interest assigned to later batches of clams in the life of capital will be higher using this method of assignment than that assigned to earlier batches. In effect, the method of assignment of capital costs is relatively most favourable to the first batch grown out. If a greater proportion of capital costs is assigned to the first batch of clams, this will tend to reduce the optimal length of time for growing them out compared to later batches and compared to the estimates given later for the first batch. Because the capital is used jointly to produce a number of batches of clams over several years, the allocation of capital costs to different batches of clams is to some extent arbitrary.

It should be kept in mind that our objective is a preliminary evaluation of the economic viability of giant clam farming in a simple framework. In a more complex framework, which we hope to develop in the future, some of the arbitrariness in allocating capital costs may be reduced by building a model which does not concentrate on determining the returns (imputed returns) to a single batch of clams and the optimal period to hold these, but which concentrates on determining the optimal set or array of batches of clams for a farm. Optimality conditions can be inferred from this other model, however, given the limited importance of capital costs, it is possible that the adoption of a more complicated model would not substantially change the results obtained here with the simple model. The capital costs described above are presented in Table 3.

TABLE 3 CAPITAL REQUIREMENTS

	YEAR 1	YEAR 2	YEAR 11
Long term			
Worker accomodation	80000		
Tractor	20000		20000
Utility truck	15000		15000
Short term			
Setting up of protective:			
- lines (1)	15000		
- exclosures (2)		27000	
TOTAL	130000	27000	35000

(1) Lines will be replaced every three years with an equal cost

(2) Exclosures will be replaced every two years with an eq. cost

2.5 OPERATING COSTS

The purchase of seed clams represents the largest operating cost in each year (see Table 4). The price paid for each seed clam is assumed to be 75c; the assumption is made that seeds are purchased from a relatively large scale hatchery at a commercially realistic price (see Tisdell et al., 1990). If the seed clams were purchased from a small hatchery, the price could be in the range of $1.5-$2.0.per seed, doubling expenditure on seed and thus reducing profitability of the farm.

TABLE 4 OPERATING COSTS AND CAPITAL COSTS ALLOCATION
(one set of clams)

Operating costs

Year (1)	Seeds	Wages	Miscellaneous expenses	Total
1	75000.00	30000.00	10000.00	115000.00
2		15000.00	5000.00	20000.00
3			3333.33	3333.33
4			2500.00	2500.00
5			2000.00	2000.00
6			1666.67	1666.67
7			1428.57	1428.57
8			1250.00	1250.00
9			1111.11	1111.11
10			1000.00	1000.00
11			909.09	909.09
12			833.33	833.33
13			769.23	769.23
14			714.29	714.29
15			666.67	666.67

Capital costs allocation

	Year 1	Year 2
Worker accomodation	2000	
Tractor	2000	
Utility truck	1500	
Lines	5000	
Exclosures		13500
Total	10500	13500

(1) Years of growout

It is assumed that one worker can operate the farm. This seems to be a realistic assumption for at least the initial period in which no harvesting is carried out (the first 10-13 years as it will be shown later .on). In the first operational year, total labour cost is allocated to the only set of clams existing on the farm whereas in the second year total labour cost is shared equally between the two sets of clams now in stock. This assumes that one worker can transfer the first set of clams from the lines to the exclosures and place the second set in the lines. It should be noted that no labour costs are allocated to each set of clams after their second year in the ocean worker provides surveillance, the cost of which should be allocated between the different sets of clams present on the farm, the surveillance cost is very small compared to that of handling clams. It was therefore decided to treat it as part of labour cost allocated in the first two years that a set of clams is on the farm.

No provision has been made for fees for specialized consultancies that might be required to control possible diseases contracted by the clams. The amount of the allowance to be made will be more precise only when longer practical experience is gained in the mariculture of giant clams.

The last item in the operating costs section is the allowance for miscellaneous expenditures and includes fuel and repairs. It has been assumed that ten thousand dollars will be sufficient and that it will remain constant over time. It could be assumed that such an allowance increases over time, reflecting an increasing need for repairs. However, given the limited importance of miscellaneous expenditures, the adoption of the second assumption would decrease only marginally the profitability of farming giant clams. Miscellaneous expenditures are allocated between different sets of clams on the basis of the number of sets of clams in stock. In the early years of the enterprise when the stock is increased each year by 100,000 clams (up to the year when the harvesting commences), miscellaneous expenditures are a larger component in each set's operating costs, compared to the situation where the maximum number of sets is stocked on the farm.

The list of costs presented here may be an underestimate of the likely costs that a clam mariculturalist will face. No provision has been made for insurance. The insurance premium will depend on the risk of higher than expected mortality rates that could arise, for example, from diseases or natural elements such as a cyclone. The insurance will also be required to cover eventual lenders of capital (funds needed to start the enterprise) against a possible loss of the principal asset of the farm: the clams.

Another important item not included is the cost of harvesting and packing of the meat: unfortunately, at this stage there are no estimates of these costs and further assessment is certainly needed. It should be established for example if refrigeration is needed; if special machinery is required and so on. Thus the profits and prices estimated are for the clam meat in situ. A further cost will be the farm lease for the reef and land area; however, this cost is likely to be in the order of a few hundred dollars and will not affect the results of the analysis. Note that it may be possible to sell the shells in addition to the meat of the clams and this will add to revenue.

3. RESULTS OF THE ANALYSIS

Results of the empirical analysis are presented in this section. First, the optimal harvesting age for the first set of clams grown out on the farm is determined by looking at the maximum present value of the operating profit that could arise from the cultivation of 100,000 clams. The net present value also gives an indication of the economic viability of the project.

Then, the financial analysis for the project as a whole (i.e. taking into account **all** sets of clams introduced over the years and related costs and revenues) is presented. Given that the first harvest will occur only several years after the opening of the farm, it is opportune to look at the total borrowings incurred and compare them with the assets. For simplicity, total borrowings will be contrasted with the total value of the clams (by far the major asset) on the farm.

3.1 DETERMINING THE NET PRESENT VALUE

In order to establish the optimal harvesting age, the maximum present value of the operating profit of set of clams needs to be found. This operation has been performed for the **first** set of clams acquired for our hypothetical farm. Results of this analysis are presented in Figure 2, and Tables 5-8. The net present value has been calculated applying alternatively the discount rates of 5% and 10% to the profit/loss arising from the sale of the clams at a price of $3, $5 and $7 per kilogram.

TABLE 5 OPERATING PROFIT/LOSS FOR ONE SET OF CLAMS
Interest Rate 5%
(dollars)

Year (1)	Net profit/loss if meat sold at		
	$3 per kg	$5 per kg	$7 per kg
1	-113166.899	-100761.499	-88356.0984
2	-107275.665	-63100.2751	-18924.8851
3	-71997.3461	3814.881511	79627.10912
4	-46549.9374	54167.75228	154885.4419
5	12918.19197	161268.8503	309619.5086
6	77112.44911	276412.872	475713.2949
7	141740.1215	392520.2654	643300.4094
8	203355.3643	503901.6733	804447.9824
9	259385.8205	606312.348	953238.8756
10	308058.8931	696834.2681	1085609.643
11	348282.6164	773680.3095	1199078.003
12	379513.8004	835976.0803	1292438.36
13	401631.527	883550.0735	1365468.62
14	414824.925	916747.28	1418669.635
15	419498.6443	936272.099	1453045.554
16	416196.3016	943061.0791	1469925.857
17	405540.5083	938183.2171	1470825.926
18	388187.3374	922764.2731	1457341.209
19	364792.8676	897931.18	1431069.492
20	335989.5203	864772.7545	1393555.989

(1) Years of growout

TABLE 6 OPERATING PROFIT/LOSS FOR ONE SET OF CLAMS
Interest Rate 10%
(dollars)

Year (1)	Net profit/loss if meat sold at		
	$3 per kg	$5 per kg	$7 per kg
1	-119441.90	-107036.50	-94631.10
2	-122441.92	-78266.53	-34091.14
3	-97523.83	-21711.60	54100.63
4	-84039.85	16677.84	117395.53
5	-38302.03	110048.62	258399.28
6	10206.48	209506.90	408807.32
7	56980.21	307760.36	558540.50
8	98335.46	398881.77	699428.08
9	131435.17	478361.69	825288.22
10	154212.98	542988.35	931763.73
11	165251.44	590649.14	1016046.83
12	163647.15	620109.43	1076571.71
13	148880.77	630799.31	1112717.86
14	120701.06	622623.42	1124545.77
15	79026.13	595799.58	1112573.04
16	23862.21	550726.99	1077591.76
17	-44761.45	487881.26	1020523.97
18	-126843.77	407733.16	942310.10
19	-222451.57	310686.74	843825.05
20	-331750.09	197033.14	725816.38

(1) Years of growout

TABLE 7 NET PRESENT VALUE OF OPERATING PROFIT/LOSS FOR ONE SET OF CLAMS (Discount rate 5%) (dollars)

Year (1)	Net present value of profit/loss if meat sold at		
	$3 per kg	$5 per kg	$7 per kg
1	-107778.00	-95963.33	-84148.67
2	-97302.19	-57233.81	-17165.43
3	-62194.01	3295.44	68784.89
4	-38296.75	44563.94	127424.64
5	10121.74	126358.36	242594.99
6	57542.50	206263.54	354984.59
7	100732.06	278956.82	457181.59
8	137638.92	341060.49	544482.06
9	167202.41	390834.35	614466.28
10	189121.44	427795.79	666470.15
11	203633.63	452354.85	701076.07
12	211327.48	465502.76	719678.04
13	212993.77	468565.47	724137.16
14	209514.78	463019.67	716524.57
15	201786.02	450362.89	698939.76
16	190664.32	432027.15	673389.97
17	176935.98	409326.23	641716.48
18	161299.86	383427.62	605555.37
19	144360.92	355341.86	566322.79
20	126630.92	325923.76	525216.60

(1) Years of growout

TABLE 8 NET PRESENT VALUE OF OPERATING PROFIT/LOSS FOR ONE SET OF CLAMS (Discount rate 10%) (dollars)

Year (1)	Net present value of profit/loss if meat sold at		
	$3 per kg	$5 per kg	$7 per kg
1	-108583.54	-97305.91	-86028.27
2	-101191.67	-64683.08	-28174.49
3	-73271.09	-16312.24	40646.60
4	-57400.35	11391.19	80182.73
5	-23782.55	68331.54	160445.62
6	5761.29	118261.18	230761.08
7	29239.86	157929.73	286619.59
8	45874.22	186081.29	326288.36
9	55741.34	202872.06	350002.77
10	59455.78	209345.51	359235.25
11	57919.62	207018.92	356118.22
12	52143.02	197585.97	343028.92
13	43125.46	182720.09	322314.73
14	31784.36	163956.21	296128.05
15	18918.23	142629.68	266341.14
16	5193.11	119854.24	234515.36
17	-8855.81	96524.71	201905.23
18	-22813.97	73334.39	169482.75
19	-36372.61	50799.76	137972.14
20	-49312.54	29287.72	107887.98

(1) Years of growout

Profit/loss (Tables 5 and 6) has been calculated using the relationship:

$$V_t = R_t - C_t$$

$$= P_t X_t - C_t$$

where V_t = profit/loss at time t after interest;

R_t = revenues at time t;

C_t = total (cumulative) costs at time t inclusive of interest;

P_t = price per kg of clam meat at time t;

X_t = number of kg of clam meat sold at time t.

Revenues at time t arise from the sale of the batch of clams at time t; total (cumulative)costs at time t include all capital costs and operating costs incurred from period 1 to period t to produce the batch of clams under consideration. Interest costs are included in total costs as it is assumed that total (cumulative) costs are financed by borrowed funds. Or alternatively, if funds are provided by the farmer it is supposed that the interest represents the return which the farmer could get by investing these funds elsewhere. The optimal length of time to hold the first batch of clams can be estimated by maximizing the net present value of discounted value of V_t (the farm's surplus on this batch) in relation to time. V_t is discounted using the rate of interest. Its discounted value is shown in Tables 7 and 8 for rates of interest of 5 per cent and 10 per cent respectively. The reason for discounting this surplus is that once this surplus fails to grow with the passing of time at as fast a rate or at a faster rate than the rate of interest, the farmer can increase his/her realizing the surplus and investing the funds realized at the going rate of interest.

As far as estimating the optimal length of time for a batch of giant clams is concerned, it should be noted that the same result could be obtained by counting the present value of the total costs (interests not included) and subtracting it from the present value of the revenue and maximizing, that is, by discounting back rather than by computing forward. However, the first approach is adopted here.

From Table 8 and Figure 2, the optimal harvesting age is seen to be eleven years (ten years of culture) if the discount rate of 10% is adopted. The use of a discount rate of 5% (see Table 7 and Figure 2) shifts the optimal harvesting age by three years; the clams should now be harvested at fourteen years of age (after thirteen years of culture). Note that the optimal length of time of culture of the clams is sensitive to the rate of interest but not to the price of clam meat.

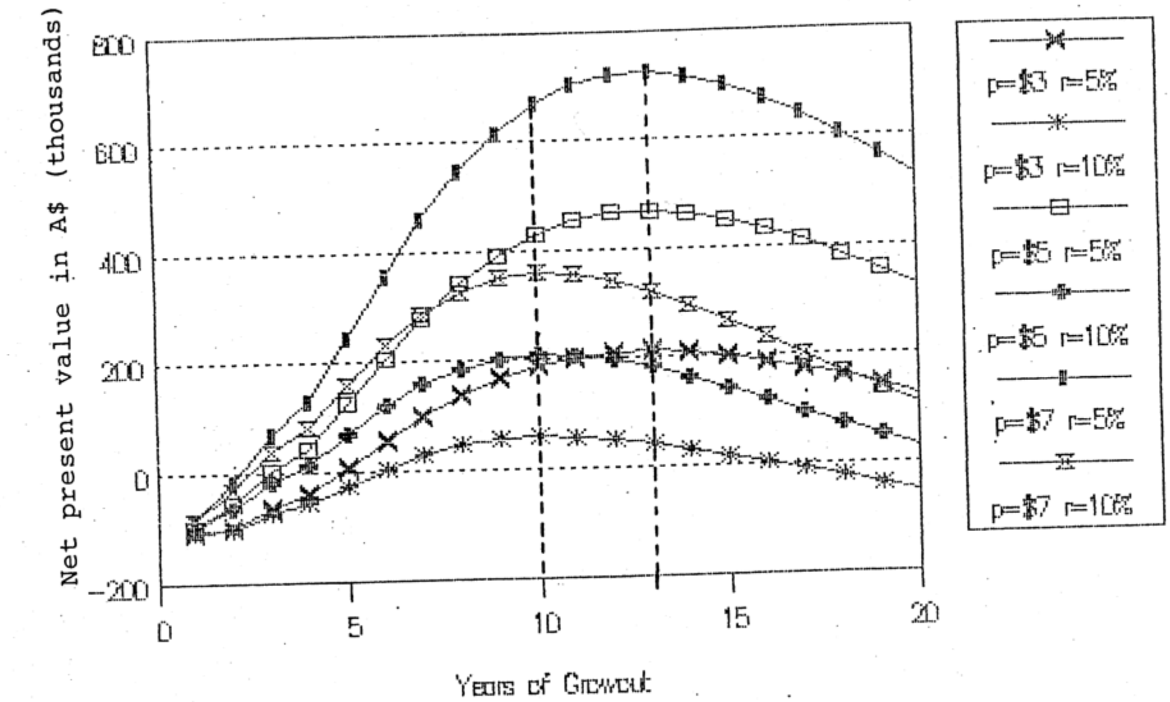

Figure 2 Net present value of first set of clams as a function of years of ocean growout for alternative rates of interest (r) and prices (p) per kg of clam meat as indicated

From Figure 2, it can also be seen that even if the sale of the clams takes place at a price of $3/kg, the operation still generates a positive net present value. Notice that $3/kg is a very low farm-gate price or *in situ* price if compared with a possible retail price of $10-$12/kg that could be fetched on the Australian market for the flesh (Tisdell and Wittenberg, 1990).

A company paying a 10% rate of interest (real rate) on borrowed funds and holding its first batch of clams for 10 years of culture (the estimated optimal period of time) would make, in round figures, a profit of $154,000 on the batch if the meat sells for $3 per kg; $542,000 if it sells for $5 per kg and $931,000 if it sells for $7 per. kg. Given the nature of the assumptions made, a somewhat smaller profit may be received from subsequent batches up to a point. Nevertheless, a return in excess of 10% on the first batch seems to be a realistic possibility and prospects for positive returns on overall operations are encouraging.

Observe from Tables 5 - 8, that for all the cases considered a profit can be earned on the first batch of clams after 6 years or less of ocean growout even though it is necessary to hold batches longer in order to maximise profit.

While this analysis indicates that the culture of clams will in all probability be profitable, initial operations do involve considerable financial outlays and risks. Normally several years will elapse before there is a cash inflow to the farm. Let us, therefore, analyse the financial position for the clam farm **as a whole**.

3.2 FINANCIAL ANALYSIS

Results of this financial analysis are shown in Table 9 and Figures 3 and 4.

TABLE 9 FINANCIAL ANALYSIS (interest rate 10%)
(dollars)

		Price $7/kg		Price $5/kg		Price $3/kg	
YEAR (1)	TFNFY	TBFYII	FBYE	TBFYII	FBYE	TBFYII	FBYE
1	245000	269500	269500	269500	269500	269500	269500
2	142000	183150	452650	183150	452650	183150	452650
3	115000	171765	624415	171765	624415	171765	624415
4	157000	235142	859557	235142	859557	235142	859557
5	115000	212456	1072012	212456	1072012	212456	1072012
6	142000	263401	1335413	263401	1335413	263401	1335413
7	130000	276541	1611955	276541	1611955	276541	1611955
8	142000	317395	1929350	317395	1929350	317395	1929350
9	115000	319435	2248785	319435	2248785	319435	2248785
10	157000	397579	1285650	397579	1674425	397579	2063201
11	150000	293565	90323	332443	943374	371320	1796424
12	142000	165232	-1233337	250537	130417	335842	1494170
13	130000			156042	-777036	292417	1148491
14	142000					271049	781443
15	115000					204644	347991
16	157000					207499	-82607

(1) Years of growout

Legend:

TFNFY: Total Funds Needed for Year.
Includes all operating costs and capital costs

TBFYII: Total Borrowings for Year Including Interests

FBYE: Financial Balance Year End.
Accumulated borrowings less revenues.

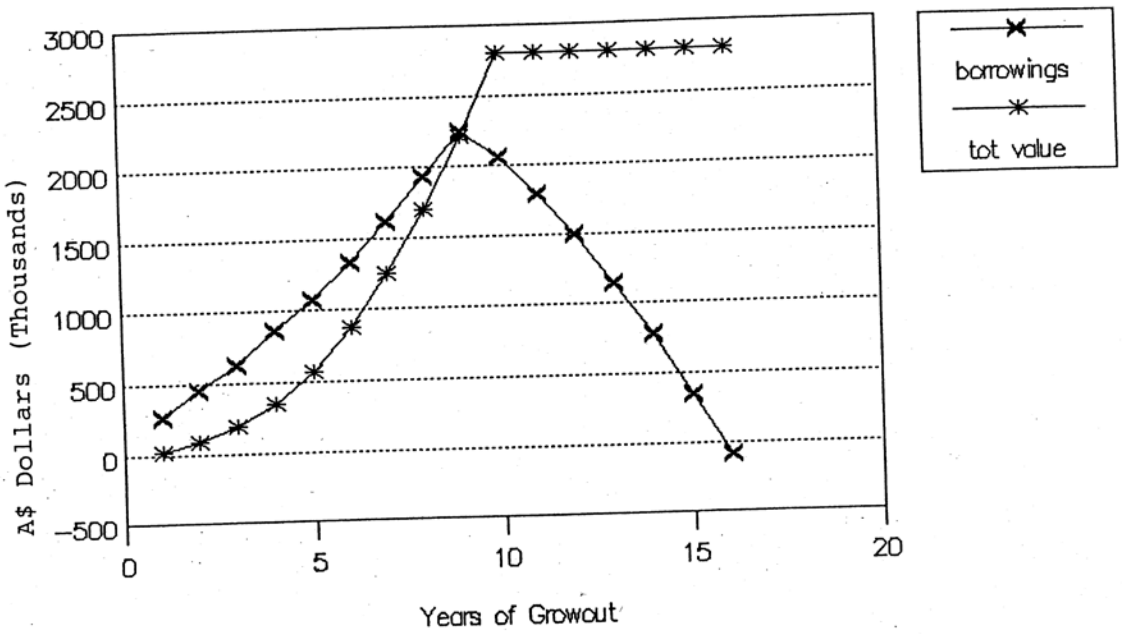

Figure 3 Borrowings and Total Value of Clams (Interest rate 10% - Price $3/kg)

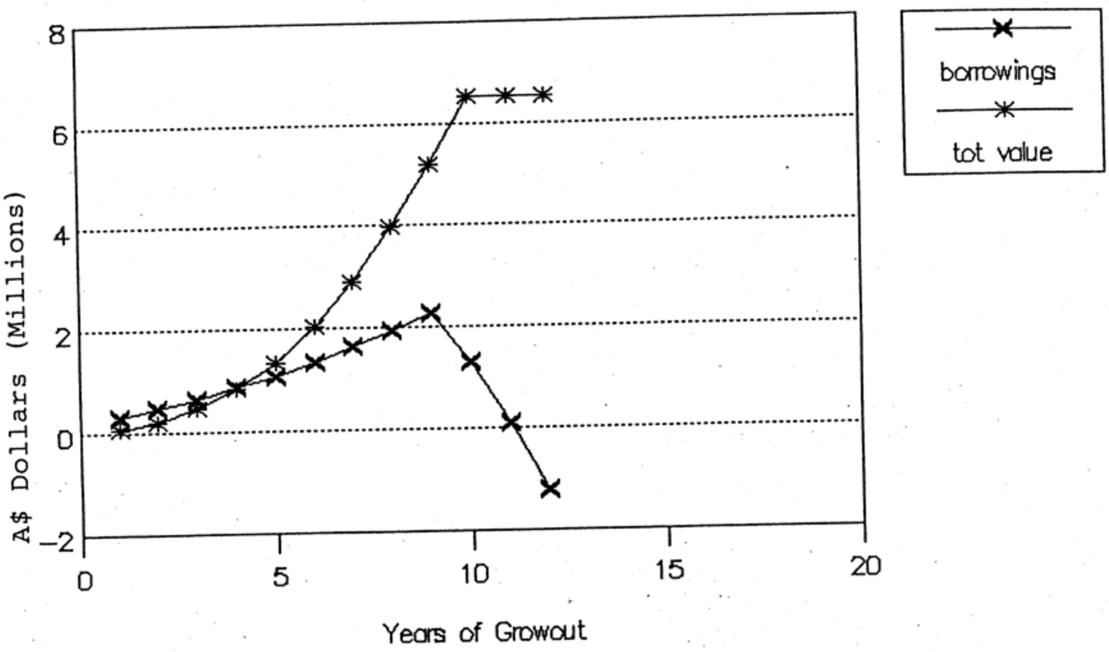

Figure 4 Borrowings and Total Value of Clams (Interest rate 10% - Prive $7/kg)

Borrowings comprise **all** funds needed for capital expenditures in setting up the farm and in subsequent years to replace ‘lines’ and ‘exclosures’ when needed. All operating costs are also paid for by borrowed funds. In each year, accumulated borrowings include compounded interests due on previous years' borrowings. The **real** interest rate of 10% was adopted as it reflects the conditions of Australian financial markets in mid-1990.

The total value of the clams is calculated as the market value of the stock of clams present on the farm at the relevant time. Notice that the total market value of clams on the farm remains constant after ten batches, that is, when one batch reaches eleven-years old. In fact, the adoption of an interest rate of 10% implies that the optimal harvesting age, as determined .in the previous section, is at age eleven for each set of clams (ten years of ocean culture). Therefore, if the economic situation for the first batch broadly applies to all subsequent batches, the farm will have a maximum of ten sets of clams when the fully operational conditions are reached, and this occurs in year ten of culture. Also, in year 10 of culture borrowings start to decrease because the first set of clams is sold.

It is assumed that each year's revenues are constant; the price does not change (in real terms) and the quantity of meat sold in each year does not change.

From Figure 3, if a sale price of $3/kg is assumed, it only in year 9 of culture that the total value of clams on the farm (the asset) matches total borrowings. If the risk of the occurrence of natural hazards and diseases that could affect the stock of clams (the major asset of the farm) is high, it appears that financing such an enterprise could be a risky operation. A significant insurance cover would seem to be necessary.

Note the long period needed for paying off the borrowings incurred. It will take six years to pay back the borrowings after payback begins if clam meat sells at $3 per kg, and this on the assumption that in each year all the revenues are devoted to this objective.

If a sale price of $7/kg for meat applies (see Figure 4) the picture is very different. It is now in year five that the total value of clams (the asset) exceeds borrowings; also, the large gap between these two elements is much smaller in the initial years than if the price of meat is $3/kg. Notice that it now takes only two years to pay off total borrowings once repayment begins. A price of $7/kg would also make the project more attractive for financing given the higher value of the principal capital asset.

When the price of clam meat is $7 per kg, it takes 4 years for the value of the principal asset of the firm to equal the debt, and 9 years for this to happen when the price of the clam meat is $3 per kg. The **payback** period for a farm commencing operations from scratch is 11-12 years if the price of clam meat is $7 per kg, 12-13 years is $5 per kg, and 15-16 years if it is $3 per kg. The payback period is therefore a long one. This, however, is also true in relation to some tree crops such as coconuts, which take 11-14 years from planting to bear, and for many commercial timber crops which cannot be harvested for at least 20 years, even though thinnings and prunings in some cases give some cash inflow before that.

4. CONCLUDING COMMENTS

On the basis of the estimations which we have made, it would be most profitable to grow *T. gigas* clams in the ocean for approximately 10 years, that is to market giant at about 11 years of age; Even if a price of as little as $3 per kg is received for the clam meat on the farm, clam production would be profitable and would yield a real return on the investment in excess of 10 per cent. The payback period for the initial investment is a relatively long one and can be expected to be 12 years or more, depending on the price received for the clam meat. Nevertheless, a number of existing commercial projects, e.g. forestry, do have payback periods of this long or longer.

While the optimal length of time to culture clams is not affected by the general price level of the clam meat, the payback period is shorter and risks involved in the business of growing clams are lower, the higher is the price for the meat. The optimal length of time for culture of clams tends to be shorter with higher interest rates and greater general mortality rates.

The culture of giant clams, apart from the cost of the seed, requires comparatively little fixed capital. It is labour-intensive. In developed countries, because of the long payback period, the risks, and the necessity of paying for labour as it is employed at market rates, only larger companies which may find giant clam culture an attractive or feasible investment. Despite this, subsistence and semi-subsistence communities in less developed countries may find clam culture projects worthwhile. Less capital may be required than in developed countries, e.g. worker accommodation may not need to be provided, and the opportunity cost of the labour used in the project may be zero or near-zero. Consequently, the major costs (possibly almost the total cost) of the project to such communities would be the cost of the clam seed itself. The economics of culture of giant clams in such communities needs to be assessed independently of that in more developed countries.

As pointed out above, the results of this paper depend on preliminary data, and further assessment could be required when more data becomes available. However, drawing on experience at OIRS with the culture of *T. gigas* giant clams and using simple models, we have estimated that it would be profitable to culture giant clams for their meat under the conditions stated. In addition, we have determined the most profitable durations to culture clams and, under these conditions, have examined and commented on the financial flows involved in establishing clam culture as an operational enterprise.

5. ACKNOWLEDGEMENT

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