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OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

Photo: Gideon Tiroba

REPORT TO THE SECRETARIAT OF THE PACIFIC COMMUNITY

BY

HAMBREY CONSULTING

IN ASSOCIATION WITH

NAUTILUS CONSULTANTS

NOVEMBER 2011

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NOUMEA, NEW CALEDONIA, NOVEMBER 2011

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Opportunities for the development of the Pacific islands' mariculture sector: report to the Secretariat of the Pacific Community / by Hambrey Consulting in association with Nautilus Consultants

1. Aquaculture — Oceania.
2. Mariculture — Economic aspects— Oceania.
3. Mariculture — Environmental aspects— Oceania.
4. Mariculture industry— Oceania.

I. Title II. Hambrey Consulting III. Nautilus Consultants Ltd. IV. Secretariat of the Pacific Community

639.80995 AACR2

ISBN: 978-982-00-0529-7

This study was funded by AusAID under the Fisheries for Food Security Programme.

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Appendices

Preparation of this document

This report and the accompanying five country reports were prepared by John Hambrey (Hambrey Consulting), Hugh Govan, and Crick Carleton (Nautilus Consultants) between July and November 2011. They are based on a thorough review of the literature, and discussions with Government officers and other stakeholders during field visits (each roughly 1 week in duration) in Papua New Guinea, Solomon Islands, Fiji, Cook Islands and the Republic of the Marshall Islands. A list of consultees can be found in each country report.

Thanks are due to all those who spent time arranging site visits and talking to us, and to Michael Sharp of SPC who accompanied the consultant on two field visits and who offered support and advice throughout the process.

The scope of the exercise was daunting and resources limited; and there are necessarily gaps and weaknesses in the analysis. Notwithstanding these limitations, the report offers what we hope is a well-informed overview of the nature of mariculture and its potential in the region.

Notes

- Statistical data on mariculture production comes primarily from the FAO official reporting system – from FishStat, or from SOFIA 2010. It should be noted that most of the countries of the region face difficulties in providing aquaculture statistics to FAO in a consistent and accurate way. As a result, interpretation of figures presented in this document should be undertaken with care.

- Aquaculture is the farming of aquatic plant, invertebrate and vertebrate species, and covers a wide range of technologies applied to cultivation in freshwater, brackish water and seawater. Mariculture is a subset of aquaculture, and refers to the cultivation of species in brackish and seawater.

- The husbandry of organisms (e.g. the seeding and later harvesting of *Trochus* on reef systems) is not usually referred to as aquaculture or mariculture, though the operation of a hatchery and nursery facility is normally referred to as aquaculture or mariculture (e.g. the captive breeding and early cultivation of *Trochus* to a size suitable for reef seeding).

1 SUMMARY

1. This overview report addresses opportunities for the development of the Pacific Islands' mariculture sector in general terms. More specific analysis of opportunity in particular countries is presented in the five accompanying country reports (Cook Islands, Fiji, Papua New Guinea, Republic of the Marshall Islands and Solomon Islands).

1.1 GENERAL CONCLUSIONS

2. This broad ranging analysis demonstrates one simple truth: we need to get away from the idea that mariculture is good and should be promoted. It is an option to be considered, and, given its often demanding/high risk attributes, development opportunities must be reviewed thoroughly and impartially. The key to this is:
   a) better development planning of mariculture within the wider processes of economic development planning and/or integrated coastal management;
   b) more objective and informed project preparation and appraisal; and
   c) probably a greater role for the private sector as a key partner in any government or aid promoted development project.

3. Throughout all of these processes should run the themes of more thorough and realistic market appraisal, and more thorough and realistic estimates of production, distribution and marketing costs.

1.2 POOR PERFORMANCE OF MARICULTURE DEVELOPMENT IN THE PACIFIC

4. Despite substantial efforts and large injections of research and development finance, mariculture development in Pacific Island nations has been very limited. This is explained by the nature of mariculture, the manner in which mariculture has been promoted, and a range of more specific practical and economic constraints.

5. Lessons have not been learned. In particular some research and development organisations and government fisheries departments have repeatedly promoted development trials without undertaking the most basic analysis of production and marketing costs. Risks have not been assessed, and there has been a failure to compare objectively mariculture with existing and other potential income generating activities. As a result many small communities have served as guinea pigs for the testing of ambitious, technically driven and in many cases naïve projects.

1.3 THE NATURE OF MARICULTURE

6. *Mariculture is more risky than most forms of economic activity.* Most marine organisms are highly sensitive to water quality, salinity and temperature, and are vulnerable to disease, predation, theft and cyclones. Many species require significant investment and working capital, and have long cropping cycles, compounding the risk profile.

7. Many species/systems *require expensive feed* – typically more expensive than animal feed, mostly due to limited production quantities and high quality raw materials required (carnivorous feeding habits).

8. Many species are *demanding in terms of husbandry* and may not be suited to part time attention. It is harder to keep a general eye on organisms growing beneath the water.
9. Per unit *production costs in mariculture are usually higher than those in well managed capture fisheries*.
10. Many *mariculture products are perishable and costly* to deliver to market, especially from remote island locations
11. *Mariculture is highly competitive* with very efficient production already established in other parts of the world. In a global economy this competition has to be taken into account.
12. Some forms of intensive aquaculture *can be seriously polluting,* and most forms will require environmental regulation and management given the sensitivity of tropical coastal ecosystems.

1.4 THE DEVELOPMENT PROJECT APPROACH

13. Most mariculture in the region has been initiated by research, aid project, government, NGO – or a combination of these organisations. The conception and design of projects has therefore usually been driven by technical ideas or development needs. *Mariculture is often viewed as a solution, not as an option.*
14. *Critical factors for financial and economic success* – market price and volume, distribution and logistics, site suitability/comparative advantage – *have often been regarded as of lower priority*.
15. In most cases the key characteristics of mariculture as summarised above have not been adequately taken into account. The quality of *feasibility analysis* (and especially technical/economic analysis and market appraisal) during project design and preparation has often been poor and/or overly optimistic.
16. Inadequate attention has been paid to the manner in which 'poor' people invest their *time and labour*. Although sometimes addressed in livelihoods analysis, a thorough understanding of why people switch between different activities and what return (financial or other) they expect for their time input is rarely developed.
17. Many projects have failed once project based *input subsidies* are withdrawn; and indeed it is arguable that subsidies – by limiting personal investment – have actually undermined the dedication and commitment which would normally follow automatically from personal investment.
18. Many projects suffer from *short project cycle* or shifts in approach and emphasis when renewed. Given that some mariculture activities may have cropping cycles of 4 years or more and payback periods in excess of this there is little chance of activity being sustained.
19. Several projects that we reviewed appeared seriously inadequate in terms of *monitoring and analysing* the most basic production parameters – whose management would be crucial for any form of commercial success.
20. Many of these issues have been raised elsewhere and especially in *'lessons learned'* documents. Unfortunately these lessons have been offered repeatedly over the last 30 years and *have not been learned.*

1.5 PRACTICAL CONSTRAINTS

21. It is difficult to disaggregate the above problems of development delivery from the more fundamental constraints to mariculture development in the Pacific Islands countries and territories (PICTs). These relate primarily to markets, logistics, availability of suitable sites, availability and cost of feed (if required), cost and availability of seed, skills, finance, environmental issues, and social constraints. All of these issues are well known, but their relative importance varies widely across the region and they need to be assessed on a case by case basis.

22. However it is worth noting that *the market should be regarded as the first and most fundamental opportunity or constraint.* Any mariculture development initiative which does not undertake a thorough analysis of *price, of volumes of product traded or consumed, of alternative sources, of preferences and substitutes, of logistics, supply chains and power relations* – prior to any encouragement of production – is at best incompetent and at worst irresponsible.

23. In most cases the *local or national market is relatively small*, meaning that economies of scale are difficult to achieve on the back of domestic markets, and breaking into international markets is therefore likely to be difficult.

24. It is also important to assess the degree to which any new mariculture production activity has *comparative advantage* relative to production by other means or in other locations. Although it may be possible to be successful in the short term without such comparative advantage, as the market matures it will not be possible to compete.

25. *Feed* is required for some forms of mariculture and the lack of locally produced low cost feed is often regarded as a key constraint. However, we are unconvinced of either the feasibility or desirability of focusing on local feeds at least in the early stages of development in most situations. High-quality fish feed is an internationally traded commodity and it would be difficult to produce a local feed of similar quality at similar price (even after import) in many locations. It will often make sense to import feed until the sector is sufficiently large to warrant investment by a major feed manufacturer.

26. *Seed* is also a key constraint for many species, and hatcheries can play a key role in meeting demand. However, project and government run hatcheries have generally underperformed in terms of cost effective market orientated seed production. The role of hatcheries is discussed in more detail below.

27. *Technical expertise* appears to be relatively high in many countries relative to the size of the sector. Furthermore, for most mariculture species there is substantial expertise available from countries with large aquaculture sectors, especially in Asia, and more use can be made of this expertise – either by sending key staff to work with commercial mariculture businesses abroad or by sourcing foreign technicians to work for a period in country.

28. *Technical economic and market expertise* appears to be in short supply throughout the region. However, this is not simply a question of technical skill, but rather one of emphasis and awareness. A simple back-of-the-envelope calculation may be enough to throw out a perceived mariculture opportunity – and for whatever reason these have often not been done. This relates to a key point noted above: *mariculture should be seen as an option, not as a solution.*

1.6 OPPORTUNITIES

29. It is extremely difficult to discuss opportunities for mariculture development in the Pacific other than in the most general of terms. Potential is hugely varied between countries and in many cases even more varied within countries. This reinforces the view that potential must be thoroughly assessed at local level, and priorities set at regional and even national level may be of limited value. Notwithstanding this proviso we have made some broad assessments of selected species in terms of their potential to contribute to key development objectives

1.6.1 CONTRIBUTION TO LIVELIHOODS

30. The price of *seaweed* is historically high and there is currently good opportunity for seaweed development in suitable sites throughout the region, especially where labour costs are low and market access is good – although these tend to be inversely related, and there will typically be an optimum trade-off. Seaweed has classic characteristics which make it suitable as an IGA in relative isolated locations: short growth cycle, low investment, low production risk, undemanding husbandry, low perishability, relatively high value/weight ratio,
31. *Pearl oyster spat* collection can also make an important contribution to livelihoods in some locations, though suitable sites are probably fewer and husbandry more demanding. Furthermore, market conditions are such as to offer limited prospects for expansion of the industry in the short and medium term.
32. There is good but limited opportunity for *giant clam* production, especially in locations readily accessible to international airports. Although purely commercial centralised production appears to be viable (for a few modest businesses), options for engaging significant numbers of growout farmers in villages are limited and difficult, and will require a more effective development model than has hitherto been applied. Various options are discussed in the report, but it should be emphasised that the market is relatively small, and though market growth is possible, this is unlikely to become a significant economic activity.
33. *Coral farming* probably has more potential, and is more amenable to small scale artisanal production, possibly affiliated to or supported by a commercial aquarium products exporter.
34. *Sponge farming* has many characteristics similar to seaweed and is higher value; however the long growout cycle is a significant disadvantage, and increases production risk.
35. *Post-larval capture and culture* remains at an experimental stage and potential is likely to be highly location dependent. The main problem is that it is a classic technology-led option, not market led, and needs to be appraised with great care.
36. *Production of milkfish for baitfish* may be an attractive option locally but only if a set of rigorous conditions apply. We were not able to identify suitable locations in our field work.

37. *Hatchery production for restocking, coupled with effective management of MPAs* may offer opportunity for enhanced fisheries directly supporting local communities. However, the costs and returns are likely to be highly variable according to social, economic and environmental conditions, and there is very little good evidence to draw on to date.

1.6.2 CONTRIBUTION TO FOOD SECURITY

38. *Milkfish production* has been proposed as an alternative/complement to Tilapia production as a means to meet the projected supply gap for fish in some PICTs. If realistic costs are applied we consider it unlikely that production costs could be less than US$2/kg and are more likely to be around $3/kg. This relates to the high investment costs required in ponds or cages and the high cost of feed in more intensive systems.

1.6.3 IMPORT SUBSTITUTION

39. There is significant demand for high quality *marine shrimp* in many PICTs associated with increased consumption in urban areas, and tourism related demand. New Caledonia has demonstrated the feasibility of developing a significant industry and there are other examples (e.g. in the Solomon Islands and Papua New Guinea) which suggest significant potential. The key constraint here is PL supply and neither government nor private sector has been particularly successful in this regard in case study countries. A key requirement is therefore to develop effective national seed production strategies relating to commercially viable species.
40. There may be local opportunities for the production of *medium to high value marine finfish such as barramundi and possibly groupers.* However, margins are likely to be slim and success probably dependent on highly efficient commercial or semi-commercial production systems. Thorough feasibility studies should be undertaken before investments are made and local people encouraged into participation. In any case production costs are unlikely to be less than US$3/kg.

1.6.4 EXPORT EARNINGS

41. *Pearl farming* is the classic activity for generating high export earnings. Unfortunately oversupply and increasing competition from freshwater pearl means that market price is poor and inefficient producers are likely to go out of business. A period of rationalisation is therefore expected with relatively few large scale companies generating high quality product. There may be niches for smaller companies perhaps associated with resorts and producing specifically for local tourist and craft markets.

1.7 FACILITATING SUSTAINABLE MARICULTURE DEVELOPMENT

42. The many contributing factors to poor performance of the mariculture sector noted above must be addressed. Key requirements include:

    - Improved development planning, as far as possible within an integrated coastal planning and management framework, and taking full account of alternatives – such as improved management, utilisation and marketing of products from capture fisheries.

- Recognising that mariculture is an option, not a solution.
- PICT governments need to be closely involved with project design and evaluation; donor and government priorities do not always match, and initiatives are all too often externally driven.
- Conducting thorough and impartial feasibility analyses (including both technical-economic and thorough market analyses) – and creating the capacity at national level to undertake these.
- Recognising and building on the role of the private sector, and developing business awareness and skills.
- Developing clear regional and national strategies for hatchery development, operation and funding.
- Learning – and implementing – the 'lessons learned'

2 INTRODUCTION

In May 2010, Hambrey Consulting in association with Nautilus Consultants was contracted to undertake a study on *Opportunities for the Development of the Pacific Islands' Mariculture Sector.* The terms of reference were very broadly based, encompassing:

- review of past experience especially in relation to government-led efforts to promote mariculture development;
- economic, market and value chain analysis relating to mariculture in five selected Pacific Island countries (Papua New Guinea, Solomon Islands, Fiji, Cook Islands and Republic of the Marshall Islands);
- an evaluation of global market trends in major mariculture commodities, local and regional market opportunities, and investor interest;
- identification and analysis of opportunities and constraints;
- future plans and prospects in selected countries, and potential economic value.

The study involved field visits of 7-10 days in each of the five selected countries, in depth discussions with fisheries staff, fish farmers, traders and processors, financing organisations, and regulators.

Simple economic models were developed for a range of existing and possible future enterprises in the case study countries to understand the basic parameters of income, value added, employment and export earnings.

The material collected is extensive, and these reports (overview report and five country reports) represent only a partial summary.

Although this report focuses on mariculture, we include some discussion of freshwater aquaculture species because there is significant overlap in terms of market (and potential substitution) and because the two are commonly considered together in planning.

The analysis has been dependent on support from national governments – in spending time answering questions, in arranging site visits, and in providing information. It is understood that this was a significant task and that government fishery departments have their own demanding schedules. We are grateful therefore that time was freely given in most cases. However, in-country support was not always adequate to the task, and follow up requested information has not always been provided. This has constrained the analysis in some areas. Furthermore, the scope of the project has not really allowed for a significant exchange of views on all the country reports – which would have been highly desirable. It may be that this can yet be undertaken, but will require significant further resources.

3 BACKGROUND

There have been many attempts to promote mariculture in the Pacific Island countries and territories (PICTs) over the last 50 years. Very few of these have been sustained. The following species have been grown experimentally or commercially in the PICTs sufficient to enter national (and FAO) production statistics. They have been trialled or developed in many different countries, and sometimes repeatedly in one.

Table 1: Mariculture species produced in Pacific Island countries and territories (PICTs)

Species	Main countries[1]
Molluscs	
Clams (*Anadara*, bear paw, nei)	Fiji, Palau, Samoa, Tonga, Micronesia
Mussel (green, Sea nei)	Fiji, French Polynesia
Oyster (mangrove cupped, Pacific)	Papua New Guinea, New Caledonia
Pearl oyster (blacklip, nei)	French Polynesia, Cook Islands, Fiji, Papua New Guinea, RMI
Giant clam (crocus, elongate, fluted, smooth)	Palau, Samoa, Tonga, Cook Islands, Solomon Islands, RMI
Finfish	
Barramundi	French Polynesia, Papua New Guinea
Milkfish	Guam, Kiribati, Micronesia, Palau, Tuvalu
Mullet (flathead, grey, NEI)	Fiji, Guam
Spinefoot (rabbitfish)	Fiji
Marine fish nei	French Polynesia
Marine shrimp (blue, banana, tiger, whiteleg)	French Polynesia, New Caledonia, Vanuatu, Fiji, Cook Islands, Solomon islands, Papua New Guinea, Guam
Seaweed	
Seaweed (elkhorn seamoss, Cotonii, Zanzibar weed)	Tonga, Fiji, Solomon Islands, Kiribati, Micronesia

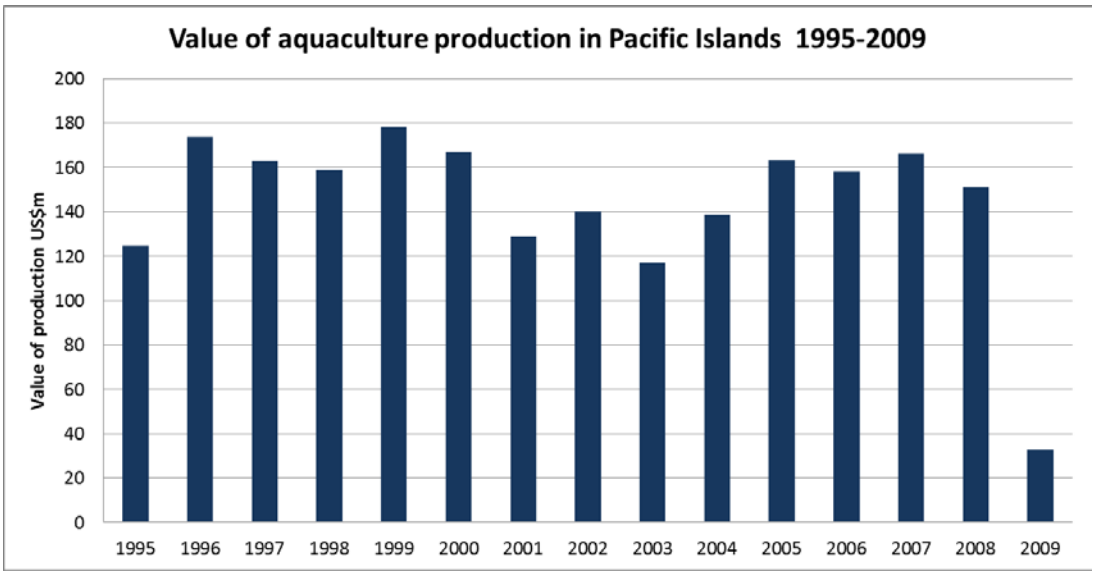
In addition, small scale trials have been undertaken on many of these species in other countries in the region, and others such as sea cucumber, sponge, *Trochus* and green snail have been grown experimentally.

Historically the value of mariculture production peaked in the late 1990s and again in the mid-2000s (Figure 1), with most value contributed by pearl and shrimp production in French Polynesia and New Caledonia. The dramatic decline in total value in 2009 is almost all attributable to a collapse in the value of pearl production from French Polynesia and a collapse in pearl production from the Cook Islands. The collapse in value from the Cook Islands was related to disease/environmental problems and market value; the collapse in French Polynesia is related mainly to oversupply and poor market price.

Production of marine shrimp has also declined slightly, but it has now taken the place of pearl as the most valuable mariculture commodity in the region (Figure 2).

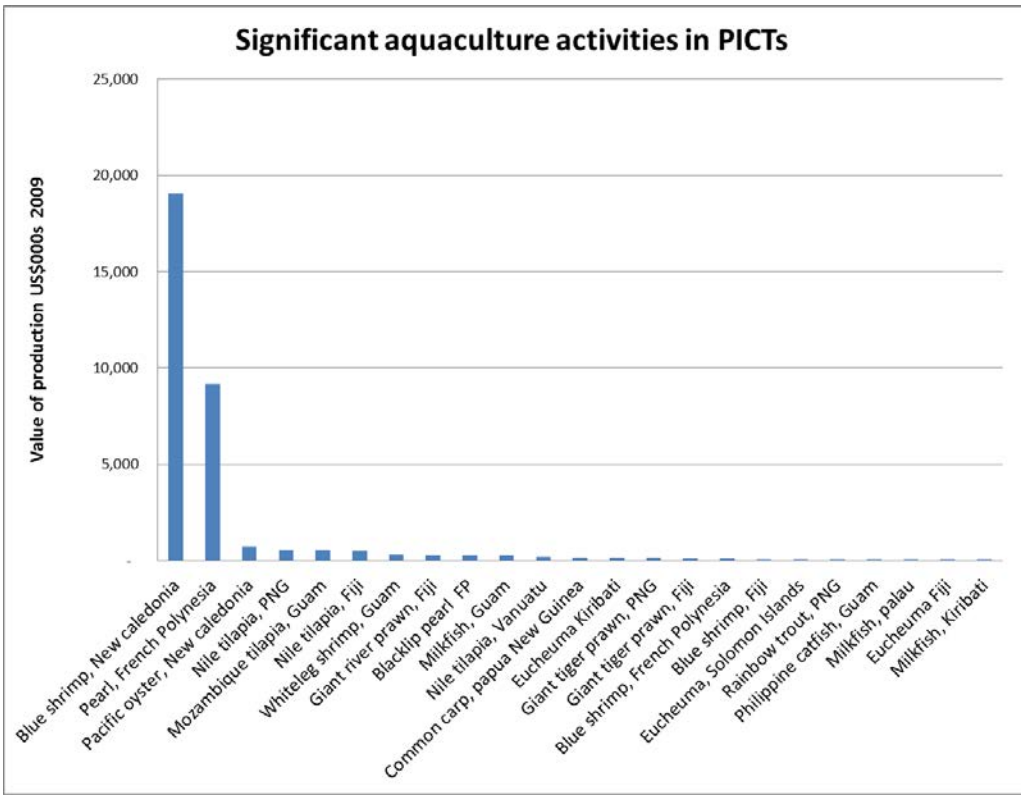
[1] This includes countries listed in FAO FishSTAT+ over the last 20 years, supplemented with other available information. However, many of these species have been trialled on a small scale in other countries.

Figure 1



Source: FAO FishSTAT+

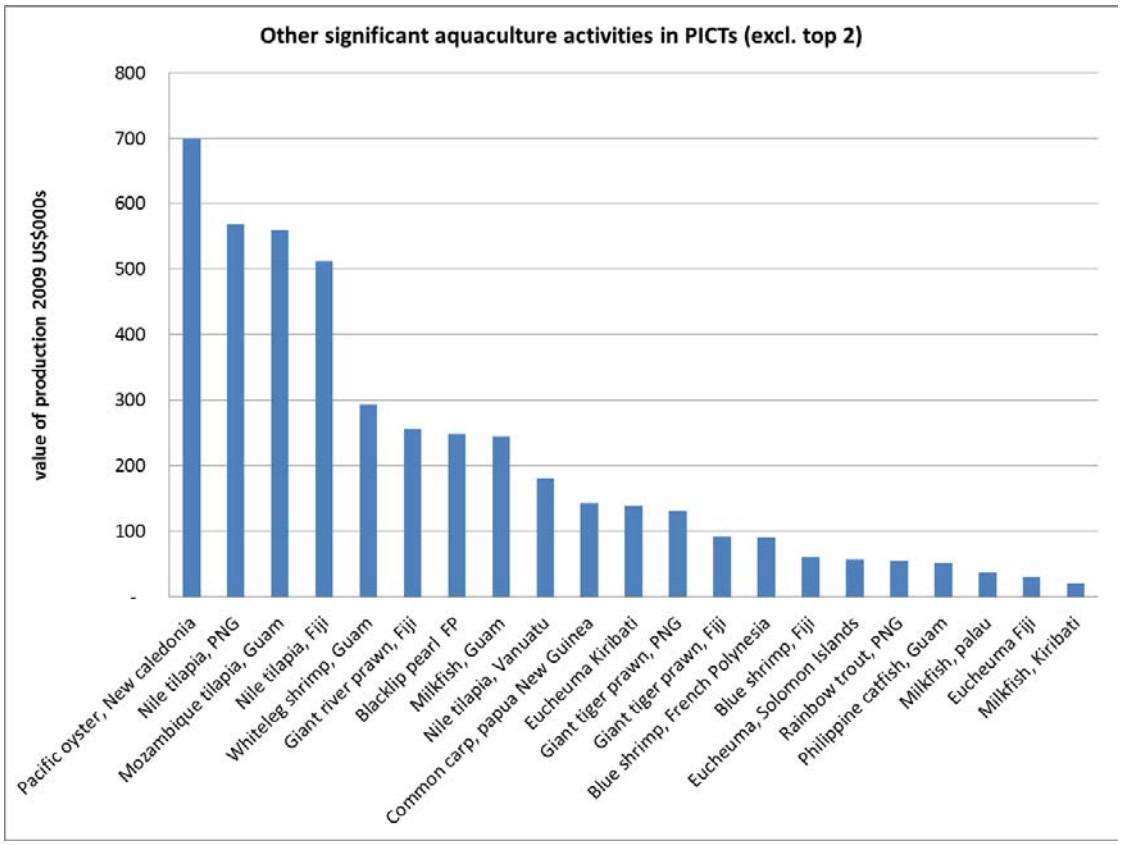
Figure 2



Source: FAO FishSTAT+

If shrimp and pearl oyster are removed from the data, the relative value of other aquaculture products is more readily seen (Figure 3). The value of most of these products is, however, relatively insignificant in both national and regional terms.

Figure 3



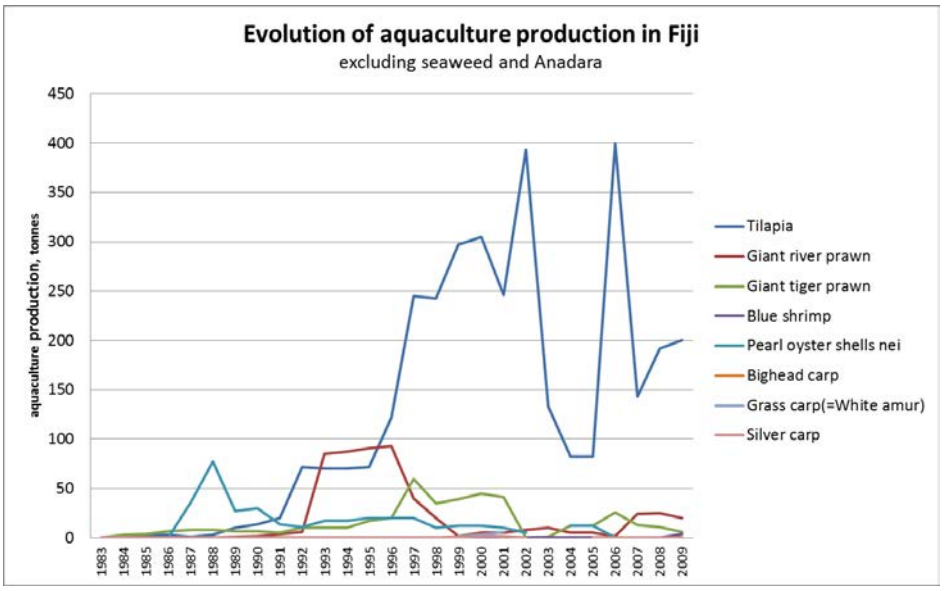
Source: FAO FishSTAT+

To date the most successful example of sustained economic benefit from mariculture in the region appears to be blue shrimp in New Caledonia, although this has shown a modest decline in recent years. Culture of Pacific oyster in New Caledonia has also been relatively well sustained, but is of far lower value. The value associated with seaweed has been erratic, with production rising to over 20,000t (dried weight) in the late 1990s (mainly from Fiji and Kiribati), but declining to less than 2,000t in 2008 (FAO Fishstat+). It is now picking up again on the back of high prices.

Other than these, there is little to show for the substantial effort and resources[2] that have been put into mariculture development in the region. The repeated failure of mariculture initiatives – whether government, aid or commercial – is reflected in FAO aquaculture production statistics. These reveal at least 39 unsustained bursts of aquaculture activity relating to different species in 14 Pacific Island countries over the last 15 years. A selected example is shown in Figure 4 for Fiji (including freshwater aquaculture), but this pattern is repeated across most countries in the region. While some of the variation probably relates to poor statistics, experience on the ground confirmed that mariculture development initiatives have been many and widespread in the region, and success has been rare.

[2] We have not undertaken a complete review of spending on R&D, training, extension, credit and grants, etc. but we estimate these costs to have been at least US$2million pa over the last 25 years.

Figure 4



Source: FAO FishSTAT+

Despite this long history of failed attempts at aquaculture development in the Pacific, there remains a widespread view that mariculture could be a key income generating activity for coastal peoples in the PICTs. Environmental conditions appear exceptionally favourable: there are huge areas of sheltered and unpolluted coastal waters; climate is relatively stable and favourable; and in many locations wages are relatively low. More recently, there is the oft quoted analysis (Bell et al. 2009) suggesting that coastal fisheries will be unable to meet future local demand for fish for food security in most PICTs, and that aquaculture could help meet this demand.

4 WHY SUCH LIMITED SUCCESS?

Despite the many predisposing characteristics noted above, success in mariculture development has been very limited. Why?

The PICTs themselves, the species trialled or promoted, and the modes of development are hugely diverse. Nonetheless some common themes emerge from this study and from relevant literature.

4.1 THE NATURE OF MARICULTURE

Many of those who have promoted mariculture have been unaware or poorly informed of its basic characteristics from an economic development perspective.

4.1.1 MARICULTURE IS A HIGH RISK ACTIVITY

Mariculture is typically dependent on high water quality, stable temperature regimes, and high quality natural or artificial feed. Without these, slow growth, disease or death are likely. Disease spreads easily and quickly in aquatic environments, especially where stressing factors associated with intensification are high. Predation is a problem for many species, and exclusion may be difficult or costly. Many aquaculture systems are vulnerable to periodic high winds, waves or tidal extremes. To these natural risks may be added security. Mariculture products may be valuable, and their relatively hidden location under water away from habitation means that theft is often easy. Almost all these risks can be reduced significantly – but this usually results in significantly increased costs.

4.1.2 THE COSTS OF MARKETING

Many mariculture products are perishable, and in some cases need to be kept alive. The costs of distributing aquaculture products (with some notable exceptions) are therefore high. This cost is compounded if production takes place in isolated locations with limited transport links. This means that many locations in the Pacific are at a substantial comparative disadvantage in mariculture production.

4.1.3 INVESTMENT

These fundamental risk characteristics are compounded by relatively high investment requirements for many species – for ponds, cages or racks, for feed, etc. Some species have relatively long cropping cycles (associated with cash flow problems and increasing up-front investment) – significantly longer in most cases than for agricultural crops.

4.1.4 DEDICATED HUSBANDRY

Mariculture is demanding. Intensive and devoted husbandry is often needed – and usually requires more effort than, for example, feeding the chickens. This level of commitment is often not compatible with a part-time activity. The ocean nursery phase of giant clam farming is a good example of this: although husbandry is relatively easy, failure to remove small predators such as *Cymatium* snails on a thorough, routine basis results in heavy losses.

4.1.5 THE COST OF FEED

Artificial feed is not required for some forms of mariculture (e.g. green mussels, pearl oyster), and is optional in others (e.g. milkfish culture) where fertilisation may be an appropriate alternative. Feed based aquaculture is almost always expensive. Most species have high nutritional requirements, and fish or crustacean feeds are typically significantly more expensive than feeds for most other animals – requiring high protein and often high fish oil content. Many are based on the use of a significant proportion of fishmeal, and are therefore not only expensive, but also of questionable suitability in terms of underpinning food security. Most carnivorous marine species not only require high-quality protein and lipids, but also very specific amino acid and fatty acid profiles.

It is also the case that feed imports attract high duties in many PICTs, placing the local mariculture industry at a competitive disadvantage relative to other, metropolitan, producing countries.

4.1.6 MARICULTURE IS HIGHLY COMPETITIVE.

The scale and intensity of mariculture production in Europe and Asia is daunting. In Asia most mariculture remains relatively small scale in terms of the size of enterprise (often family units) but is conducted on an intensive basis, and the scale of the sector as a whole ensures major economies of scale in sourcing inputs, distribution, processing and export. In Europe, N. America and New Zealand, efficiencies are derived from the scale and mechanisation of individual enterprises (a typical salmon farm now has production capacity of more than 2,000 tonnes per year). Many forms of mariculture production in the PICTs have to compete with imports from these countries, and while some PICTs have significant comparative advantage, it will be difficult to enter a relatively mature and highly competitive market.

4.1.7 ENVIRONMENTAL CHARACTERISTICS

Intensive forms of finfish and shrimp mariculture which depend on fertiliser and/or feed are by their nature polluting and subject to strict controls on siting and discharges in developed and, increasingly, in developing countries. The impacts of nutrient pollution on pristine lagoon systems are likely to be significant, siting will be crucial, and some restriction is likely.

The requirement for a high quality feed for some mariculture systems, typically incorporating a significant proportion of fish meal, also raises complex issues about the efficiency of use of the world's high quality protein and fish oil resources.

Even the cultivation of filter feeders such as oysters will generate significant pollution if kept at high stocking densities, as the authorities in the Cook Islands are only too well aware. Although no artificial feeding is required they effectively concentrate plankton, convert a small proportion of this into body mass, and release the rest either as ammonia to the water column or as faeces and pseudo-faeces (rejected food) to the sea floor.

THE ABOVE ARE GENERALISATIONS, BUT MANY OF THE FAILURES IDENTIFIED IN THE GENERAL LITERATURE AND DISCUSSED IN THE COUNTRY CASE STUDIES DERIVE FROM A FAILURE TO FULLY APPRECIATE, OR ADEQUATELY TAKE INTO ACCOUNT, THESE CHARACTERISTICS.

4.2 THE DEVELOPMENT PROJECT APPROACH

4.2.1 CONCEPTION AND DESIGN: INADEQUATE FEASIBILITY ANALYSIS

Most mariculture in the region has been initiated by research, aid project, government or NGO organisation – or a combination of these. The conception and design of projects has therefore often been driven by technical ideas (e.g. hatchery technology development) or development needs (e.g. food security, livelihoods).

Critical factors for financial and economic success – market price and volume, distribution and logistics, site suitability/comparative advantage – have often been regarded as of lower priority – to be considered at the end rather than the beginning of a project. This tendency has been reinforced by the fact that, in most cases, promoting organisations are not risking their own money. They have the luxury to be able to 'try out' interesting ideas and, in the case of scientists, further develop their own specialist expertise, rather than conscientiously address economic and commercial realities. In most cases the key characteristics of financial and economic success as summarised above have not been adequately taken into account.

Although this may sound harsh, the evidence from the field more than supports such an interpretation. We have reviewed many development project proposals, and talked to many of those involved in current projects in the selected countries. In very few cases had rigorous assessment of feasibility been undertaken addressing such information as:

a) demand for the product in terms of market price, market volume (and therefore susceptibility to price fall as production increases), and market access (cost of freight, storage, distribution, etc.);
b) likely production cost.

There is no doubt that awareness of the importance of these issues has increased in recent years[3], but the response remains inadequate and/or the analysis optimistic.

Where feasibility analysis is undertaken, market value tends to be overestimated and production costs tend to be underestimated. Market values are often based on sale of a small sample rather than a thorough exploration of the existing market volume and the price of actual and potential substitutes. Market values are often based on 2nd or 3rd hand sales, rather than a realistic 'beach' or 'farm gate' price.

Production costs are almost always underestimated. Highly favourable survival and food conversion ratios may be used (based on research or industry best, rather than average performance). Realistic capital investment costs are rarely incorporated into assessment. Labour is rarely included when considering artisanal production, despite the fact that *return on labour* is likely to be the critical parameter affecting take up.

This tendency to optimism and partial analysis is understandable – those involved have an interest, and their interest is in getting their proposal accepted and trying something out. We repeatedly came across the argument 'we need to do the trial to determine if it is feasible'. This is partly true, but only after a thorough analysis of what is possible and what is likely has been undertaken.

[3] See for example the WorldFish Center report (Albert, J., Schwarz, A-M. and Hawes, I.) Creating rural livelihoods in Solomon Islands through an environmentally friendly trade of marine ornamentals for the aquarium trade: Lessons learned.

When a project fails because of poor price, a host of excuses is offered. The most common is that the markup through the value chain is unreasonable. This may or may not be the case (although there is a general tendency to underestimate the costs of getting a product to market) but it is a fact of life to be addressed at the outset of a project, not at closure.

There is a mass of existing information available on production parameters in mariculture available from those countries that are well ahead of the PICTs in terms of mariculture R&D. It is very easy to estimate ball park costs for successful mariculture production, using established parameters together with local costs and values. Insights into market values can be commonly had from local markets, local processors, and exporters. This basic analysis is not difficult and should be routine for all project proposals.

4.2.2 UNDERSTANDING THE ALTERNATIVES – HOW PEOPLE INVEST THEIR TIME

Many mariculture development projects appear to have failed not because they were fundamentally uneconomic (though many are) but because the target group (for example semi-subsistence communities / households in remote islands) had better things to do with their time, including making money on alternatives. In several locations we were told quite simply by villagers that people were giving up (e.g. coral farming in the Solomon Islands) because they made more money on harvesting wild corals, or on copra. In Fiji the decline in interest in seaweed farming in the mid 1990s and late 2000s was related to both the price of seaweed and the price of alternatives – sandalwood, fish, copra, etc.). Although this is sometimes picked up in livelihoods analysis, it is rare for project preparation to include an actual understanding of what people expect in terms of return on their labour (which may be substantially above the national minimum wage in semi-subsistence societies), or what threshold of total income would be deemed sufficient to make significant investment of time worthwhile. It is also unrealistic to expect people to invest their time if the project is unable to tell them what the return on that time is likely to be.

4.2.3 THE PROBLEM OF SUBSIDY

The economic bias introduced as a result of project based subsidy compounds the problems listed above.

A development project will typically bring in cash to a local economy, irrespective of its economic potential. As a general rule people will seek to engage in these projects.

Since most mariculture is fundamentally risky, and since adequate feasibility studies are rarely undertaken as a part of project preparation, involvement in mariculture trials would be exceptionally risky if the costs of seed or feed or equipment, or the costs of sales had to be borne by the participants. Up to 100% subsidy is therefore not unusual, on the understanding that the participants are investing their time. Once again, however, since no one is investing their own money, the incentive to invest much time and effort to secure a return is not strong. Pearl seed collectors may be left uncleaned; predators may be allowed to get a foothold in giant clam ocean nurseries; rabbit fish may decimate seaweed; cages and nets may become fouled; water quality may be allowed to decline; feeding may be according to convenience, rather than routine. The returns are significantly reduced, and when subsidy is withdrawn or partly withdrawn, the poor returns cannot justify the costs.

Even if this decline in husbandry / effort does not take place, the necessary shift – at some point – from subsidy to independent economic activity will always be difficult. Net income will be reduced significantly and risks increased dramatically. Subsidy must therefore be kept to the

absolute minimum, and a clear and mutually understood strategy for reduced subsidy agreed from the outset. Furthermore, limiting subsidy will only be feasible if the risks are acceptable, and this can only be demonstrated with much more thorough feasibility analyses.

4.2.4 PROJECT CYCLE

Projects also suffer from the project cycle duration. Support will be continued until the end of the project cycle even if performance is poor; support and facilitation may be withdrawn rapidly just as development begins to take off. Neither of these is satisfactory.

4.2.5 PROJECT IMPLEMENTATION

During field work, some project leaders / responsible fishery officers, etc. could not tell us the most basic commercially critical production parameters, such as:

- survival
- growth rate (or time to harvestable size)
- food consumption and conversion
- cost of feed
- annual yield per pond or tank or cage
- actual prices paid (locally, nationally), etc.

In some cases, the data were available, but had not been analysed, and the lack of immediate and ongoing interest in these parameters demonstrated the lack of real interest in commercial viability.

It was also difficult to get at the real reasons for project failure or lack of uptake. For example, the high cost of feed and the low price of imports was sometimes cited as a significant contributory cause of failure (e.g. for shrimp farming in Fiji; barramundi in Papua New Guinea; Tilapia in Fiji). However, fish and shrimp feed is a globally traded commodity and prices should not be hugely different in central locations in some of the better connected islands. And being able to compete with imports has to be the number one measure of feasibility (particularly when some protection in favour of local production is already provided by the imposition of import levies in many countries). So was the high feed cost associated with lack of scale in purchasing feed, high local distribution costs, or with poor food conversion rate? The latter is at least as important as price, and far more variable, and may be related to poor survival, poor water quality, disease, low quality feed, etc. Project managers, fishery officers and extension agents should all have a thorough understanding of these issues if the economics of production are to be improved, and if realistic assessments are to be made of potential.

4.2.6 LACK OF COHERENCE BETWEEN GOVERNMENT AND PROJECT PRIORITIES

Very often project focuses are short term, driven by research or donor agendas, and less informed by longer term government priorities/strategies and agendas. This mismatch can undermine project sustainability and compromise ‘exit strategies’.

4.3 PRACTICAL CONSTRAINTS

It is difficult to disaggregate the above problems in terms of promotion, facilitation and support of mariculture development from the more fundamental constraints to mariculture development in the PICTs. These relate to:

- markets
- logistics
- availability of suitable sites
- availability and cost of feed (if required)
- cost and availability of seed
- skills
- finance
- environmental issues.

These are discussed in broad terms below and, in relation to specific opportunities, in section 5.

4.3.1 MARKETS

The market is the fundamental opportunity and constraint associated with any enterprise. Even when the objective is production for subsistence food the market cannot be ignored – it may be cheaper to buy than to produce for home consumption (in real terms or in terms of opportunity cost). Markets for mariculture products vary hugely between and within PICTs, but in most cases there are some fundamental market constraints that must be recognised.

The first is that for many products, particularly in the urban centres and tourist resorts, there will be significant competition in the form of low-cost imports. These low costs are associated with the nature of aquaculture in other countries. In Asia there is a very long history of mariculture, wages are low, and producers are skilled. Although individual enterprises are often small (typically a family unit – though this is beginning to change), the scale of the sector as a whole is huge in many countries, with substantial economies of scale in seed and feed production and distribution, water supply, processing, marketing and distribution. In other major mariculture nations, such as Norway, Chile and New Zealand, costs are kept down through very high labour productivity and substantial economies of scale. A typical salmon farm in Norway or Chile now produces more than 2,000 tonnes. Green mussel farms in New Zealand deploy tens of kilometres of long lines. The markets for many internationally traded products are relatively mature, meaning that margins are slim, and gaining a foothold is ever more difficult. For higher value products the marginal costs of importation will often be less than the higher costs of production at relatively small scale in PICTs. Cheap imports were cited as contributing to the failure of shrimp farming in Fiji and Cook Islands and barramundi farming in Papua New Guinea.

The second major source of competition – for some species – is capture fisheries. This is discussed in some detail below in relation to food security. Broadly speaking, mariculture is more expensive and more risky than fishing (especially well managed fishing) although fuel costs associated with some forms of modern fishing, and declining catch per unit effort, may be shifting the balance – for some species in some locations.

WHILE THERE IS A VIEW THAT THIS BALANCE WILL NECESSARILY SHIFT IN FAVOUR OF MARICULTURE IN THE FUTURE, IT WOULD BE FOLLY TO PROMOTE MARICULTURE BEFORE THIS SHIFT IS REFLECTED IN SUFFICIENTLY HIGH MARKET PRICE AND SUPPLY OPPORTUNITY.

The third key dimension of the market has been touched on already. An estimate of market price is pointless in the absence of an understanding of supply, volume, and the price of possible substitutes. Local demand is usually limited and will not allow for economies of scale. National demand may be higher, but more substitutes may be available. International demand is complex, and though well understood for major commodities such as shrimp, is poorly understood for emerging products such as aquarium giant clams. Product size and quality (or even colour) may have a substantial impact on price.

4.3.2 COMPARATIVE ADVANTAGE

If mariculture development is aimed at import substitution or export, the farmers will need some form of comparative advantage to be successful in the long term, even if the economics appear favourable at the present time. This may relate to climate, site quality and availability (discussed below), broodstock/seed, labour costs, energy costs, skills, feed, freedom from disease, market access, etc. If overall significant advantage cannot be identified, it is likely that production will not be sustained in the medium to long term.

4.3.3 LOGISTICS

Freight costs are often cited as a major constraint to many forms of economic activity in the PICTs, and apply particularly to the transport of fresh, chilled or live product, or product with a relatively low value/weight ratio.

In practice, not all PICTs are at a significant disadvantage in this respect and some islands are relatively well served, with deep-water ports and respectable international air links. Indeed transport / distribution costs may be comparable with or better than those of some successful aquaculture industries (e.g. West Coast of Scotland, Norway, Chile, etc.).

The problem in most cases lies with access to the outlying islands and the limited and costly internal freight systems. This means that logistics represents a major issue for successful siting of mariculture enterprises within countries, and may mean that opportunities for mariculture are as variable within as between PICTs. In general the best locations – subject to site suitability – will nearly always be close to major urban centres. This represents a major dilemma for those wishing to create opportunities for those who are already most economically disadvantaged.

4.3.4 SITE QUALITY AND AVAILABILITY

Siting requirements for mariculture are demanding and multidimensional and will not be discussed in detail here. In general terms the PICTs are relatively well placed with numerous suitable sites for different species and forms of mariculture. However it should be noted that while commercial farms have generally balanced environmental requirements against quality of infrastructure and market access, development projects have consistently underestimated the importance of the latter.

Many sites are simply not available for reasons related to ownership, tenure and tradition and this has served as a significant brake on commercial enterprise.

4.3.5 FEED AND FEED COSTS

There are many forms of mariculture that do not require costly feed inputs (including some forms of finfish culture), and this represents a particular advantage where mariculture is being promoted for food security reasons.

However, intensive feeding with high quality feed is required for some species (such as most shrimp and carnivorous finfish), and may be desirable in the case of species such as milkfish and Tilapia in order to increase yield, reduce growout times, pay off investment in ponds or cages more rapidly, and generally improve cash flow. This may however increase production costs (per kg), financial risks, and the danger of disease, and may not be appropriate for food security purposes. These are all vital issues to be considered when developing production models, e.g. for Tilapia and milkfish, and have not been thoroughly addressed in most development initiatives to date.

Feed costs whether local or imported were cited as contributing to mariculture failures in Fiji, Cook Islands, RMI and Papua New Guinea. Several projects and reviews have identified feed costs as a major constraint, and substantial resources are being put into research on production of low cost feeds.

However, although undoubtedly an issue, *we are unconvinced that in most cases it is as significant a constraint as some would argue.* High quality fish feed is an international commodity, and when traded in large volumes does not vary greatly in price between the major trading centres in the world. Given the reasonable trade connections of many of the major islands in the region, the costs of imported feed should not be unacceptably high by international standards, unless very small volumes are involved (though it is the case that many PICTs still levy high duties on such imports) or high import levies are applied. Transport costs may be more of a constraint *within* some countries, particularly where mariculture activity is located some distance from major ports and internal distribution costs may be higher than international ones. This is an area where local availability rather than absolute cost of feed may be more critical, though it is still not evident that small-scale production of high-protein feeds is an appropriate use of marine resources that could otherwise be used directly for human consumption – a trade-off between local needs and wider trade.

Nor are we convinced that it will be possible to produce low cost fish feeds except in rather exceptional circumstances. The trend throughout Asia has been toward dry pelleted formulated feed, despite the availability of a range of feed ingredients locally and a previous tradition of local or farm based feed manufacture. Modern fish feeds are scientifically and economically optimal, delivering high and consistent performance. They are easy to store and handle and greatly reduce labour costs.

In any case, *food conversion ratio is as important as feed price*, and the rates apparent in some trials and programmes in the region would guarantee financial difficulties in any country. There is a critical trade off here: more expensive feeds should allow for more efficient food conversion; and poorer conversion may be tolerated if feed is sufficiently cheap. *Each enterprise or programme must work out this trade-off according to local opportunities*, and choose the feed which gives the minimum cost per kg of production. *Given the demanding nutritional requirements of many fish, this may be the most expensive imported feed*. None of the trials we visited appeared to be addressing this issue, nor does a thorough analysis of these economic trade-offs figure as a significant element in any of the current research projects aimed at developing local feeds based as far as possible on local ingredients. If such local feeds are

developed, and if they generate economically attractive food conversion rates, it may well be that the producers should be exporting their feed and not the fish.

DO NOT ASSUME THAT BECAUSE A FEED IS EXPENSIVE AND IMPORTED IT IS A CRITICAL CONSTRAINT OR LIKELY CAUSE OF FAILURE.

Other elements of feed management practice are also important – development and implementation of supplemental feeding strategies (that could decrease pellet feed dependence), appropriate selective breeding programmes (growth performance traits), selection of potential omnivorous species instead of carnivorous ones, and integrated aquaculture approaches. Unfortunately, feed conversion ratios and feed management practices are not well-researched within the region, and this is a missing next step in feed initiatives undertaken so far in the region (which, faced by the lack of data, tend to formulate according to a 'best bet' approximation of a species' actual nutritional requirements rather than the optimal balance between cost and performance).

However there is another economic dimension to this, which is that if feed is imported, then a large proportion of the *potential value-added to the country is lost*. Establishing a viable locally (or regionally) based fish feed industry is therefore a rational medium to long-term objective, assuming it can compete on quality and price with imports. However this cannot be done until there is sufficient demand from fish farmers. *In most cases countries will have no option but to use high quality imported feed until such time as the industry has grown sufficiently to support local specialist high quality feed production.* Unless there are real formulation and production skills and excellent and competitively priced local ingredients, trying to supply an emerging sector with cheaper locally produced but second rate feed is likely to be counterproductive. If such a phased approach is to be successful, governments will need to minimise import tariffs – at least in the short to medium term.

4.3.6 WILD SEED AND BROODSTOCK

Seed is a critical requirement for most species, and where wild seed is not available, hatcheries will be required. For some hatcheries, wild broodstock is required at least in the early stages (e.g. giant clam, some marine shrimp species, pearl oyster, etc.).

Some countries have significant wild seed resources and this may be a comparative advantage, though much depends on location relative to suitable growing sites, abundance, behaviour, labour costs associated with collection, and the quality of seed.

Species for which abundant wild seed is available in some countries include:

- milkfish and mullet
- blacklip and gold lip pearl oyster
- mangrove crab, land crab and coconut crab

Species for which wild broodstock are available include:

- marine shrimp including tiger shrimp
- giant clam
- sea cucumber

Species for which mature adults can be broken up to generate large numbers of offspring include:

- sponges
- corals
- seaweed

And there are probably many more.

There are also a whole host of seed organisms which can be harvested through post-larval capture techniques, though to date this has not proved economically viable.

However, information about the location, extent and abundance of these resources, seed quality, or any estimates of potential sustained yield, was very limited in the case study countries, even for those species (such as milkfish and shrimp in Fiji) for which trials were underway. This kind of information should be gathered before rather than during trials since it is fundamental to any feasibility analysis – whether for private sector or government led initiatives. We understand a survey of pearl oyster spat distribution is being undertaken in Fiji, but this kind of work should be part of regular, routine basic information collection by government fishery officers.

It is notable that shrimp farming is being constrained in both Papua New Guinea (private hatchery) and Fiji (government hatchery) through a lack of mature wild broodstock – despite the probability that these could be sourced relatively easily within the country, given appropriate exchange of information and dialogue between fishermen, government and hatchery. Given the fact that *P. monodon* is native to many PICTs, and that this species underpinned the dynamic growth of shrimp farming in SE Asia over 20 years, it is arguable that more resources and effort should be put into identifying and sourcing wild broodstock[4] – at the same time as exploring the potential for import of more easily domesticated species.

It should be recognised, however, that sourcing wild broodstock can be an expensive process – in SE Asia good wild tiger shrimp broodstock are purchased from fishermen for several hundred dollars each – but the investment is regarded as essential. Some of these broodstock are imported from other countries.

4.3.7 HATCHERIES

All the case study countries had hatcheries of one kind or another and in most cases more were under construction or being planned. Most hatcheries have been established in the past under aid programmes and are now government run. They are often seen as basic infrastructure, which, once established, will literally seed a growing industry. There are also several private commercial hatcheries (e.g. for pearl in Papua New Guinea and Fiji, shrimp in Papua New Guinea, giant clams in RMI). The WorldFish Center runs its own hatchery at Nusa Tupe in the Solomon Islands, and several more are associated with the University of the South Pacific and other colleges / universities in the region.

Most government run hatcheries appear to be underperforming – because they cannot meet demand; because they produce unwanted seed; or because they have not been well maintained. They have tended to be driven by research / aid project funding, and when this finishes, they lack the resources to adequately maintain production or facilities. Over the last few years, for example, the government hatchery at Galoa in Fiji has failed to produce adequate marine shrimp PL to supply several established farms. The reasons are complex, but probably include:

[4] It was notable that local fishermen in the vicinity of Milne Bay claimed to be able to catch mature tiger shrimp.

- lack of sufficient wild broodstock and/or seasonal limitations on availability, maturity and quality
- high PL mortality and declining productivity, possibly associated with disease
- lack of expertise in algal culture and problems with quality of algae stock
- cost of holding sufficient broodstock in the hatchery
- chronic underfunding and lack of maintenance and re-investment.

We would also suggest – *though we stress that we had inadequate time or remit to fully explore these issues* – that all these problems may have been exacerbated by lack of effective management and limited incentives for PL production.

The lack of incentive – and resources – to produce seed efficiently in government run hatcheries is exacerbated by the tendency under government and aid funded initiatives to provide free seed. Not only does this have the potential to undermine commitment to good husbandry in growout as discussed in section 4.2, it also means that success in producing seed in the hatchery is not rewarded with a financial return. Not only does this reduce incentive, it also means that hatcheries become a long-term drain on government resources. Further, the private sector is less likely to put money into hatcheries to produce seed if they are competing with government hatcheries that are providing seed free, so this is hindering the private sector from entering this area unless it is specifically for their own operation.

Sustained production of species in current demand – such as shrimp in some countries – may also be compromised or superseded by research or aid programme opportunities, which bring in income to the hatchery, but which tend to focus on less well established technologies.

A final problem relates to changes in government policy. Thus there is current demand for giant clams for the aquarium trade in Fiji, but the focus of government policy is now on restocking. While this may be perfectly reasonable it does represent an opportunity cost (or an opportunity for the establishment of a private hatchery), which needs to be carefully addressed.

The issues of hatchery strategy, performance and funding are discussed further in section 6.4, and are crucial issues for more sustained mariculture development.

4.3.8 SKILLS

Existing resources

Relative to the size of the sector at the present time aquaculture sections in PICT fishery departments and in some cases local government appear to be relatively well resourced, and are capable of offering a range of extension and training services. These are complemented by the training and education offered by colleges (such as the National Fisheries College at Kavieng in Papua New Guinea), USP and other colleges and universities in the region. There are, furthermore, many opportunities for training abroad and/or on aid funded aquaculture development projects. But, private sector capacity is not as well established, and for both public and private sectors, practical skills rather than technical knowledge may not be as well developed.

It would also be worth exploring opportunities to use government / aid-run hatcheries more effectively to train for commercial production, but this can only be done if the hatchery has a commercial section or sub-group with the explicit task of operating on a commercial basis.

Economic development expertise

Most training is *technically focused*, and links with business, economic and market studies are limited. Certainly we found virtually no real skills of this type in government fishery departments or related to development projects. There appears to be an assumption that economic expertise can be bought-in to generate some figures at the end of a project. This represents a major weakness. Economic analysis must be integral to project preparation, planning, monitoring and evaluation, and the economic expertise has to be combined with in-depth technical understanding if the analysis is to be well informed. A*nyone engaged in aquaculture development should have a basic grasp of feasibility analysis*.

Closely related to this, there is a need for training of and deployment of development officers rather than fishery technical specialists.[5] These people should be able to understand and assess the potential for a range of income generating activities, including but not restricted to mariculture. This would reduce the common tendency for mariculture specialists to promote mariculture as such rather than rational development based on local capacity and resources.

Drawing on foreign practical expertise

It should also be recognised that – with regard to technical skills – there are *major opportunities for training, and sourcing trainers, in other parts of the world where mariculture is well established*. In Papua New Guinea it is notable that a local company with strong Malaysian connections is promoting seaweed cultivation in coastal villages, and has brought in Malaysian technicians to work on site with local farmers. This hands-on training could and should be extended to other species and systems. The alternative, perhaps even more useful, would be to send key staff to work on fully commercial farms in Asia for a period of time.

4.3.9 FINANCE

Good business opportunities should be able to attract finance, and most countries have aid funded, government funded or bank funded schemes targeted at small scale development. Mariculture is usually risky however, and it is appropriate that credit should not be *too* easy to obtain, especially in the absence of a thorough business plan and risk analysis.

The response of government and aid organisations in the region has often been to heavily subsidise mariculture developments themselves, despite the lack of thorough analysis, and the problems associated with such subsidy have been discussed in section 4.2.

Government and aid organisations can, however, facilitate bank lending by undertaking thorough and realistic sectoral and exemplary enterprise analysis of potential and viability, offering generic guidance (a kind of prospectus) to funders about risks, opportunities, likely returns, and favourable / unfavourable conditions for different types of mariculture development. This may of course reduce the chances of funding (if significant risks are identified) but that is as it should be. Unfortunately, in the past the ready availability of livelihoods focused subsidies and enthusiastic promotion by technical specialists have distracted from the thorough economic development analysis required.

[5] See for example http://www.fspi.org.fj/index.php/the-community-tool.html

4.3.10 ENVIRONMENTAL ISSUES

Environmental issues did not feature strongly in discussions with stakeholders in most case study countries, except in the Cook Islands, where there are significant concerns about both marine and terrestrial water quality, and where the intensity of coastal tourism development has probably begun to affect coastal waters. Concerns here are compounded by the prevalence of ciguatera in reef fish in Rarotonga and, to a lesser extent, in Aitutaki. Given the characteristics of some forms of mariculture as described in section 4.1, it is likely that environmental constraints may become significant in heavily used lagoons.

It is also worth noting that the black pearl industry in the Cook Islands has already suffered the consequences of over-stocking and possibly some environmental degradation, which may have contributed to the disease that did so much damage in the early 2000s.

Broader environmental elements captured in CITES and OIE (World Organisation for Animal Health) regulations have undoubtedly played a role in restricting giant clam exports and the aquarium trade more generally.[6]

4.3.11 BIOSECURITY AND AQUATIC SPECIES INTRODUCTIONS

A key potential comparative advantage of many PICTs is their isolated location and therefore relatively high 'natural' biosecurity (protection from, and resistance to, disease, and reduced likelihood of wanted introductions of non-native species), which should reduce the risks associated with disease and some predators, and also offer opportunities for the production of certified disease-free stock – already exploited, for example, by islands such as Hawaii.

However, several countries have already imported stock and, possibly with it, disease. Thus Fiji may have imported IHHN (Infectious hypodermal and hematopoietic necrosis), YHV (Yellow head virus), GAV (Gill associated virus), HPV (Hepatopancreatic virus) or MBV (Monodon baculovirus) with various shrimp stock brought in at various times from different countries.[7]

Biosecurity concerns and the need to fulfil appropriate protocols may also represent a bottleneck in terms of starting new ventures with species such as *Cottonii*[8] or *Trochus* that are not present in some Pacific countries. Risks and procedures may need to be clarified. For example, in RMI considerable efforts were required to sanction the introduction of Cobia. Also in RMI there was significant resistance from academics and conservationists to the introduction of *Cottonii* for seaweed growing trials.

[6] Kinch, J. and Teitelbaum, A. 2010. Proceedings of the regional workshop on the management of sustainable fisheries for giant clams (Tridacnidae) and CITES capacity building. SPC Aquaculture Technical Series. ISSN: 0377-452X; Kinch, J. Teitelbaum, A. Proceedings of the subregional workshop on the marine ornamental trade in the Pacific (2008 : Noumea, New Caledonia) (SPC Aquaculture Technical Papers / Secretariat of the Pacific Community) ISSN: 1683-7568.

[7] Patrois 2011.

[8] '*Cottonii'* is the trade name used to describe the seaweed *Kappaphycus alvarezii* – a major source of kappa carrageenan; the trade name '*Spinosum'* is used to describe the seaweed *Eucheuma denticulatum* – a major source of iota carrageenan.

5 OPPORTUNITIES

5.1 GENERAL

There are some good opportunities for mariculture development in the PICTs – especially where the various constraints noted above do not apply or can be managed. The nature and degree of opportunity varies hugely both within and between PICTs. This will depend on:

- price and volume of local, national and international markets
- access to local, national and international markets
- presence or otherwise of favourable trading networks
- actual or opportunity cost of local inputs, including labour
- knowledge, skills and access to technical expertise/advice
- motivation, commitment and a range of other social factors
- favourable climatic conditions
- site quality and availability

Some general opportunities worth highlighting include:

- those related to enhanced biosecurity (e.g. disease-free status) in isolated Pacific Islands;
- those related to (locally) rapid growth of urban centres, the shift from subsistence to trade economy, and the increased demand for commercially traded finfish;
- those related to tourism development and associated demand for high quality marine food and jewellery and crafts associated with mariculture products;
- those associated with the spectacular marine biodiversity of the islands;
- those related to the exceptionally high quality of the marine environment in many Pacific islands – qualities that are no longer available in many other countries active in mariculture.

In any aquaculture development planning or promotion, it is essential that the diversity of social, economic and environmental conditions within each PICT is recognised. A particular form of mariculture may have high potential in one location and very low potential in another. National level prioritisation (as has been undertaken in the various aquaculture planning exercises in the region) is therefore far less important than the capacity to assess opportunity objectively on a location by location (and even site by site) basis.

In the following sections we explore in more detail some opportunities for mariculture to contribute to the key objectives of sustainable development:

- *enhanced livelihoods* (through income generation from small-scale family or community enterprise)
- *food security* (through provision of reasonable cost/price high quality finfish or other marine products)
- *import substitution*
- *export earnings and value added*
- *employment.*

It should be emphasised that this is not comprehensive – there are thirty or more species/systems that may warrant analysis in any particular situation. The following represent

selected examples taken from particular countries to illustrate the nature of opportunity and the key factors to be considered. The key to successful mariculture development is to fully understand the characteristics of the species/system on the one hand (inputs, outputs, cycles, risks), and the development context (site, people, markets) on the other.

5.2 CONTRIBUTION TO IMPROVED LIVELIHOODS

5.2.1 SEAWEED

The price of seaweed is historically high at present, and in some locations alternative income generating activities, such as bêche-de-mer production, are not possible,[9] so that the opportunity cost of labour is relatively low.

Seaweed has characteristics which make it particularly suitable for production by poor people in isolated locations:

- relatively low investment requirement;
- relatively undemanding husbandry (therefore amenable to part-time activity);
- relatively low production risk (though can be vulnerable to grazing and cyclone damage in some locations);
- short cropping cycle (reinforcing the low production risk and improving cash flow);
- easy to harvest, dry (where/when weather suitable) and store;
- relatively good value to weight ratio (at the present time), and sufficient demand volume and ease of handling to generate economically feasible transportation (once dried);
- amenable to interesting development models in terms of agreements between families / communities and commercial traders.

In our case studies, seaweed cultivation appeared to be showing significant actual or potential impact in Solomon Islands, Fiji, and Papua New Guinea. In Solomon Islands, for example, around US$60,000 in income was generated in 2010 in the Wagina area, with median income of around US$571 per family or group per month, and with a few making substantially more. This represents a major impact on the local economy.

Value added in seaweed production tends to be high as a proportion of income generated because of the limited inputs required other than labour. Our evaluation of seaweed farming in Papua New Guinea, Solomon Islands and Fiji suggests that 1 tonne of seaweed production at the present time may generate up to US$557 value added and 0.1 Full Time Equivalent (FTE) of labour. Additional value added is generated in freight, storage and export, which depend greatly on location of production relative to main export port. Furthermore, the total cost of freight to market will significantly impact return on labour / value added for the producers. In other words, despite the advantages noted above, more isolated producers will be at a disadvantage in terms of freight cost, and this would have to be compensated by lower wages (or return on labour) or higher productivity associated with site quality or husbandry.

[9] Sea cucumber has been heavily impacted by overfishing and there are, for example, current bans in place in Papua New Guinea, Solomon Islands and Vanuatu.

The Pacific Island nations are unlikely to contribute more than a small proportion of global demand and therefore price is unlikely to be sensitive to increased production, except where this is associated with major increases in global production.

The price of seaweed has varied significantly historically and is likely to do so in future, dependent on the global volume of carrageenan production and the price of substitutes. It has already been suggested that the current high price of seaweed is making terrestrial alternatives more attractive[10] and price may therefore have peaked at least for the moment. Clearly this has a major effect on value added and return on labour, and producers are likely to abandon production at the point where other activities (such as copra, fishing, bêche-de-mer) generate a better return.

The need for substantial stock of plants to generate adequate supply of seedlings means that when/if prices go up again, it will take some time before production can rise to economically significant levels, and governments will need to examine the costs and benefits associated with holding significant stock as a reservoir for rapid start up.

5.2.2 PEARL OYSTER SPAT COLLECTION

The collection of oyster spat for selling on to pearl farms is a significant family / community / social group activity in countries such as Fiji. It has some characteristics in common with seaweed cultivation – relatively low investment costs and relatively high value to weight ratios.

However, it also has some disadvantages, including a rather longer production cycle, and (though probably highly variable according to site) the need for more intensive husbandry in order to maximise health and growth of the spat. In other words, this is more suited to better organised groups and/or as a more full time semi-commercial activity.

Although investment costs are relatively low, and value added as a proportion of income is high, investment costs may nonetheless be significant for poor people in isolated locations and, as for many such activities, projects and/or government have tended to subsidise lines and collectors – partially reducing the incentive for dedicated husbandry which would follow from significant personal investment.

It is notable that there were different views as to the relative value of wild spat collection versus hatchery production. In Papua New Guinea, the only (goldlip) pearl farm is based entirely on hatchery production of spat and the manager was of the view that hatchery spat is equal to wild sourced spat, and supply far more reliable. In Fiji, the largest pearl farmer was of the view that wild spat was much better – and in any case, collection of wild spat was an important income earning activity for communities.

We did not examine the economics of spat collection in detail and cannot offer specific figures on investment requirements, value added and employment generation, though some general figures for the pearl industry as a whole are given below. However, it is clear that with the difficulties in pearl farming itself, the demand for spat is likely to reduce. It is therefore difficult to see this as a significant area for economic growth.

Pearl farming (including mabe/half-shell pearl production) may only represent part of the market for wild or hatchery originated spat. Harvesting and cultivation for the mother of pearl (MoP) industry remain significant, supplying regional as well as international processor and

[10] Current Philippines prices US$1400-1700/t raw dried seaweed.

handicraft industries. Whilst traded unit value remains low, volumes are high and support valuable intra-regional value added industry.

5.2.3 GIANT CLAMS

Production of giant clams in hatcheries, followed by growout in ocean nurseries, has been promoted in various parts of the Pacific since the 1980s. It has been regarded as a significant opportunity for income generation and enhanced livelihoods in isolated coastal communities. The driving force for its early development was that it was a self-feeding organism – with its symbiotic zooxanthellae – and could simply be grown on the reefs and harvested for its high value adductor muscle, lower value mantle meat, and possibly also its shell for a range of applications. In practice this failed to take off because of:

- the long growout period
- high risk of mortality (from predation, cyclone)
- the small proportion of the animal that is high value product, and relatively high shipping / exporting costs.

If the cost of seed had been fully accounted this would also have been a significant issue from the outset.

In the 2000s the emphasis shifted to production for the aquarium trade, which offered several significant advantages, including shorter growout phase (although still between 1 and 3 years); an established trade and marketing network through aquarium products exporters; and good prices for relatively small animals, with importers prepared to pay relatively high shipping costs.

Various business models were adopted. In the Solomon Islands for example a major aid project[11] with involvement of the WorldFish Center, New Zealand Aid Programme and WWF took place between 2005 and 2010 but has not been sustained. Although there are different perspectives on this, the causes of failure probably include the following:

- Modest scale hatchery production implies high seed cost;
- Losses (to predators etc.) in the ocean nursery phase compound high seed costs;
- Small-scale ocean nursery production in scattered and isolated locations implies even higher seed costs (delivery), and marketing costs (freight, aggregation/ temporary storage and other costs);
- Relatively poor prices to producers related to high transportation costs, lack of market information (on the part of producers) and single monopoly exporter.

This failure is despite the fact that the exporter could sell many more giant clams than produced.

In the Cook Islands, a completely different situation holds. The government has the capacity to produce significant quantities of giant clam seed (at least 100,000 pa) at its hatchery in Aitutaki. An exporter of marine ornamentals can sell significant quantities (20,000–30,000 a year). At the present time the government produces a steady stream of clams and runs its own ocean nursery within an MPA that is serviced once a week at significant cost. Production for export has been low relative to potential – around 8000–9000 units a year over the last two years. Although the

[11] NZ Aid Programme and WorldFish Center Project. Creating rural livelihoods in Solomon Islands through environmentally friendly aquaculture and trade of marine ornamentals.

government would like to see local people take over the ocean nursery phase, it has been unsuccessful in persuading them of its attractiveness, although this relates more to the lack of a clear business model than to a lack of commercial viability.

Our figures suggest that if internal freight costs can be minimised, giant clam farming for the aquarium trade is financially viable. Depending on hatchery output (there are major economies of scale related to the high costs of technical management and basic operation) clam seed should cost between US$0.5 and $1.5/piece. Taking a value of $1/pc and a survival in the ocean of 70%, along with various other assumptions about labour input (at national minimum / standard agricultural rates) production cost approximates to US$2/clam – substantially lower than the likely purchase price by exporters of between US$2.4 and $4.8. However, cost is very sensitive to survival rate, and 70% survival[12] is only likely with dedicated husbandry in a favourable location. At the present time, importers are prepared to pay freight charges in addition to the basic price, though this is unlikely to apply to significant internal freight costs as the market matures.

This therefore appears to be a relatively attractive activity if an appropriate business model and growout mechanism can be developed – which has not been achieved as yet in either Solomon Islands or Cook Islands.

In RMI, a commercial model has been developed with most production harvested from an extended hatchery / raceway system operated by an exporting company. This has significant advantages, not least the potential to exclude predators, improve security, and locate production close to an airport. However, livelihood benefits are limited. The hatchery / exporter is happy to buy clams from village farmers who are provided with seed by government hatcheries. Growth is apparently 50–100% faster in ocean nurseries compared with the raceway system. The company would buy all it can get from villages (at US$2.5-3/pc) but seed supply to farmers is inconsistent. The company does not seem keen to provide spat directly to farmers, perhaps because survival rates would be inadequate to justify cost.

It would seem therefore that a few small-medium scale combined hatchery / nursery operations scattered at key locations across the Pacific, and close to cost effective air routes to major markets, could meet global demand at least in the short term. If more production was needed but on-site expansion constrained, these operations could then farm out some production to smallholders in the future.

Overall, however, with a product of this sort it makes sense to begin with relatively centralised strategically located production, and then expand outward if necessary to meet strong demand. To date – because of the livelihoods perspective – production has been scattered and isolated in the first instance, followed by attempts to rationalise collection and aggregation of product (as in the 'depot' set up under the Solomon Islands NZ Aid Programme project).

Whatever model is used, it is essential that production increases steadily to meet market demand and future growth. There is a real danger of many hatcheries across the region setting up on the basis of the current relatively favourable price, only to find the price collapsing relatively quickly. Global trade in giant clams appears to have been around 200,000 at its height in 2006, of which up to 50,000 were cultured. This is not a big market. A single economically viable hatchery operation would be around 100,000 production, translating into perhaps 60,000 after (economically viable) growout – or just under 1/3 of the peak market volume. While smaller operations (for example, commercial lease on part of a government hatchery)

[12] These rates have apparently been achieved by fisheries staff in the Cook Islands, but seem high given experience elsewhere in the region. Rates as low as 20% are not unusual and would make production completely uneconomic.

may be possible, and there is undoubtedly potential for market growth, it is clear that this is unlikely to become a major economic sub-sector, and we should beware of injecting too much effort – both in terms of the return on that effort, and the danger of over-rapid expansion. To give an idea of overall potential, we estimate that 200,000 in exports of aquarium giant clams from the PICTs might generate around 15–25 FTE jobs, and perhaps US$1 million in export earnings including a high proportion of value added.

A critical constraint may however be the need for second generation broodstock in order to meet CITES specifications, and here the existing government operations have a substantial comparative advantage, which might be exploited by leasing out to more commercial operators. This is especially the case in respect of those species most in demand for the aquarium trade: *Tridacna maxima, T. crocea* and *T. derasa.*

SUCCESSFUL GIANT CLAM FARMING FOR THE AQUARIUM TRADE WOULD PROBABLY START WITH EXPORTER INVESTMENT IN AND MANAGEMENT OF GIANT CLAM PRODUCTION, PERHAPS THROUGH LEASING A PART OF AN ESTABLISHED GOVERNMENT GIANT CLAM HATCHERY AT REASONABLE RATES. THEY ARE BY FAR THE BEST PLACED TO ESTIMATE DEMAND AND LIKELY PRICE, AND MANAGE HUSBANDRY AND PRODUCTION.

5.2.4 CORAL FARMING

Coral farming has been undertaken in several countries and is still active in several, including Solomon Islands, Fiji, Cook Islands, and RMI.

Subject again to location, coral farming appears to be economically viable and has significant advantages over giant clam cultivation from a livelihoods perspective:

- depending on the methods used, seed is effectively free – or rather can be produced by the grower him/herself by 'fragging' or dividing either wild or previously cultured coral;
- lower risk of mortality;
- shorter production cycle.

Taken together these imply easier entry (less investment required) and far lower risk, and make the activity much more suitable as a part-time activity.

There is also a specific sub-segment of the market for cultured corals, though this is probably only around 20% of the total market. Given trends in consumer awareness this proportion is likely to grow over time. The key to success is intense colour, and there are opportunities to source exceptional mother stock and perhaps select for colour intensity. The actual size of the market is unclear and deserves further research, but is undoubtedly significantly larger than that for giant clams.

In terms of development models it is probable that – as for giant clams – aquarium exporting companies would need to take the lead, possibly with government / NGOs facilitating a contract or satellite farming model.

5.2.5 SPONGE FARMING

There has been rather little activity in growing sponges in the Pacific Islands considering some highly favourable characteristics, including simple vegetative reproduction, relatively low maintenance requirements, easy storage, and relatively high value to weight ratio. The disadvantage is the relatively long growout period of 1–4 years (compared with, for example, 6 weeks in the case of seaweed).

These characteristics may warrant further in-depth analysis of markets, supply chains, and production costs in a range of locations to establish viability and potential. However, it should be recognised that the length of the growout period is a significant disadvantage, with potential problems in terms of cash flow, production risk (e.g. cyclone) and balance between supply and demand.

5.2.6 POST LARVAL CAPTURE AND CULTURE

This will not be addressed in this report. We were not able to visit any successful examples in the case study countries, and we understand that there remain significant technical difficulties, including in particular the effort and cost involved in feeding the early stages.

In any case this is not a market-led technology – it is 'let's see what we can catch; let's see if we can grow it; let's see if we can sell it'. Successful mariculture must begin with identified demand for a product followed by efforts to identify the most cost-effective method to meet that demand.

5.2.7 EXTENSIVE MILKFISH PRODUCTION FOR BAITFISH?

There is a possibility of production of milkfish for baitfish for the tuna longline fleet in certain locations in the Pacific. These bait fish are grown to around 15 cm in length and around 100 grams in weight (takes in the order of 2 to 3 months), and are sold live for baiting the longlines at around US$2/kg.

In Palau for example there are two milkfish production operations: one run by the tuna long-line companies specifically for the production of baitfish in large ponds; and a joint project between the private sector and Ngatpang State specifically for the production of milkfish for food.

In the order of a tonne of juvenile fish are harvested per week for sale on the local market for on-growing. These are then reared in ponds for 6 months, and subsequently in cages in the lagoon for the last month or two before harvest.

However, milkfish cultivation has been tried in a number of PICTs and later discontinued. So not only is pricing important, but proximity to a longline fleet interested in using this source of bait (this is mostly concentrated in the south and east of the region), and potential for on-growing for local consumption, are likely to be critical factors. Since milkfish is not a high value species, to be feasible certain conditions must pertain, e.g.:

- site potential for low-cost excavation of shallow ponds with tidal exchange, or adaptation of natural features to create suitable shallow and easily managed ponds;
- plentiful local supply of fry;
- low labour costs for fry collection and pond management / harvesting;

- high skills in extracting maximum output for minimum (fertiliser only) systems;
- capacity to produce bait sized fish throughout the fishing season;
- close proximity to sheltered wharf / harbour convenient for the tuna fleet to take on bait;
- sufficient scale to meet the needs of the relevant tuna fleet or part of that fleet.

This is a demanding set of conditions, and governments / aid projects should take great care in promoting this activity. In any case, production for this market alone is inherently risky, as noted by Fitzgerald (2004)[13]: '*The transient nature of tuna fleets and the numerous external factors that impact on their operations would place at risk an aquaculture venture's sustainable successful operation that was developed solely to meet a potential live bait market*'.

5.2.8 RESTOCKING

Restocking using aquaculture produced individuals has been promoted for almost as long as aquaculture in the region and certainly over the last 30 years. Governments and projects continue to propose aquacultural resource enhancement (ARE) as a tool for re-establishing or increasing depleted stocks of commercially important species. However, numerous trials and review papers have done little to vary the consensus of policy advice on restocking, stock enhancement and ARE in particular[14]:

> 'RESTOCKING WILL NOT HAVE A BENEFICIAL EFFECT IN THE ABSENCE OF FISHERY MANAGEMENT – IF RESOURCES ARE DEPLETED BECAUSE THEY ARE BEING HARVESTED BEFORE THEY GET A CHANCE TO REPRODUCE, THE SAME THING WILL HAPPEN TO RE-SEEDED CLAMS'.

This is not the place to go into great detail but in essence the management advice for most species that might be expected to respond to ARE can be summarised as follows:

1. If wild stocks are depleted but enough remain to replenish populations, then national and community based management approaches should be strengthened including moratoriums, closed areas, closed seasons and monitoring.
2. If wild stocks are too depleted for significant reproduction to be expected, then aggregation of wild individuals in closed areas is an option. A last resort would be restocking either from translocated individuals or hatchery reared specimens.

From the data on hatchery costs and survival rates apparent in this study and the opportunities for improved coastal fisheries management that exist[15] far greater evaluation of aquacultural resource enhancement is required before scarce financial resources could be justifiably diverted from other options for improving coastal fisheries management.

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[13] FitzGerald, W J. Jr. 2004. Milkfish aquaculture in the Pacific: potential for the tuna long-line fishery bait market. SPC Aquaculture Technical Papers.

[14] Preston G.H. and H. Tanaka. 1990. A review of the potential of aquaculture as tool for inshore marine invertebrate resource enhancement and management in the Pacific Islands. SPC / Fisheries 22/IP5. FSM Department of Economic Affairs. Coastal Fisheries Consortium. Pohnpei, December 12-14, 2000. Working Paper 9. Future Operations of the National Aquaculture Center. Friedman K., Purcell S., Bell J. and Hair C. 2008. Sea cucumber fisheries: A manager's toolbox. ACIAR Monograph No. 135, 32 pp.

[15] Govan, H. et al. 2009. Status and potential of locally-managed marine areas in the South Pacific: Meeting nature conservation and sustainable livelihood targets through wide-spread implementation of LMMAs. SPREP/WWF/WorldFish-Reefbase/CRISP Gillett. R. and I. Cartwright. 2010. The future of Pacific Island fisheries. SPC, Noumea.

5.3 CONTRIBUTION TO FOOD SECURITY

A fish supply gap for many PICTs has been reported in the literature (Bell et al. 2009) related to heavy current pressure on wild stocks, increased population, climate change and urbanisation. It is believed that traditional coastal fisheries will be unable to meet demand and that supplies in future will need to come from increased coastal fisheries for large pelagics and other species round FADs, diversion of more tuna from the offshore tuna fishery, and from aquaculture.

The role of mariculture in this is unclear and likely to be limited at least in the short to medium term. The predicted supply gap is unlikely to be reflected in fish prices for some time to come, and when it is, alternative supplies (tuna, more distant coastal fisheries) are likely to be accessed in the first instance.

Mariculture (and freshwater aquaculture) technologies are well known globally and can be applied rapidly where / when prices are suitable. Mariculture planning should therefore be based on proper appraisal of current and likely medium-term prices for the relevant species and their substitutes – not long-term speculation.

Most marine finfish are relatively demanding and expensive to produce and more suited to commercial production for high-value restaurant markets. The partial exception is milkfish, which can be grown more extensively (including in fertiliser only systems) and which is less demanding from a fish nutritional perspective. However, in most cases freshwater Tilapia would probably be a better option. Seed production is cheaper, growout easier and more flexible (given quality stock) and it can be grown in fertilised only systems, supplementary feeding systems or intensive systems in ponds or cages.

5.3.1 MILKFISH

Where milkfish is to be considered, it is essential that realistic estimates of production costs are made, and market price and volume thoroughly understood. Clearly both of these vary hugely both within and between PICTs, but some baselines or benchmarks can be put down.

Milkfish are normally grown in brackish-water ponds, and the costs of these should be properly accounted. In some economic analyses, the costs of pond and water management infrastructure are not included, and are regarded as more general national infrastructure investment. Our view is that the costs of ponds should be allocated to the mariculture enterprise when assessing financial viability. This cost varies between locations across the Pacific, but is likely to be of the order of US$20,000/ha, although it may be less for ‘shallow pond’ (typically fertiliser only) production systems in favourable locations.

The other major production costs are labour and fertiliser, and in more intensive systems, feed. If tidal water exchange is not possible there may also be significant pumping costs.

The cost of labour is obviously highly variable across the region (e.g. varying from $0.2/hr in Solomon Islands to $4/hr in Cook Islands and higher still in some other islands) and labour usage will vary to some degree in inverse proportion to cost. However, it is reasonable to assume at least 1 FTE per ha.

If feed is not used, a crop of 0.5 to 2 t/ha/yr can be achieved. In this case the major costs relate to the initial investment in pond infrastructure. With intensive feeding in deeper ponds, yields of 5 to 10t/ha/yr may be achieved. Where feed is used, the costs depend on feed price and food conversion ratio. The cost of dry formulated food, whether local or imported, is unlikely to be less than $600/tonne and may be more than $1,000. Given a food conversion rate of between

1.5 and 2, this means feed costs alone will be between US$1 and $2/kg, and total production costs (farm gate) in the range US$2-3/kg (see Table 1). This will make farmed milkfish relatively expensive compared with other fish in many countries in the region, and given the relatively high risk profile of mariculture and the significant investment requirements, suggests that thorough feasibility studies should always be undertaken prior to any form of trial or promotion. Given the uncertainties about viability, it is inappropriate to speculate on the potential future contribution to food security, employment, value added and so on.

5.4 IMPORT SUBSTITUTION

5.4.1 SHRIMP

Shrimp farming has been undertaken for many years in New Caledonia and is one of the most successful mariculture activities in the region. It has also been undertaken in Guam, Fiji, Papua New Guinea and Solomon Islands.

PICTs are relatively well placed to farm shrimp. The technology is globally established with a significant pool of international technical expertise. The product has a relatively high value to weight ratio and is in demand throughout the world and within PICTs, especially those which are more highly developed or have a significant tourism industry. Many of the PICTs have favourable climate and suitable sites with reasonable access to local and in some cases international markets. Isolated island nations also have the significant potential comparative advantage of high biosecurity, of particular importance given the chronic problems associated with shrimp disease throughout the world. Some PICTs have the additional comparative advantage of low labour costs.

A further relevant consideration in import substitution is the relatively high level of import duties for seafood products applying in many PICTs (as much as 40%). While a few are reducing tariffs as WTO members, and there are various free trade arrangements on the horizon (EU, AU, NZ), most of the countries maintain high rates of duty on imported seafood from the serious competitors in Asia. Conversely, there are developing tariff free trade arrangements between PICTs (Melanesian Spearhead, PICTA – Pacific Island Countries Trade Agreement) which, if shipping is available and affordable, may allow trade with neighbouring countries on these preferential terms.

Against all of these advantages has to be set an understanding that shrimp farming is a highly developed and highly competitive industry. Labour costs are still low in Asia, but skills are high, and the scale of production has allowed for the development of highly efficient infrastructure, supply, distribution and processing systems. To compete with these producers whether through import substitution or for export will not be easy.

It is instructive to explore the reasons for the apparent lack of success of shrimp farming in Papua New Guinea, Solomon Islands and Fiji. In Papua New Guinea a commercial farm was established in Rabaul between 2005 and 2007 (including a hatchery, 10 ha of ponds and a processing factory) by a large local multi-sector company. The enterprise was successful initially (good crop in 2008) but is now constrained by lack of broodstock.

In Solomon Islands a commercial company was established in the late 1980s and production rose steadily up to 15 tonnes by 2000. The farm was then affected by ethnic tensions in 2002 and closed, although the proprietor was of the view that this was an excellent business and is seeking to restart production.

In Fiji both artisanal and commercial scale production of shrimp has taken place in the past, but development has been constrained by a variety of factors, the most important of which has been a lack of consistent seed supply from government and university run hatcheries. The reasons for the lack of any successful sustained hatchery and farm production of marine shrimp in Fiji are many but may include:

- inadequate biosecurity; HPV, MBV, MoV, GAV and IHHNV have all been identified in Fiji populations of *P. monodon*[16];
- chronic disease in farms and possibly hatchery, associated with high mortality and declining productivity;
- lack of expertise in algal culture and problems with quality of algae stock;
- lack of sufficient wild broodstock and/or seasonal limitations on availability, maturity and quality;
- cost of holding sufficient broodstock in the hatchery;
- chronic underfunding of hatchery?
- lack of effective management and incentives for PL production at government run hatcheries;
- high feed costs (currently sourced from China or Taiwan [expensive]) and spoilage / storage problems with feed;
- local fisheries staff suggested lack of scale, skills, infrastructure, and the cost of land or loans on land were also factors;
- unfortunately there has also been some introduction of disease in the past, though its current significance is uncertain.

It has recently been suggested[17] that the key to success in shrimp production is to have domesticated stock (and this probably implies use of, for example, whiteleg shrimp). However, the Asian industry grew for 20 years on the back of wild broodstock sourcing, and many PICTs have native *P. monodon* stocks – a species which is particularly attractive as a larger higher value product. It is unclear at present whether the opportunity to source wild broodstock has been fully explored in, for example, Fiji and Papua New Guinea.

In any case it would appear that there is significant potential for shrimp production in many PICTs, especially where sites are available close to urban centres, tourism centres and ports / airports. However, in order to compete with Asian and South American imports, farms will need to be very well managed, maintain disease-free status, and use state of the art skills.

5.4.2 BARRAMUNDI AND OTHER MARINE FINFISH

As a marine finfish, much of what was said above in relation to milkfish farming is pertinent. However, barramundi is likely to cost somewhat more than milkfish to produce because, as a carnivorous fish, it cannot be grown in fertilised only ponds and its nutritional requirements are more demanding so that the cost of formulated feed is higher. It is, however, well suited to growout in cages, opening up opportunities where pond aquaculture is not possible, assuming

[16] Patrois, J. 2011. Shrimp farming in the Pacific Islands countries and territories: Status and trends in 2010. Secretariat of the Pacific Community. ISBN 978-982-00-0491-7.
[17] Jacques Patrois and Tim Pickering. 2011. Shrimp aquaculture in the Pacific Island countries and territories: Current status and analysis of progress. Presentation to the FAO/SPC regional scoping workshop: Development of a Pacific aquaculture regional cooperative programme. Tanoa International Hotel, Nadi, Fiji, 11 October 2011.

that environmental impacts are acceptable and local markets, or access to international markets, are adequate.

There may be opportunities for production of barramundi in some of the Pacific Islands where there is either strong demand for a restaurant sized marine finfish or where there is strong urban demand. In Papua New Guinea there is a specific opportunity to supply a buoyant catering sector supplying quality frozen fillet to mining camps and hotels.

In all cases, however, margins are likely to be relatively slim for a relatively high risk activity, and very thorough locally focused feasibility studies need to be undertaken.

An example of likely minimum costs is presented in Table 2. In practice we would anticipate a typical cost associated with small to medium scale production of closer to US$3/kg, at least until husbandry skills are fully developed.

5.5 EXPORT EARNINGS AND HIGH VALUE ADDED

Shrimp farming has the potential to be an export activity in addition to import substitution and has been discussed above.

5.5.1 PEARL FARMING

Pearl farming is struggling at present, related to a combination of factors including:

- over-supply, especially for lower grade pearls;
- poor market price related to the above and the poor health of the world economy;
- high investment costs and long payback period, leading to particular difficulties as price falls;
- high labour (technician) costs irrespective of location (there is a world market for good technicians).

The current farm gate value of pearls appears to be below average production cost, and new private sector investment in the industry is therefore highly unlikely at the present time. Nonetheless, a New Zealand Aid Programme is seeking to encourage reinvestment in the industry in Cook Islands and the Government of Fiji continues to offer significant support to the industry.

The future appears to be fairly clear. It is likely:

- there will be significant rationalisation and specialisation of the industry;
- there will be fewer larger farms serving the international market for high-quality round pearls – these will be highly efficient, with excellent marketing and market connections;
- there will be an array of smaller more specialist producers targeting local tourism and craft / jewellery markets, perhaps set up in association with major tourism developments;
- there may be farms specialising in more easily and consistently produced mabe pearl selling bulk into the craft / jewellery industry.

5.6 EMPLOYMENT

The main areas for employment generation are probably as follows:

- Further development of seaweed farming with the bulk of employment in the lowest wage areas (though there will be a trade-off here with market access).
- Further development of shrimp farming and processing, with the bulk of employment in the latter.
- Employment in giant clam farming is likely to be very limited, with somewhat more but still limited employment in coral farming.
- Opportunities for other forms of mariculture development are unclear on a region wide basis and could only be explored through more detailed feasibility studies on a country by country basis.

Mariculture production may also be linked to additional economic benefits deriving from post-harvest handling, processing (handicrafts, de-boning / filleting of fish, etc.) and distribution.

5.7 EXEMPLARY PRODUCTION COSTS AND ECONOMIC CHARACTERISTICS

To fully understand the financial characteristics of different production systems requires rigorous investigation of local environmental and physical conditions, investment and input costs, financing costs, skills, time inputs, market, market access and market chain characteristics. As we have noted repeatedly in this report this investigation has rarely been done adequately in respect of mariculture opportunities in the region. In this study we have not been able to undertake rigorous financial and economic analysis of all the various options since the diversity of such options precludes this, but we have examined a few examples in the field, and reviewed the literature or information provided by consultees in respect of others. The following table sets down a summary of the major costs and the cost structure of some of these enterprises, the possible returns in terms of value added and return to labour. By comparing production costs with likely market value it also allows for a broad assessment of potential and financial risk. It should be emphasised that these figures are examples only. Actual figures will vary significantly according to location and the various factors listed above.

The figures are derived from simple spreadsheet models and data / parameter summaries. It is notable that one of the most critical characteristics of an enterprise type from both commercial and livelihoods perspectives is the labour input required – and yet information on labour input is absent in most analyses and trial monitoring data.

Table 2. Rough estimates of costs and returns (US$) for different mariculture enterprises based on examples in case study countries.

	Barramundi (PNG)	Shrimp farming (PNG)	Seaweed cultivation (PNG)	Milkfish (Solomon Islands)	Giant clam farming (Cook Islands)	Pearl farming (Cook Islands)
Capital charge	0.44	6.49	0.02	0.2	0.63	1.68
Seed	0.56	1.35	0.04	0.08		0.25
Feed	1.16	1.49	-	1.38		
Fuel	0.12	3.48	-		0.14	0.60
Management		0.27			0.12	
Other labour	0.28	0.14	0.18	3.51	0.48	7.02[18]
Other inputs	0.07	0.18	0.02	0.35	0.01	0.96
Total operating costs US$/kg	**2.64**	**13.4**	**0.26**	**2.5**	**1.75[19]**	**10.5[20]**
Illustrative farm gate price	3.17	18	0.63	2.82	2.36	11.9[21]
Likely wholesale market price range US$/kg	2.3-4.5	*10-30*	0.63[22]	0.7-3	2-6	7-12
Profit margin	17%	26%	59%	11%	42%	12%
Value added US$/tonne	815	4,840	557	812	62%[23]	70%[24]
Return on labour US$/FTE	5,499	66,167	5,846	667	23,430	Data poor
FTE/tonne	0.15	0.07	0.1	1.2	0.07 per 1000	Data poor
Potential annual production (tonnes)	100?	200?	Several thousand	500	200,000 clams	200,000?

Notes:

- All figures for costs are in US$ using exchange rates for September 2011.
- Most of the above depend critically on assumptions about market price, the price of feed and food conversion efficiency (where relevant) and the amount of labour required. *In most cases, realistic and well informed figures for these parameters are not readily available at the present time.*
- *Capital charge* is a composite charge including a) depreciation (usually over 10 years); b) maintenance of ponds/cages/equipment at 5% (ponds) or 10% (cages and associated structures), and c) interest on initial investment, taken as 5% (i.e. assuming relatively cheap credit).
- *Value added* is estimated as profit + cost of labour; this is value added for the enterprise and does not include upstream and downstream value added which may be highly significant.
- *Return on labour* is effectively the total value added divided by the amount of labour in full time equivalent (FTE) required to generate that value added.

[18] roughly 60% of labour costs relate to operation by technician.
[19] Total cost US$/clam.
[20] Total cost US$/pearl.
[21] Note this is an average price taking into account only 10 –15% are grade A and 40% B & C. Probably optimistic at the present time.
[22] Actual price currently agreed August 2011.
[23] Value added/income.
[24] Value added/income.

- 1 FTE is taken as 8 hours per day for 240 days per year, or 1920 hrs.
- None of these estimates include charges for rent or licences.

The following key points emerge from this analysis:

a) Although estimated profit margins are generally positive and in some cases healthy, the likely range of market value, when compared with production cost, suggests that most will only succeed if market value is close to the upper end of its likely range – and this means that location must be such as to minimise marketing costs. Most would not succeed in more isolated locations.
b) Profit margins on seaweed, shrimp, and giant clam farming appear relatively healthy. If efficient disease-free productions systems can be set up, these are likely to be successful in suitable locations throughout the Pacific region. Shrimp farming will almost certainly depend on a good local market to become established.
c) Profit margins for finfish culture (barramundi, milkfish) are likely to be very slim, and given the expected price range of the products, and uncertainties about food conversion and productivity, there is a high risk of loss and failure. Very thorough location-dependent feasibility analysis should be undertaken before promoting these activities.
d) Pearl farming is not an attractive option at the present time unless a clear niche can be exploited.

6 DISCUSSION AND CONCLUSIONS: FACILITATING SUSTAINABLE MARICULTURE DEVELOPMENT

This brief and broad ranging analysis demonstrates one simple truth: we need to get away from the idea that mariculture is good and should be promoted. It is an option to be considered, and given its relatively demanding / high risk attributes, development opportunities must be reviewed thoroughly and impartially. The key to this is better development planning, more objective and informed project preparation and appraisal, and probably a greater role for the private sector as a key partner in any government or aid promoted development project.

Throughout all of these considerations run the themes of *more thorough and realistic market appraisal, and more thorough and realistic estimates of production, distribution and marketing costs.*

6.1 INFORMED / IMPROVED DEVELOPMENT PLANNING

Most of the existing country aquaculture development plans are inadequate in terms of addressing the two major themes noted above. They are based mainly on 'banging heads together' and superficial analysis of feasibility and impact. These plans should either be more thorough (implying substantial costs in background research on production costs and markets) or they should be more focused on processes and mechanisms to support sustainable mariculture development, such as:

- how to fund thorough market / market chain analysis for a range of possible products;
- how to source and deliver technical and economic advice to both private sector companies and target communities;
- how to increase the effectiveness of government / NGO / research organisation / private sector collaboration and partnership in creating sustainable mariculture enterprises;
- how to develop and use existing hatcheries most effectively in terms of supplying potential short-term demand while at the same time developing more strategic longer term potential / expertise;
- how to identify key opportunities and constraints in spatial terms: suitable areas or sites, price and cost variation within country, distribution and transport infrastructure, distribution and marketing systems (individuals, organisations, etc.), and community development needs.

There may be specific opportunities to analyse and address constraints, such as:

- opportunities to overcome local freight disadvantages through creative integration of freight infrastructure with other activities.

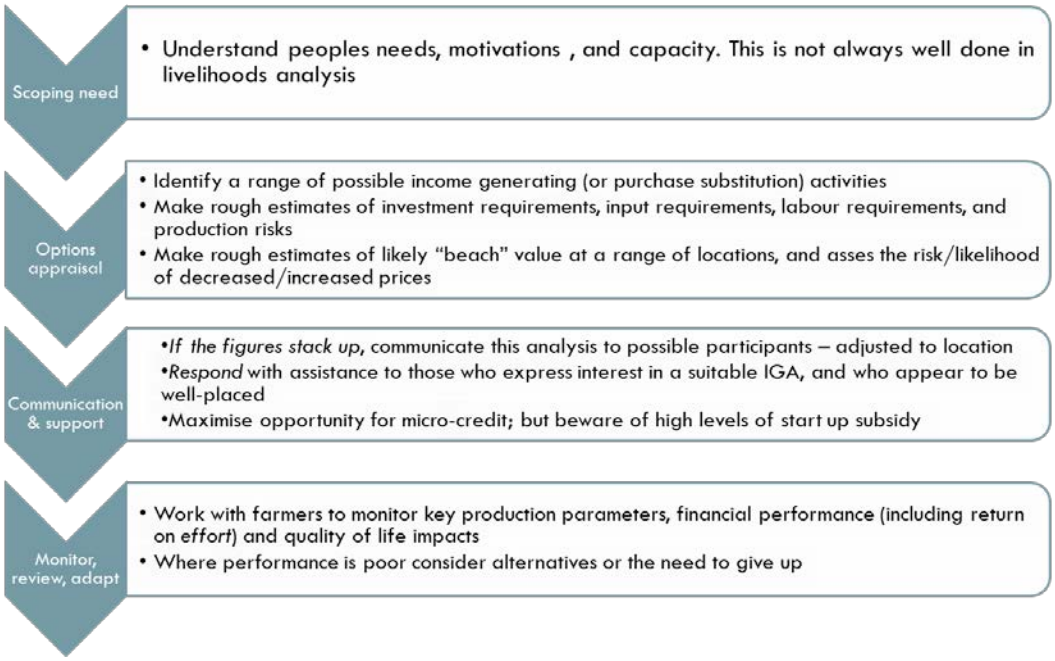
The tendency to generate rough headline priorities by banging heads together is dangerous, because the resulting plan, agreed by government, may be taken as the 'bible', and the assumption is likely that mariculture will work for the top priority commodities.

6.2 DEVELOPMENT PROJECT DESIGN, PLANNING AND MONITORING

A large part of mariculture activity in the past has been driven by research funded, aid funded or government funded development 'projects', usually with the objective of promoting a particular species or technology as a new alternative income generating or food generating activity. The limitations of this approach have been thoroughly aired in section 4.2.

The key to more effective interventions designed to promote enhanced livelihoods, food security and economic development is *not to start with mariculture as a solution, but rather to be aware of it as a possible option*. This necessarily requires a thorough understanding of the key characteristics outlined in section 4.1. The ideal process for development interventions has been analysed endlessly in the development literature, but the key characteristics are simple and widely agreed, and are summarised in Figure 5.

Figure 5: A simple development planning process.



Options appraisal is a key part of this. Given the relatively high risk nature of mariculture, analysis of this option must be thorough. This will usually require market and financial feasibility analysis. Although this is often undertaken it is rarely as *thorough, informed, or independent* as it should be. Both market and financial analysis require a combination of general economic and sector-specific skills and knowledge. Thus a non-specialist independent economist is unlikely to question production parameters offered by scientists – often far more optimistic than those achieved by fish farmers in practice. Similarly, there is no single 'market price' for a product. A full understanding of the market chain (logistics, businesses, power relations, etc.) as well as market demand is required to be able to estimate realistic medium-term prices at particular locations.

6.3 COASTAL / INSHORE PLANNING AND MANAGEMENT AS THE WIDER CONTEXT

It is arguable that if integrated coastal management (ICM) and its latest incarnations (EAFM and EBM) are to have any real meaning and impact they must serve as the framework for both the utilisation and management of coastal resources as a basis for sustainable development. In other words, mariculture planning and facilitation should be subsumed under an integrated natural resource planning process. Unfortunately, while ICM and its relatives represent the ideal approach to sustainable coastal development, they have proven complex and unwieldy and there are few good examples of effective implementation. However, small island states have a huge opportunity to implement more integrated planning and management, given the focus on coastal issues and the relative simplicity of government in many locations.

A rational planning and management process would identify the full range of opportunities and constraints associated with marine resource use, including mariculture, and put in place mechanisms to facilitate and manage development as appropriate to the needs of local people and the limits of the environment. Within such a process, mariculture might or might not be a priority, and there would be the opportunity for a rational comparison of opportunities associated with fishing, mariculture, freshwater aquaculture, agriculture and other sectors.

In this case as with those discussed above, however, there would be the requirement for objective independent analysis of costs and returns associated with competing resource use.

6.4 DEVELOPMENT MODELS

However well this type of development project design, planning and implementation is undertaken, it may be that the development project approach is simply inappropriate and that we need to look at more subtle ways of facilitating and enhancing community and economic development – again with mariculture as one of the technical options. There are three key elements that may need to be considered more fully in future.

6.4.1 THE ROLE OF THE PRIVATE SECTOR

There is increasing awareness of the importance and potential role of the private sector, and a lack of understanding of the operations of the private sector have almost certainly contributed to the failure of some mariculture development projects.

There are some clear opportunities, with examples of private sector involvement including the following:

- In Fiji, the largest ornamentals exporting company has just established a new holding facility in Vanua Levu and will be assisting a village / community in coral farming and collection alongside agreed purchase of product produced. Chinese companies are also working with villagers to encourage seaweed production.
- In Papua New Guinea, a Malaysian company is working with isolated villages to facilitate and promote the production of seaweed, including provision of full time 'live in' Malaysian trainers. Also in PNG a private processing company is keen to develop Cobia or barramundi farming on a contract farming or similar basis.
- In Fiji, pearl farmers work in various ways with communities and groups to collect and supply pearl oyster spat.

- In Cook Islands at least one private sector company is interested in working with government to produce and market more giant clams, and in RMI a private hatchery buys clams from community farmers grown from spat provided by government.
- In Solomon Islands, several trading companies are working with local communities to promote seaweed farming and secure supplies. At least one of these companies is also keen to work with government to develop new activities such as sea cucumber and giant clam production.

There are no standard models, and even those referred to in the literature such as contract farming, nucleus estate, credit and buy back systems, etc. are far from standardised. There is potential for a host of different working relations depending on the nature of the species, local conditions, skill levels and other contextual issues. Our review of these approaches did not reveal any magic bullet, but was encouraging in so far as there appears to be heightened awareness on all sides of the opportunities. In reviewing the performance of various contract farming and nucleus estate type systems elsewhere in the world, it is notable that the main problems arise from either misunderstandings about the nature of the relationships from the outset, seriously imbalanced power relations, or over-investment and overly optimistic financial projections for participants – especially the contract farmers.

The involvement of the private sector at the very least is likely to bring a dose of realism and hard headedness that has been lacking from so many of the projects we reviewed. In any case many mariculture ventures are far more suited to commercial rather than artisanal development because of the risks, scale, efficiency, and commitment required. It should not be forgotten that commercial development may also bring livelihood opportunities as exemplified above.

A key to successful commercial development is ready access to good basic information about mariculture production systems and product markets. Interestingly, however, some of the private sector people we talked to emphasised the former rather than the latter, not because markets are unimportant – far from it – but rather because they themselves would be best placed to explore market potential and marketing costs. It is likely however that private sector interest would be increased if thorough and broad based feasibility studies were to be funded or made available.

As with smaller scale enterprise, government should always beware of offering subsidy, other than, for example, tax holidays or similar incentives which cause limited market distortion.

6.4.2 THE ROLE OF THE HATCHERY

We have noted in section 4 the consistent under-performance of government run hatcheries, and perhaps confusion about the role of these hatcheries. As a result they have tended to become opportunistic rather than strategic, taking the chance to trial new species or engage in research when funds become available, but failing to underpin a developing mariculture sector and develop a sustainable financing mechanism.

Examples of successful hatchery development have tended to be where public hatcheries are devoted to improved broodstock maintenance, training and research, while commercial private hatcheries and nurseries are devoted to mass production of seed.

We see a critical need here for regional and national strategies for hatchery development and management. Hatcheries can fulfil five main functions, i.e.:

- research on new species – especially local species – that may be particularly well suited as mariculture candidates;
- training, which can be partially related to research, but which also needs a more practical and commercial dimension;
- trial production of promising species for which thorough feasibility studies have been undertaken and which can feed directly into trial or demonstration growout facilities;
- broodstock development, maintenance and management;
- efficient and consistent production of species for which there is established private sector demand.

It is arguable that individual countries cannot afford research hatcheries unless they also play a major role in training, and are associated with key education and training establishments in the region. *There is an opportunity for SPC to facilitate a regional strategy aimed at rationalisation of research and training hatcheries across the region* – building up centres of excellence relating to different species or species groups in the most appropriate locations, minimising duplication of effort, and facilitating consistent research funding for these specialist centres.

Hatcheries that focus on trial production of the most promising species in order to support realistic growout trials or demonstration centres are perhaps the most important and the most difficult to fund. Regional R&D funds available to these hatcheries often tend (unsurprisingly) to focus on species which have not yet been shown to be commercially viable, for which significant further research is required, or which meet the needs of a particular development philosophy (generally related to poverty or environment). Mechanisms need to be explored for the funding of more practically and commercially based production, including making realistic charges as soon as is practicable. While it is understood that free or part subsidised seed may be a key factor in facilitating the take-off of mariculture activity, it is essential that it does not become the norm, and that realistic charges are introduced as soon as possible. It is also important to facilitate private sector hatchery development (or leasing of hatchery facilities to the private sector) as soon as it is apparent that any form of mariculture has significant commercial potential. It appears that government hatcheries distributing free seed may have undermined private sector opportunities for the production of seed for commercially viable species.

Given the many international / regional research facilities, national hatcheries should focus on commercial species and balance production with *emerging* demand. This requires clever, informed, strategic hatchery management – and comparative market / economic feasibility studies for all species in each country. *Again, there may be an important role for SPC in exploring with national governments financing options for hatcheries.*

It is worth bearing in mind the Japanese and Taiwanese approach to hatchery provision, i.e.:

- a national or regional research organisation with one or more experimental hatcheries focusing on new species / varieties;
- a district hatchery focusing on mass production of commercially important species, which occasionally produces less well-established species where the economic outlook seems favourable; although these hatcheries are government run they usually generate a substantial proportion of their income / operating costs from sales of seed;
- commercial hatcheries, often operated by larger companies with their own growout farms, and also mass producing seed of species in strong demand;
- universities and research institutes, which may also establish their own semi-commercial sub-divisions.

7 RECOMMENDATIONS

1) SPC and national governments should seek to strengthen mariculture development planning within the context of national economic development planning and integrated coastal management. This should include not only review of mariculture resources and technical/market opportunities within a wider social and economic context, but also a thorough analysis of the roles and capacity of both private and public sector, and regional/international organisations, in facilitating sustainable development of the sector.

2) SPC and national governments should explore the desirability/feasibility of setting quality standards, protocols and minimum requirements for research and development projects and other development interventions.

3) SPC and national governments should target a greater proportion of their aquaculture resources to:

   - undertaking and/or facilitating thorough market and market chain research on key commodities/species with aquaculture potential, at regional, national and local levels
   - ensuring that such analysis is made available to economic planning and development departments (as well as fisheries departments), key players in the private sector, the training sector, and others who may consider joining the private sector
   - building capacity to undertake thorough market research and feasibility studies at local level across the region
   - raising awareness of the real, rather than the ideal nature of mariculture as a business
   - following up, where appropriate, with solid technical and market intelligence support

4) SPC and national governments should carefully review the strengths and weaknesses of alternative rural, urban and peri-urban development models, drawing on experience in fisheries, agriculture, forestry and small-scale artisanal enterprises throughout the world – and consider their application to mariculture development in different social, economic and environmental contexts. Particular account should be taken of the role of the private sector in development.

5) SPC should seek to develop with member countries a regional hatchery strategy, and where appropriate support and facilitate national hatchery strategies. These should take account of:

   - the need to match supply of seed with demand
   - the need to ensure that seed production is ultimately self-financing
   - the need to charge all farmers or potential farmers a realistic price
   - the opportunities for facilitating, and in some cases partnering, private sector developments
   - the need to focus more strategic and longer term research and/or broodstock development, management and maintenance on centers of excellence
   - the need to develop a consistent and coherent policy on introductions

6) SPC should seek to support and facilitate a more open minded and strategic approach to the issue of cost effective feeds. The current set of largely technical research initiatives should be supplemented with more comprehensive appraisal of options, including:

- the strengths and weaknesses, financial and economic characteristics of fertilised v. feed based mariculture systems
- the strengths and weaknesses, financial and economic characteristics of using local feeds, nationally produced feeds, or imported feeds
- the desirability or otherwise of import tariffs on fish feeds and fertilisers.

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Appendix A

OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

COUNTRY REPORT: COOK ISLANDS

Report by Hambrey Consulting in association with Nautilus Consultants

www.hambreyconsulting.co.uk

To the Secretariat of the Pacific Community

November 2011

THIS REPORT

This brief report was prepared in support of a wider study on Opportunities for the Development of the Pacific Islands' Mariculture Sector for the Secretariat of the Pacific Community (SPC), and forms one of a set of five country case studies undertaken between early August and September 2011. Reports were prepared for the following countries:

- Cook Islands
- Fiji
- Papua New Guinea
- Republic of the Marshall Islands
- Solomon Islands

Roughly one week was spent in each country, including site visits and discussions with stakeholders. Thanks are due to all those who spent time talking with us (see list of consultees on page 60) and especially to Dorothy Solomona, Ben Ponia, Koroa Raumea and Richard Story.

An overview report was also prepared drawing on the case studies, published information, and desk based analysis.

SUMMARY

Cook Islands is small in terms of population and land area and extremely diverse in terms of access and opportunity. The Southern group is dominated by tourism and has good links with New Zealand and direct flights to the USA. The Northern group is much more isolated, with very limited communications.

- The only significant aquaculture activity at present is the culture of **black lip pearl.** This has declined greatly in recent years as a result of environmental problems, disease, and more recently, poor market conditions. A recent initiative funded by the New Zealand Aid Programme aims to rejuvenate the industry through a combination of quality management/branding (the *Avaiki* brand) low interest loans, and a centralised marketing system offering part advanced payment on prospective sales. However, production costs are relatively high and international competition intense, and it remains to be seen whether the interventions will be effective. The key to longer term success will be to combine the new measures with significant increases in production efficiency, more effective marketing, and more activity in value added (local jewellery manufacture).
- There is small scale export **of giant clam** (mainly *T. maxima*, some *T. derasa*), produced in the government hatchery on Aitutaki with growout in a designated MPA, and exported through a small local aquarium products company. Around 6,000 were exported in 2010 and a similar number so far this year. Economic viability appears to be good if scale can be increased; but at the present time there is no clear business model, and engagement of local farmers in the critical ocean growout phase has been limited. This production stage is characterised by relatively high investment in seed (if real costs are to be born), 1 to 2 year production cycle and the need for dedicated though not hugely demanding husbandry. Without this the risks of failure are high.
- There is a **good market in Rarotonga for high quality seafood**, and local fishing activity and/or resources are inadequate to meet this demand. Although reef fish and shellfish resources are more abundant and relatively cheap in the Northern Group, transportation to Rarotonga is too infrequent and too costly. Although this may be viewed as an opportunity it is unclear what role mariculture might play. Land close to the coast is in short supply for the construction of ponds and significant costs would attach to the necessary effluent treatment systems. Cages sited in lagoons are unlikely to be acceptable for environmental reasons, and offshore sites too exposed.
- Trials have been undertaken **on tilapia and Pacific oyster** on Rarotonga but have not been sustained. The reasons for failure vary according to perspective, but probably included the high cost of pumping, lack of community agreement on water use issues, the high cost of feed, an over-ambitious integrated production system, and poor financial management.
- The government is about to restart trials on freshwater prawn (*Macrobrachium*) to exploit some of the potential demand for high quality seafood. Commercial **shrimp farming** might be feasible as an alternative or supplement to *Macrobrachium* farming, but land and water resources are limited in Rarotonga, and freight costs are likely to be too high to justify production on the other islands. Either way it will be extremely difficult to compete with cheap imports from Asia.
- There may be opportunities to grow **milkfish** in Aitutaki where there is significant area of suitable land behind the foreshore where ponds could be built. Wild seed are probably available locally, but if not might be imported from the Northern group where they are abundant. However, the local market for this species is limited, and it is not generally favoured amongst tourists. Environmental concerns would be significant for

any intensive (feed-based) production system, and extensive production might not justify the costs associated with pond construction. Any initiative should therefore be underpinned by very thorough local market survey and feasibility study.

- Milkfish are already grown/captured in semi-natural lagoons in the northern group. It has been suggested that this might be further developed to supply **baitfish** to the 40 or so long liners that operate in the area and land to Samoa. Critical questions here relate to the volume of baitfish required, size, seasonality, and the price that might be paid. Again, there would be no point in undertaking trials without thorough preliminary feasibility study.
- Overall Cook Islands lacks comparative advantage in mariculture production (high wages, limited sites, high fuel costs, poor market access) and any investment in this area should be undertaken with great care.

COUNTRY CHARACTERISTICS[1]

Cook Islands is a small country comprising 15 islands scattered across the central South Pacific. 1500km separates Pukapuka in the northwest and Mangaia in the southeast.

Land area: 240 sq km EEZ 1.8m sq km	Population density 67/km2
Length of islands coastline 419 km	
Population: 15,529 (GR 2000–2009 1.5%) 90% of population resides in Southern group	Population estimate for 2030: 16,261
GDP 2009: US$204m	Per capita GDP: US$9,611
GDP growth rate (2009): -2.9 (very variable)	GDP Fisheries: US $3.3m
Poverty (% below PL): NA	Adult literacy: 99%
Life expectancy 67	National minimum wage: US$4/hr
Fisheries production (2007): 2000 t	Fisheries exports: 1,259 t
Per capita fish consumption (local): 35 kg/yr	Per capita fish supply: 57 kg/yr
Local wholesale fish price: US$5-7, up to $13 for high quality parrot fish	Exchange rate NZ$/US$ 2011 1.25

HISTORY AND CURRENT STATUS OF AQUACULTURE AND FISHERIES DEVELOPMENT

PEARL FARMING

Pearl farming in Cook Islands was first trialled in the 1970s, commercialised in the 1980s and took off in the 1990s. Production was originally on Manihiki, but extended to Penrhyn in the 1990s and Rakahanga in 2001. In 1994 a government run hatchery (powered by generator + solar) was established on Penrhyn with assistance from USAID. On Manihiki, however, they were able to source sufficient high quality wild seed. Up to 2000, the government gave support for purchase of lines, diving kit and so on, and also provided free seed from the hatchery on

[1] FCO Country Profile; BBC country profile; SPC socio-economic data; Gillett 2010; FAO country profile, fisheries

Penrhyn[2]. They also paid for technicians for the first two seeding events for new farms, and 14 locals were trained as technicians (10 are still practicing, 2 of the top Japanese standard).

By the year 2000 there were 81 farms with 160 km of lines and 2 m pearl oysters in the (40 sq. km) lagoon at Manihiki, and perhaps 300 farmers in total. $18-20 m worth of pearls were being exported – 90% of all Cook Islands exports. In total around 1000 people were involved in the business. A substantial proportion of the workforce is Chinese.

Unfortunately, due to a combination of high stocking density and exceptional warm weather, there was a serious outbreak of *Vibrio* bacteria which caused 85% mortality, and remained a problem for 5 years. This not only had an immediate negative effect on the industry (especially relating to payback problems), it also resulted in reduced economic activity more generally with knock-on effects on infrastructure, freight and other services. A lagoon management plan is now in place and the disease is no longer a serious problem.

In the mean-time global pearl production increased rapidly and prices fell to less than 50% of their previous value. The number of farmers has declined to around 30, and the number of hanging shell has reduced to around 600,000. Exports have plummeted to $1.5-2 m. The problems are compounded due to the poor state of equipment and infrastructure, including the Penrhyn hatchery. There is a need for substantial re-investment.

A 2010 industry performance review[3] suggested (on the basis of current reported costs) a minimum economic pearl price of $30. In practice the average income per pearl produced declined from $21 in 2006 to $15 in 2009 and has declined further since. In other words, as it stands, the industry is not economic and there is a need to increase productivity, quality and efficiency if it is to succeed in future. It has been suggested that this may require a further rationalisation to around 10 larger scale producers.

Two major steps have been taken: the preparation of lagoon management plans and Code of Practice (CoP) to minimise the risk of future environmental/disease problems, and the introduction of a stimulus package to underpin the economic regeneration of the industry. The $3 m package, supported and implemented by the New Zealand Aid Programme[4], the Bank of Cook Islands and the Ministry of Marine Resources includes components to address key financial problems in the sector:

a) *Cash flow problem*: farmer specific credit; low interest rates (3-5%[5]), repayment as % of crop
b) *Slow sales*: up front purchase by Avaiki pearl exchange at guide price/fixed price
c) *Marketing* and quality initiative, including CoP and *Avaiki* branding and quality guarantee
d) 5% VAT
e) *Fuel* subsidy

In addition the ministry has established a $20,000 revolving fund.

The programme has now been in place for 6 months, and success or otherwise cannot be assessed as yet.

[2] They now charge between $0.1 and $1 depending on size
[3] Agri-Business group 2010. Pearl Farm Profitability Review. Prepared for CIMRIS
[4] New Zealand Aid Programme Design Document May 2011. Cook Islands Pearl Industry Support programme 2011-2013
[5] At least 9% from alternative sources

MARINE ORNAMENTALS

Wild ornamentals, mainly fish, have been collected since 1988. Production/export has been around 10,000 pieces pa, with up to 50 divers involved, though this is now down to a few full time professionals.

Following overharvesting of local stocks of Giant clams in the 1990s, the Government of Cook Islands imported *T. derasa* and *T. maxima*, and successfully spawned these and native species at the government hatchery on Aitutaki. Between 2003 and 2006 30,000 clams (mainly *T. derasa* and *T. maxima*) were exported through a locally based aquarium supplies company. This ceased in 2007 due to OIE (World Organisation for Animal Health) restrictions but restarted in 2010. Around 15,000 have been exported since.

The constraint to increased exports appears to lie in the ocean nursery or growout phase. The hatchery has sufficient broodstock and tank capacity to produce more than 100,000 seed a year, but have failed to engage locals in the critical growout phase. As a result, most of the clams currently exported are nurtured by government fishery staff in one of the lagoon's MPAs. The government is keen to engage more growers in order to exploit the undoubted market opportunities, but an attractive business model has not been developed. The main problems are:

- The high real costs of clam seed (roughly NZ$0.4–$1) depending on scale of production and other assumptions.
- The high risks of loss to *Cymatium* and other predators in the absence of dedicated husbandry.
- The long growout period (1–2 years) before cash benefit is realised.

Taken together these imply significant financial risk and commitment making it relatively unattractive despite the potential for good returns.

Some trials have been undertaken on post-larval capture and culture (**PCC**), but this has shown little economic promise. There was some success with capturing mantis shrimp but they are cannibalistic and difficult to rear. Trials also revealed many bonefish, but these were invariably dead. Surgeon fish and spinefoot were amongst the most common species

SHRIMP AND PRAWNS

Some trials on marine shrimp and freshwater prawn have been undertaken (as far back as 1992), but were not pursued due to high (imported) feed, seed, and labour costs. A new initiative is now underway to trial production of *Macrobrachium rosenbergii* with imported seed to be grown in tanks on Rarotonga, but with the intention to produce seed in the Aitutaki hatchery eventually. This is seen as a potential sideline for many farmers, but the growout business model has not so far been fully developed.

MILKFISH

There is a traditional harvest of milkfish from natural ponds/lagoons in Penrhyn, and seed are abundant and relatively easy to capture in the northern islands.

SEAWEED

Seaweed farming has been trialled in Palmerston and Penrhyn but has not taken off. It is likely that labour is too limited and/or too expensive, and freight also too expensive for the modest volumes that might be produced in the northern islands. Palmerston was considered the better location because of the established transportation/trade in parrot fish.

TILAPIA-OYSTER POLYCULTURE

Trials have been undertaken (funded by FAO and the New Zealand Aid Programme) by a local NGO (the Cook Islands Growers Association) on growing Tilapia integrated with Pacific oyster. This failed for a range of reasons related to problems with the availability and cost of water supply, high feed costs, poor financial management, inadequate and unclear agreements between the various parties etc. It is also arguable that the project was over-ambitious in attempting a complicated integrated production system from scratch.

OTHER

Coconut crab farming has been suggested as an option especially as a ranching type operation on some of the smaller islands.

Land crab rearing is already undertaken in Aitutaki by around 500 local households, each collecting and growing perhaps 200 animals in chicken mesh enclosures, on a half yearly cycle. It is usually possible to rear 100 in a 4 x 4m pen – with access to water. They are fed rather like pigs - coconut and food scraps, fruit - and sell at $1-2 for 200 g crab.

Trochus was introduced to the Cook Islands in the 80s and has become well established on Rarotonga and Aitutaki. It is now harvested roughly on a 5-year cycle, and no further introductions have been required. The Ministry of Marine Resources (MMR) undertakes periodic stock surveys and then agrees a quota with local councils. MMR then puts out tender for collection, cleaning, drying, and export of the shell, which is used primarily for the manufacture of buttons. It is stronger than pearl shell.

OPPORTUNITIES AND CONSTRAINTS

The following is not meant to be comprehensive – there are many other species/possibilities. This analysis focuses on those with greatest potential and/or greatest current interest.

Table 1: Mariculture opportunities and constraints

Opportunities	Constraints
General	
Reasonable air and sea freight from Rarotonga, Aitutaki and to a lesser extent other islands in southern group.	Limited and costly air and sea freight from northern group.
Ex pearl farmers may have finance and interest in mariculture.	'Banks will not provide money for this type of venture' (CIGA). Normal loan rates from CIDB 9.5-11.5%; commercial rates 18%. Outer island grant funds have ended.
Tourism has probably reached a ceiling – there is a drive to invest in complementary new areas.	There are likely to be conflicts between tourism and any form of high input (feed) mariculture unless state of the art effluent treatment was applied. If so …the high costs would make it difficult to compete with imports.
Foreign investment is generally encouraged (employment, skills) by government. Up front tax breaks may be offered.	Foreign investors need a local business partner, and there are reserved areas (e.g. taxi) and/or need to be resident.
Most islanders own a few acres of land and may offer 60-year leases (Rarotonga, Aitutaki).	Customary tenure in the Northern group may limit initiative/development. There are significant concerns about water quality, availability, pollution, alien/exotic species. Aid organisations usually require EIAs.
Pearl	
Opportunities for more value added – craft industry. Make use of more lower cost, lower quality pearls. Export only the best.	Poor market conditions, especially a flood of B and C grade pearl – from Cook Islands and French Polynesia.
Avoid competition with China. Compete only in the higher value pearl and value added markets.	Production of high quality FW pearls in China.
Specialisation and segmentation of production: hatchery/nursing specialists, mabe producers,; round pearl producers.	Global overproduction of mabe; intense competition from Indonesia and China.
Rationalise and streamline production; reduce production costs	History of partial subsidy rather than informed commercial investment.
Finfish	
Existence of ciguatera means supply of reef fish from capture fisheries very limited creating a market opportunity.	Mistrust of locally produced finfish because of ciguatera association.
More than 100 t of finfish and shrimp is imported to Rarotonga/Aitutaki at around $10 and $17/kg, respectively.	Abundant tuna/other large pelagics offer a partial substitute for other forms of finfish and are likely to remain much cheaper than farmed fish. Any intensive finfish will raise pollution problems – especially cage culture. May conflict with tourism and recreational bonefish fishing.

	Polyculture systems are usually inadequate to address these problems for a range of reasons.
Grouper juveniles have been found to be seasonally abundant in reef nets.	Grouper culture tends to be expensive, would require high quality imported feed, and in many suitable locations would be incompatible with lagoon water quality objectives.
Wild milkfish seed is available in northern islands.	Locals would exact a charge, and transport costs are high.
Some locals and increasing numbers of Asian tourists favour milkfish.	
The shrub/tree *Moringa oleifera* is high in protein and vitamins and could be a useful ingredient in locally produced fish feed.	It would be very difficult to produce a competitive substitute for high quality imported fish feed.
Chicken manure (3-4 t/month) is available on Rarotonga to fertilise fish ponds.	Land is in short supply in all the islands.
40 longline vessels operate in vicinity of the northern islands and require large quantities of baitfish.	Price payable for baitfish may not justify pond construction/modification or generate sufficient return on labour.
	Quantity of baitfish required and regularity of supply required may be incompatible with small scale production.
Some local interest in growing milkfish (for food) on Aitutaki.	About 4 ha readily available; 6 ha available.
Reasonable sites for pond development with potential for mainly tidal water exchange.	Suitable milkfish pond sites may also be suitable for taro or other crops.
There is now a ban on bonefish fishing to build up/conserve stocks for high value sport fishing market – people are looking for alternative income generating activity.	Bonefish likely to be susceptible to pollution.
Milkfish currently sells at $7-10/kg in Aitutaki.	Market is small and price will fall rapidly if production becomes significant.
	Already have GIFT Tilapia, which may prove easier and cheaper to grow than milkfish and will also appeal to Asian visitors.
	Water shortage, contamination issues.
	Porous limestone not good for containment. May need liners, implying significant investment.
Giant clam (ornamental) and coral farming	
Well established exporter of ornamental fish, corals and clams.	Single exporter implies potential for monopolistic behaviour.
Direct flight to Los Angeles.	Freight to other destinations may be subject to up to 12 hr delay in New Zealand.
	Now fewer connections, higher rates.
Resorts have negative view of coral collection and more positive view of coral farming.	Poaching
Clams may be grown conveniently on coral pebble.	Cyclones may disrupt long growout phase.
Shrimp and prawns	
Prawns a significant import – in other words there is significant demand.	
Significant quantities (100 t?) of shrimp is imported to Rarotonga/Aitutaki at around $17/kg.	It will be difficult to compete with imports from highly efficient producers in Asia, South America and elsewhere in the Pacific.

Table 2: Mariculture opportunities

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	**Site availability**	**Local markets**	**National markets**	**International markets**	**Comparative advantage**	**Production and market risks**
Marine shrimp	fair	Limited except for Rarotonga	good	fair	medium	medium
Seaweed	fair	none	none	good	low	medium; medium
Coral	good	poor	poor	fair	low-medium[6]	medium
Giant clam	good	poor	poor	fair	low-medium[7]	medium
Pearls	fair	poor	fair	medium	medium	medium; high
Marine/BW finfish (milkfish)	fair	limited	fair but limited at present fair	fair	low	medium; medium-high

Table 3: Potential contribution to development objectives

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Commercial viability	Import sub-stitution	Export earnings	Livelihoods & poverty alleviation	Food security
Seaweed	low-medium	zero	high	good	low
Marine/BW finfish (milkfish)	unclear	low	zero	unclear	fair
Marine shrimp	fair	good	medium[8]	low	low
Pearls	unclear[9]	low	high	low	none
Coral	fair	none	fair	fair	none
Giant clam	fair	none	fair	fair	none

[6] Depends critically on location, enterprise structure and logistics
[7] Depends critically on location, enterprise structure and logistics
[8] Probably site limited
[9] Dependent upon significant efficiency/productivity/quality improvements

RECOMMENDATIONS TO GOVERNMENT OF COOK ISLANDS AND SPC

- Continue to explore and facilitate options for increased production efficiency, niche marketing and value added in the pearl subsector.
- Beware direct or indirect subsidy to ailing pearl farms, which, in the absence of appropriate incentives, may slow the necessary readjustment.
- Undertake more thorough understanding of giant clam market: price paid for different sizes; time taken to reach different sizes; premium associated with different species and colours; likely market volume and opportunities for expansion.
- Explore more seriously options for government–private sector partnerships to exploit track record in giant clam production, and human, biological and physical assets associated with government hatcheries
- Explore more efficient approaches to ocean nursery growout and maintenance, including possible out of water maintenance of clam cages.
- Undertake thorough analysis of the domestic finfish market before promoting finfish mariculture of any kind. Consider shrimp farming as alternative use of marine/brackish water ponds.

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Appendix B

OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

COUNTRY REPORT: FIJI

Report by Hambrey Consulting in association with Nautilus Consultants

www.hambreyconsulting.co.uk

To the Secretariat of the Pacific Community

November 2011

THIS REPORT

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Roughly one week was spent in each country, including site visits and discussions with stakeholders. Thanks are due to all those who spent time talking with us (see list of consultees on page 77) and especially to Leilani Kotobalavu for arranging meetings and site visits.

An overview report was also prepared drawing on the case studies, published information, and desk based analysis.

SUMMARY

Fiji is a relatively large island nation with a range of marine and freshwater resources, a diverse population in terms of food preference, and a strong tourist industry generating a range of significant local and national markets. Air and sea communications are relatively good from the larger islands, offering access to international markets including those for live ornamentals.

- Opportunities for mariculture for **food security** in rural coastal areas are limited, since there remain significant coastal fisheries resources, and there is an opportunity for increased consumption of offshore large pelagics, especially in urban centres. In the event that such resources become depleted or are not available for economic reasons, there is significant capacity and infrastructure for the production of *Tilapia* in inland areas and this is likely to be easier and cheaper to produce than marine species such as milkfish.
- There are fair opportunities for cash generation for poverty alleviation, value added and foreign exchange earning through **seaweed cultivation** in favourable locations (i.e. reasonable transport infrastructure; suitable environmental conditions; limited alternative income generating opportunity). These opportunities are likely to continue to be cyclical, depending on both the global seaweed commodity markets and the returns associated with local alternative income generating activities such as fishing, copra and bêche-de-mer production.
- The country imports significant quantities of **marine shrimp** and local conditions are relatively favourable for marine shrimp production (year-round stable and suitable temperatures; site/land/water availability). Both artisanal and commercial scale production of shrimp has taken place in the past, but development has been constrained by a variety of factors, the most important of which has been a lack of consistent seed supply. Unfortunately there has also been some introduction of disease in the past, though its current significance is uncertain. There appear to be two main options for the future:
    - relatively small scale production of large fresh product for the premium restaurant market; and/or
    - larger-scale capital intensive commercial production with the medium term opportunity for competing in international markets.

  In either case production would need to be highly efficient and relatively disease free to compete with product from Asia and South America.

- To date there has been greater success with the alternative and close substitute freshwater ***Macrobrachium;*** this may offer better and lower risk prospects, and may be a better strategic option in terms of government capacity to facilitate at the present time, with benefits shared amongst a larger number of participants.
- There is strong political will to produce significant quantities of **giant clam, *Trochus* and possibly sandfish (sea cucumber)**, primarily for restocking, taking advantage of the recent proliferation of marine protected areas. It is impossible to assess the economic returns from this at the present time, but the initiative – if well monitored and assessed – should provide invaluable information on the effectiveness of restocking for the region as a whole.
- There is significant existing export of ornamental fish and live rock. There is an opportunity for modest development of **coral and giant clam mariculture** to supply this market. In the case of coral, the biggest constraint is probably a relatively undeveloped or undifferentiated market for cultured product. In the case of **giant clams**

the limitation relates more to a lack of product. The government hatchery is focused on restocking; and there are no current nursery growout businesses or development initiatives. However, given the existence and experience of several exporting companies, significant demand for giant clam, and fair access to markets, there is a clear opportunity for a relatively small scale commercial development, either with integral ocean growout, or, if well managed, engaging artisanal farmers for the ocean growout phase. However, this may become a competitive market given capacity elsewhere in the region, and production methods will need to be efficient.

- **Pearl farming** has been established for some time but is currently struggling as a result of relatively poor market conditions and shortage of spat. There is an opportunity to develop a more productive and vibrant spat sector, bringing significant benefit to coastal communities as an underpinning to a few commercial pearl farms. The latter will need to be large and highly efficient to compete in major international markets, or might be smaller with the object of supplying less demanding product for the local crafts/jewellery and tourism trade.
- Air and sea connections with major markets are relatively good from Nadi (air) and Suva (sea). This, taken together with the substantial local and tourist markets means that *Fiji is relatively well placed for mariculture development compared with many other countries in the region.*

COUNTRY CHARACTERISTICS

Land area: 18,273 sq km EEZ: 1.3m sq km	Population density 47/km2
Length of islands coastline: 5,010 km	
Population: 851,745 Population growth rate[1] 2000–2009: 0.5%	Estimate for 2030: 946,320
Percentage urban population 51% (330,000 in Suva/Nausori/Lami/Nasinu)	
GDP 2009: US$2.5 billion	Per capita GDP: US$2,963
GDP growth rate 2009: -3%; 2010: (est)0.1%	GDP Fisheries 2007: US $56 m
Fisheries production (2005): 40,000 t	National minimum wage: US$2/hr indicative[2]. Local casual wage US$1.2/hr[3]
Per capita fish consumption (local): na	Per capita fish supply (residents): 36.8 kg/yr
Local wholesale fish price: US$1–$ 4.6	Exchange rate US$/Fiji$ 2011: 1.74

[1] Substantial outmigration
[2] Standard rate in sugar plantations
[3] Suggestion in discussions that real casual labour wage rate may be higher – at F$3/hr, = US$1.7

HISTORY AND CURRENT STATUS OF AQUACULTURE AND FISHERIES DEVELOPMENT

Fiji has a long history of aquaculture development initiatives dating back to FAO/Government of Fiji initiatives in the 1970s. Species trialled have included tilapia, freshwater prawns, carps, marine shrimp, milkfish, rabbitfish, mullet, seaweed, giant clams, *Trochus*, pearl oysters, bêche–de-mer, sponges, turtles, mud crab, and corals.

The history of production of species (excluding production <0.5 tonnes) is illustrated in Figures 1 and 2. Although inadequacies in reporting explain some of the inconsistency, there is no doubt that aquaculture production has been limited, erratic and in many cases unsustained. '*The Fiji Government and donors have made a substantial investment in aquaculture*' but the current level of production '*is however quite small*' (FAO 2009).

Figure 1: Evolution of aquaculture production in Fiji

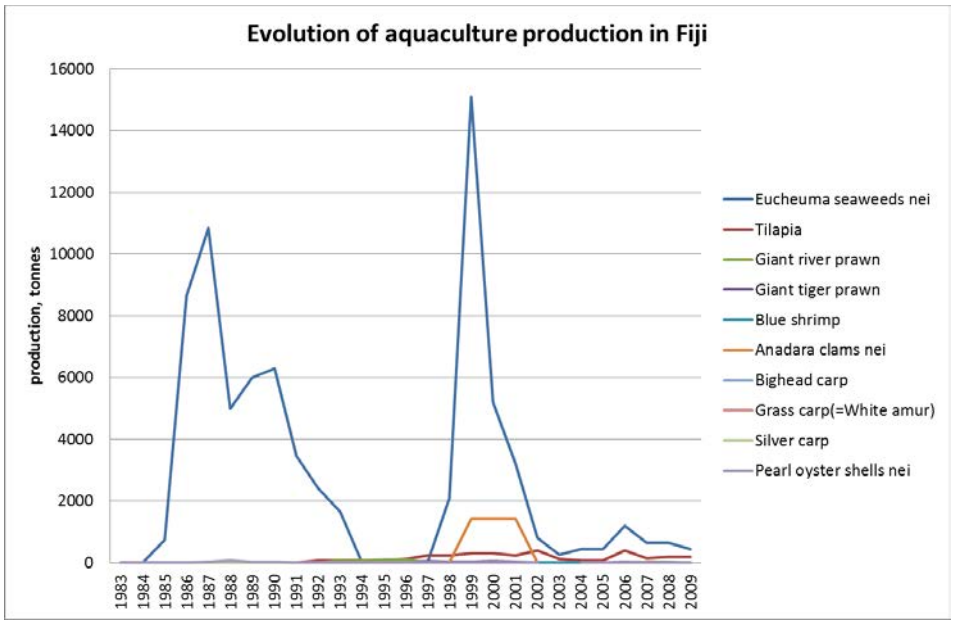
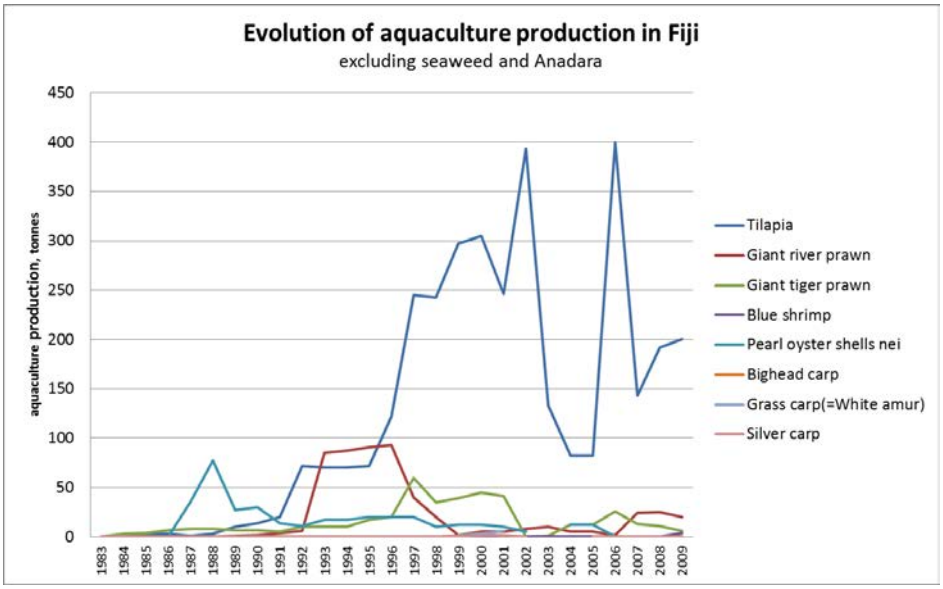


Figure 2: Evolution of aquaculture production in Fiji (excluding seaweed and *Anadara*)



SEAWEED

Seaweed (*Kappaphycus cottonii,* previously known as *Euchema*) is currently flourishing in Fiji, and is regarded as the No 1 opportunity by many fisheries staff, especially in those locations where there is little alternative (i.e. away from main urban centres). It has been strongly supported and subsidised for more than 20 years.

Seaweed production has been a significant activity since the 1980s, but production has been erratic, affected by both prices and cyclones. Production peaked initially at over 10,000 tonnes in the mid 1980s, but price fell and production went into decline. Production is subject to complete collapse once output falls below a critical economic export level, and this in turn means that rebuilding the industry when the price rises again tends to be slow. Production boomed again in the 1990s and reached 15,000 t in 1999, and there is a resurgence of interest at the present time. There are currently around 77 production units or groups engaged in seaweed cultivation, and around 150 people – including many women and children. According to some fisheries staff the most efficient and durable production unit is the family. Historically most of the activity has been in the Lau Group, but the current high price is encouraging wider interest.

Producers tend to switch to seaweed when prices are favourable, and back to other products (such as bêche-de-mer, reef fish, sandalwood and copra) if prices fall, compounding the unstable nature of the industry. As one fishery officer put it: 'when it's funded it works'.

The current resurgence is however primarily related to a significant price rise (up to F$0.9 in the islands and as high as $2/kg in Suva), strong government support (including provision of lines, seedlings, and in some cases boats), and increasing commercial support from Chinese companies. There are 3-4 commercial companies involved, with warehouses in Suva and Labasa, and baling machines. Such has been demand that some companies have also been purchasing wet seaweed. Some of these companies are actively encouraging and supporting production by communities – especially those closer to Suva - providing growout lines and technical advice. The product is usually shipped direct to Hong Kong.

Production and returns have always been constrained by limited capacity and infrequent and high cost of freight to the outer islands, but this may be overcome with a new government subsidised vessel given by China for transport of natural resource products.

The main constraints include:

- Shortage of seedlings (when price is high)
- Cost of freight from outer islands (should improve with new Chinese vessel)
- Weather and poor drying facilities for some locations
- Grazing at some sites – especially close to reef (there is often 10–15% grazing damage)
- Ice-ice disease at shallow sites
- Lack of effective management strategies
- Limited technical assistance and follow-up
- Inadequate seedling selection
- Lack of suitable varieties

The possibility of establishing a seaweed processing plant in Fiji has been considered on several occasions – but its success would clearly be contingent on stable and adequate supply – despite likely continuing price variation. The ability of major processing plants in Asia to source globally gives them significant comparative advantage.

USP together with ACIAR and an investor from Australia are currently surveying sea-grape resources in Fiji. These have some value in local markets, and there has been some success in harvesting these in Samoa

PEARL FARMING

Pearl farming has had mixed success in Fiji. Early trials were undertaken in 1963 using wild pearl shell for implanting. In 1998 an ACIAR project was initiated to develop spat collection and trial production. Japanese technicians were brought in with aid funding in 1999 and 2000. Hatchery production was also introduced at this time, albeit with limited success. Several companies became established – some Japanese, some local, some partnerships. Training was sourced from Japan, Cook Islands and Tahiti.

There are 11[4] pearl farms in operation with around 66 full time staff, and more than 200 part time and seasonal workers involved in spat collection, harvesting etc. Five companies are local; three involve foreign investors. The farms are concentrated around Savusavu and Taveuni Island on the south coast of Vanua Levu, and around Rakiraki in Western Division (north coast of Viti Levu). There are now around 18,000 shell in the water, down from 50,000 as a result of a cyclone in March 2010.

The largest company (J Hunter Pearls) has 46 full time staff, and runs a small hatchery which is also trialling sea cucumber preproduction. There are three Fijian professional technicians, one of whom is of international standard.

Most of the seed is collected on spat collectors in the wild; this serves as an important village based economic activity, including in some of the more isolated islands. Spat collection is undertaken by families, communities, youth/women's groups etc.

The Fisheries Department engages in monitoring, evaluation and trial spat collection.

[4] One fishery officer suggested that in fact there were only 8 currently active pearl farms.

Three farms have closed in recent years in Western Division and several others are struggling. The industry faces several challenges:

- Inadequate wild spat supply, related in part to lack of spat collection activity, poor collection sites, and inadequate husbandry/maintenance (cleaning etc.) of collectors
- Poor performance of hatchery reared seed
- Loss of stock and gear as a result of cyclone (up to 90% losses in 2010)
- Lack of investment and high cost of finance for local farms
- Poor market price
- Disease in some locations (where there is high stocking density; limited current)

It has been suggested that the shortage of seed might be made up by the establishment of a government run hatchery, but as one commercial pearl farmer said, '*free spat would be the death of the industry'.*

Local fisheries staff are of the view that farms need to hold more than 10,000 shell to be viable. Investment is required for at least five years before a company becomes profitable.

Given the current state of the markets, opportunities for investment and expansion are limited. However, there may be opportunities for efficient medium scale farms associated with tourism and local jewellery manufacture. Production of mabe pearl from *Pteria penguin*, which exhibits a much faster production cycle (3 months conditioning; 7 months growout), may also be an opportunity.

MARINE SHRIMP

Initiatives relating to marine shrimp farming date back to the 1970s and 1980s with FAO/Government of Fiji trials at Raviravi on *F. merguensis*, *F. indicus* , *L. stylirostris* , and the native *P. monodon*. Production has not been sustained at this site.[5]

In the 1990s a shrimp farm was established using imported *P. monodon* and *L. stylirostris*. FAO data suggests that production reached more than 100 t pa in the mid-1990s, but suffered from lack of seed and disease problems, and production declined in the late 1990s.

In 2002 a private shrimp farm was established using circular tanks and seed (*L. stylirostris)* imported from Brunei. This farm failed for reasons that are unclear.

In the early 2000s the fisheries department established a marine/brackish water hatchery at Galoa with the object of providing free seed to farmers. Between 2007 and 2010 three small artisanal farms were established.

Related to these public and private sector initiatives, marine shrimp production rose to 20–30 t in the mid/late 2000s, but the government hatchery failed to produce significant or consistent supplies of post-larvae, and production declined once again and is currently insignificant.

The reasons for the lack of any successful sustained hatchery and farm production of marine shrimp are many but may include:

- Inadequate biosecurity. Two viruses, YHV and GAV, appear to have been imported with Australian seed, and other viruses: HPV, MBV, MoV, GAV and IHHNV, have all been

[5] Patrois, J. 2011. Shrimp farming in the Pacific Islands countries and territories: status and trends in 2010. Secretariat of the Pacific Community. ISBN 978-982-00-0491-7

identified in Fiji populations of *P. monodon*.[6] Chronic disease is now an issue in farms and possibly in the government hatchery. This is associated with high mortality and declining productivity.
- Lack of expertise in algal culture and problems with quality of algae stock.
- Lack of sufficient wild broodstock and/or seasonal limitations on availability, maturity and quality.
- Cost of holding sufficient broodstock in the hatchery.
- Lack of effective management and incentives for PL production at the government run hatchery.
- High feed costs (currently sourced from China or Taiwan) and spoilage/storage problems with feed.
- Lack of any mechanism for sustained and sufficient funding of government hatchery production.

Local fisheries staff suggested that lack of scale, skills and infrastructure, and the cost of land or loans on land were also factors.

The government hatchery is currently being refurbished and will have a target of 1 m PL – enough to supply 6 farmers, stocking at 15/m2 with projected production of 5–10 t/ha. Apparently there are plenty of good sites available and production could be increased.

MILKFISH

Milkfish trials have been undertaken in the past but have not been sustained.

JICA and the Western Division Fisheries Department are currently supporting a community trial in Western Division, implemented through an NGO,[7] based on wild seed collection (collectors are being trained). The 1.5 ha system is designed to allow for tidal water exchange and multiple stocking/cropping. The fish rely in part on natural algae but are fed supplementary feed and grow to market size in approximately six months. Various options for the future are under consideration, including integrated culture with shrimp or Tilapia.

Although there has been some harvesting, production parameters - and in particular feed conversion rate and feed costs - are not yet available, and no economic feasibility study or economic modelling was undertaken prior to establishing the trial.

The main problem would appear to be the lack of an established market. Some fish have been sold in small quantities in the local village at F$5 and fish markets at F$6. However a fish processing company was of the view that the price for significant amounts of milkfish would be poor – perhaps as low as F$2/kg. There may also be a market for small milkfish as baitfish (15 cm) for the long line tuna fleet. This might be worth around $1–2/kg, which may be inadequate to support a feed based production system.

A government scheme has been introduced to promote milkfish. The farmer pays 1/3 and government pays 2/3 of the total investment, including inputs for the first year (which could be two cycles). The farmer is also given access to Fiji Development Bank funding which allows him/her to borrow money at an interest rate of 8% compared with commercial loan rates of 16–20%. In other words, entry is highly subsidised. Although no projects have been funded to date, there is apparently interest.

[6] Patrois, J. 2011. Shrimp farming in the Pacific Islands countries and territories: status and trends in 2010. Secretariat of the Pacific Community. ISBN 978-982-00-0491-7
[7] Freshwater Aquaculture International

GIANT CLAMS

The giant clam *Tridacna gigas* became extinct in 1916 and *Hippopus hippopus* became extinct in 1940. In 1960 both species were reintroduced. ACIAR provided support between 1984 and 1993 for reintroduction and hatchery production. Over the last 10 years 3,000-5,000 two to three year old clams have been produced each year at the Makogai research station for restocking, mainly in MPAs (more than 15 have been restocked). There is now some evidence of natural recruitment of *T. gigas*, but not of *Hippopus*.

There is also demand for giant clams for export for the aquarium trade, but limited hatchery production has constrained export activity. Nine hundred were exported in 2006.

There are currently 17,000 giant clam seed in the Makogai hatchery, but these are likely to be used for restocking, which is the present government priority. There is a shortage of broodstock of *T. maxima* and *T. crocea* – the species favoured in the aquarium market. Production costs of clams from the Makogai hatchery have not been worked out.

CULTURED CORAL AND LIVE ROCK

Corals have been cultured by Walt Smith since 1999, and these represent 20–25% of coral exports at the present time. However, there is no premium associated with cultured rock or corals.

Walt Smith uses its own staff to culture live rock or corals, although some payment may be made to MPA owners to keep an eye on them. The company has just invested more than $200,000 in a new holding facility in Labasa. They hope to source more exotic marine aquarium fish and will also be working with two local villages to grow corals. They will provide expert guidance and commit to buying corals every month. The key to success will be to grow and perhaps develop highly coloured specimens.

Coral culture is relatively straightforward, although there may be problems with bleaching and algal fouling in some locations, especially during El Nino. Security can be a problem at some sites, but there are opportunities associated with resorts and MPAs, where security is likely to be less of an issue.

Live rock has been a significant export from Fiji since the early 2000s. Exports are mainly to USA, UK, Ireland, and Ukraine. Four companies have been involved (two consistently). Up to 700 people were involved at the peak of this activity. In 2007 quotas were introduced (1,400 t initially, reduced to 800 t in 2011), in part to satisfy CITES disquiet related in large part to inadequate reporting. Quota allocation is based on track record. The sudden reduction in quota has had a significant negative impact on some companies.

However, other companies are successfully culturing live rock by simply planting lightweight volcanic rock on the reef, and this offers a potential way around the quota restrictions.

TILAPIA

Production of tilapia is not mariculture, but an understanding of the economic potential of tilapia is fundamental to understanding possible future markets for farmed marine finfish (and demand for food security), and possible development models for mariculture.

Production of tilapia dates back to 1962, and has received substantial support from the Government of Fiji, FAO, UNDP/SPIFDA, CDF, JICA, and ACIAR. Objectives have included subsistence, commercial, livelihood and food security, and foreign exchange, according to the fashions of the time.

Around 265 farmers with 531 ponds are currently engaged in aquaculture production, mainly of tilapia and some freshwater prawns, and mainly in Central and Western Divisions. The government estimates that 200 t of tilapia is being produced, worth $1 m (corresponding to unit value of $5/kg or US$2.7/kg).

The tilapia growout farms are largely underpinned by the freshwater hatchery at Naduruloulou. The hatchery's roles include supplying broodstock and seed; acting as a broodstock bank; providing training, demonstration and advice; and undertaking marketing. They have a pelletiser and are able to develop feeds and perform trials on them. A full time ACIAR funded development officer works on all aspects of tilapia farm development. The main challenges include the cost of feed and equipment, and the need for technical and management skills.

Production is currently highly subsidised. Prospective farmers must present a letter of interest. If the site is suitable, with potential to divert water into ponds, then ponds are dug and free seed provided – though this may stop under the new aquaculture decree.

Economic returns have been estimated by the Fisheries Department at more than 100%, with payback in Year 1 (Table 3). However, they exclude costs of labour and seed, and give no indication of labour requirements – so returns to labour and real economic returns cannot be accurately estimated. Furthermore, the cost of feed has risen sharply in recent years. Nonetheless, making some rough estimates on labour requirements indicates a production cost around F$4–5/kg, which suggests the economics of production are marginal if the suggested price of $5/kg is realistic. However, much depends on:

- efficiency of labour utilisation;
- costs of feed; and
- food conversion ratio.

Production appears to be in decline at present, perhaps related to high feed costs and limited market associated with the recent increase in coastal finfish production following a major fisheries development programme in the Northern Division. It appears that suitable sites are plentiful, as evidenced in a 'freshwater aquaculture strategic plan'.

GIANT RIVER PRAWN

In 2001 a small Penaeid shrimp hatchery was established as part of the USP marine studies programme. This also suffered from lack of wild broodstock of *P. monodon*, and has been adapted for use in rearing *Macrobrachium rosenbergii* and *M. lar.* This is now supplemented through production from the government hatchery at Naduruloulou. Production of river prawns has been significant, reaching nearly 100 t in the late 1990s, and rising again to more than 20 t in recent years. The reasons for the cyclical production are unclear but are likely to relate to bursts of seed production and extension activity on the part of government.

RESTOCKING

Following its success with the 'plant a million trees' scheme, the Prime Minister is now promoting the idea of 'plant a million' marine seed – including *Trochus*, giant clam, pearl, and

sea cucumber, and this will be used to exploit and further strengthen the idea of MPAs. Some of these may be associated with villages and used to restore stocks for commercial purposes; others will be used for conservation – e.g. to strengthen marine tourism.

HATCHERIES

There is already significant hatchery infrastructure: the freshwater hatchery at Naduruloulou, a brackish-water/marine at Galoa, a marine hatchery at Makogai, and private commercial hatchery near Savusavu. However, partly in response to this drive for restocking, but also with a view to promoting aquaculture more generally, both Western Division and Northern Division are proposing to build or refurbish their own 'multi-purpose' hatcheries – for restocking, research and to provide seed to farmers. As yet it is unclear whether this will become a national strategy.

OPPORTUNITIES AND CONSTRAINTS

The following is not meant to be comprehensive – there are many other species/possibilities. This analysis focuses on those with greatest potential and/or greatest current interest.

Table 1: Mariculture opportunities and constraints

Opportunities	Constraints
General	
Significant domestic market for food products for both local population and tourism.	Significant supply of capture fishery products at modest prices.
Long history of trials with a wide range of species.	Lack of focus on commercial opportunities
Existing government and private sector hatchery infrastructure.	Changing government policy. Underperforming and under-resourced hatcheries.
Fair transport links within islands and to export markets.	Limited freight capacity and frequency and high cost of freight to outer islands.
$40 m import substitution fund, lower interest loans, FDB development funds, tax breaks for regions.	Entry conditions can be onerous – commercial banks implement their own conditions. High commercial interest rates (18%).
Local feed manufacturers and some fishmeal production.	High quality low cost fish feed not yet available.
Finfish	
There is strong demand for fishery products in the substantial urban and inland areas.	At the present time, supply of marine finfish is relatively good, and there is increasing supply of large pelagics from FADs and the tuna fishery.
Milkfish seed appears to be relatively abundant.	There is no established market for milkfish, and there is therefore great uncertainty about market value, with estimates ranging from F$2–F$5.
High levels of subsidy are available for digging ponds and setting up in pond aquaculture.	Tilapia is likely to be easier and cheaper to produce and may be a partial substitute.
There may be a market for baitfish for 40 locally based long-liners.	Price of baitfish unlikely to exceed F$1.8/kg.

Shrimp	
Significant imports of marine shrimp (c 600 t). Suitable sites. Strong government support.	Lack of shrimp seed. High feeds costs. Some chronic disease. Low cost imports.
Giant clam (aquarium)	
Several exporters would like to buy small giant clams for the aquarium trade. Selection for colour should yield high price. Good access to US aquarium market. Fair access to European market. Opportunity for local community/family engagement in nursery phase. 'Planting' in MPAs. Second generation broodstock at Makogai.	Government hatchery at Mokagai cannot meet supply, and currently prioritises restocking. Giant clams require dedicated consistent care and predator removal. $30 CITES permit (more the paperwork than the cost…).
Cultured coral	
Easy to culture. Improve image of export companies and contribute to local communities. Culture intense colour corals. Planting in MPAs – share security/maintenance costs. Non Detrimental Finding (NDF) required for wild collection in any new areas or species. There has been restriction of development of new areas.	No market premium for cultured coral. Wild supply coral 'grows much faster than we can harvest'. Security required during growout.
Pearls	
Comprehensive spat survey being undertaken. Commercialisation of spat production? Restocking of mother shell in MPAs. Strong demand for mabe pearl? Production of mabe from *Pteria penguin*? Small 'boutique' farms: jewellery, tourism. Focus on quality – colour and size	Shortage of spat, especially Viti Levu. Inadequate husbandry of collector lines. Poor market conditions generally. Strong competition from Indonesia. License required to source wild *Pteria.* Cyclone damage. Sites – need shelter + good current.
Seaweed	
Rapidly increasing price up to F$2/kg in good locations. Integrate with sea cucumber restocking and MPA management? New Chinese funded freight vessel. Closer relations between producers and exporters. Processing plant in Fiji?	Opportunistic and inconsistent production. Weather and drying facilities. Greatest interest in locations where highest cost. Would require very high volumes – but might source also from other Pacific Islands.
Restocking	
Multiple benefits from MPAS – broodstock supply for all species. Shared protection of MPA and acceptable economic activities. Spare capacity of commercial hatchery for production for restocking.	Does this reduce value as MPA? Much poaching from MPAs. Underperforming government hatcheries. No understanding of the economic cost effectiveness of restocking.

OVERALL POTENTIAL

Table 2: Mariculture opportunities

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	**Site availability**	**Local markets**	**National markets**	**International markets**	**Comparative advantage**	**Production and market risks**
Marine shrimp	good	fair	good	fair	fair	high; medium
Seaweed	fair	none	none	good	fair	low; medium
Coral	good	poor	poor	fair	fair	medium, low
Giant clam	good	poor	poor	fair	fair	medium
Pearls	fair	poor	fair-good	medium	fair	medium; high
milkfish	good	limited	limited	poor	medium	medium; high

Table 3: Potential contribution to development objectives

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Commercial viability	Import sub-stitution	Export earnings	Livelihoods & poverty alleviation	Food security
Seaweed	fair	zero	high	good	low
milkfish	unclear	zero	zero	unclear	medium
Marine shrimp	fair	good	fair	low	low
Pearls	variable[8]	low	high	fair[9]	none
Coral	fair	none	fair	fair	none
Giant clam	fair	none	fair	fair	none

RECOMMENDATIONS TO GOVERNMENT OF FIJI/SPC

- Offer technical/advisory services as required to the commercial sector to underpin the current development in seaweed farming, while avoiding excessive subsidy.
- Undertake more thorough analysis of the domestic finfish market and realistic production costs before promoting finfish mariculture, including milkfish.
- Facilitate and support private sector initiatives in giant clam and coral cultivation.
- Develop a coherent strategy for government and private sector engagement in hatchery development, maintenance, and seed production, and put in place sustainable financing mechanisms.
- Strengthen research on pearl spat collection and train communities/families/ individuals in technology and husbandry. Train pearl technicians.
- Undertake more thorough market and financial feasibility studies before engaging in any mariculture R&D activity.

[8] Highly dependent on scale, efficiency, marketing
[9] Spat collection a significant activity for isolated coastal villages

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Appendix C

OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

COUNTRY REPORT: PAPUA NEW GUINEA

Report by Hambrey Consulting in association with Nautilus Consultants

www.hambreyconsulting.co.uk

To the Secretariat of the Pacific Community

November 2011

THIS REPORT

This brief report was prepared in support of a wider study on Opportunities for the Development of the Pacific Islands' Mariculture Sector for the Secretariat of the Pacific Community (SPC), and forms one of a set of five country case studies undertaken between early August and September 2011. Reports were prepared for the following countries:

- Cook Islands
- Fiji
- Papua New Guinea
- Republic of the Marshall Islands
- Solomon Islands

Roughly one week was spent in each country, including site visits and discussions with stakeholders. Thanks are due to all those who spent time talking with us (see list of consultees on page 91) and especially to Jacob Waini, Jeff Kinch and Peter Minimulu who also helped arrange meetings and site visits.

An overview report was also prepared drawing on the case studies, published information, and desk based analysis.

SUMMARY

Papua New Guinea is the largest of the Pacific Islands states and has substantial natural resources and relatively large population. Air and sea connections with major markets are relatively good from Port Moresby and other major provincial centres.

- Opportunities for mariculture for food security in rural coastal areas are limited, since there remain significant coastal fisheries resources, and coastal population density is not generally high. The use of trash fish or fishmeal in feeds for culture of most marine finfish means that costs and benefits from a food security perspective need to be carefully evaluated. Tilapia cultivation is more likely to meet food security needs than is mariculture.
- There are fair opportunities for cash generation for poverty alleviation, value added and foreign exchange earnings through seaweed cultivation in favourable locations (reasonable transport infrastructure, suitable environmental conditions, limited alternative income generating opportunity, low labour costs, and economic ambition). Recent investment by a Malaysian company in Milne Bay Province suggests both strong market demand and a significant role for the private sector in facilitating the startup of family/community based production.
- There is opportunity for modest development of coral and giant clam mariculture for the ornamental market in the vicinity of Port Moresby. There may in the future be opportunities for the culture of ornamental fish and crustaceans. This will have some local impact on rural livelihoods, but the impact in national terms is likely to be limited.
- There is growing but still limited national demand for whitefish fillet for the catering sector/mining camps, which might be met through medium scale commercial tilapia and/or barramundi or cobia production, though production efficiency will need to be very high to compete with cheap imports of Vietnamese basa and similar products.
- There is also opportunity for marine shrimp farming to service this growing market sector, and possibly develop export trade if the country can maintain disease-free status. The current operation is constrained by lack of broodstock and government controls on the import of broodstock or PL. However, *Penaeus monodon* broodstock is available from the wild, and a thorough examination of the logistics and financial feasibility of developing supply from the wild is warranted. This would also strengthen capacity to retain disease-free status.
- Opportunities for the development of a national fish/shrimp feed production industry at the present time are unclear. Although the country exports some fishmeal and has significant resources of small pelagic species, as well as some meat, blood and feather meal, national demand is as yet inadequate to justify major investments in dry pelleted feed production. Local small scale production of fish feeds may be possible in some locations in the medium term, but the strengths and weaknesses of such production compared with import/distribution of high quality feed should be explored very carefully prior to any significant investment by aid agencies, research institutions or national government. Food conversion rate is just as important as feed price, and trials must be practical, realistic and economically informed.
- Commercial production of pearls has a relatively unsuccessful history, and the existing operation is struggling with difficult community relations and poor market conditions. Significant new investment in this area would be highly risky at the present time.
- The new hatchery at Nago Island offers an opportunity for government, higher education and the private sector to work closely together to facilitate and underpin mariculture development through research, training and, where appropriate, seed production. It is essential, however, that a clear strategy for the development, operation

and financing of the hatchery is put together and that it address the short term nature of most project and research funding and the needs of the sector rather than the particular interests of researchers.

COUNTRY – RELEVANT CHARACTERISTICS

Table 1: Development context

Land area: 462,840 sq km	Population density: 15/km sq
Population (current): 6.86 m	Estimate for 2030: 9.9 m
Urban 5% (20 coastal cities > 5,000); 18% urbanised (UNICEF)	Rural 95%
GDP 2010: $9,480,047,959	Per capita GDP(current US$): US$1,382
GDP growth rate: 8%	Exchange rate v US$: 2.123. Historically steady but recent decline
Poverty: 37% below PL	Literacy: 60%
National minimum wage: US$1/hr	
Coastal fisheries production: 35,700 tonnes[1]	Offshore fisheries production: 583,000 tonnes
Per capita fish consumption: 19 kg	Coastal fisheries supply per capita: 5 kg
Offshore supply per capita: 85 kg	Total fisheries supply per capita: 90 kg
Local wholesale fish price: 5–10 Kina/kg (US$2.25-4.5/kg)	Prices higher inland
Mariculture production <100t	

Structure of the economy: About 75% of the country's population relies primarily on the subsistence economy, supplemented by smallholder cash cropping (coffee, cocoa, copra). There are rapidly expanding minerals, timber, and fish sectors, dominated by foreign investors. Manufacturing is limited.

Aquaculture institutions: Aquaculture is mainly the responsibility of the National Fisheries Authority (NFA) based on Port Moresby. At provincial government level, aquaculture officers work under the Division of Fisheries and Marine Resources. However, capacity is still very limited, with perhaps only 10 aquaculture specialists in PNG. Training is offered by the National Fisheries College Kavieng (fisheries courses and training at all levels), and the University of Papua New Guinea offers degree courses in marine biology and other relevant scientific disciplines. A university research hatchery is established at Motupore Island Research Centre. The University of Technology at Lae offers a freshwater aquaculture and food technology degree. A marine hatchery and training/research facility is currently under development at Nago Island, near Kavieng and may serve a variety of functions (see below).

Infrastructure, freight and logistics: International sea and air connections are good from Port Moresby, and fair from other provincial centres (Lae, Rabaul, Madang). A lack of infrastructure has always restricted opportunities for marketing of seafood to inland areas – and this remains an issue.

[1] FAO fishery and aquaculture country profile 2010

Feed and seed supply: Feed can be imported at reasonable cost. Fishmeal is exported. There is an animal feed plant at Lae. There are opportunities for national production of fish feeds, but these are currently constrained by lack of demand.

A BRIEF HISTORY OF AQUACULTURE AND FISHERIES DEVELOPMENT AND CURRENT STATUS

PEARL FARMING

In 1965 a pearl farm (*Pinctada maxima*) was established in the harbour at Port Moresby by Pearls Pty – a Japanese-Australian Company from Broome, Western Australia. Imported seed was used. Operations ceased in 1975 after mass mortality, allegedly due to oil release from a wreck.

Samarai Island Pearl Farm (Milne Bay Province) was established in 1967 by Dennis George and family, using locally collected spat of *P. maxima* and *P. margaritifera.* A nucleus farm approach was adopted including a pearl farming school on the Island. Despite some apparent economic success, operations ceased in 1987 due to financial difficulties.

In 1998 Coral Sea Mariculture was established on Samarai Island by a private company from Broome, Western Australia. A nucleus farm approach was considered at the project planning stage but has never been fully implemented. Wild spat collection proved unreliable and a hatchery was installed in 2002. The current commercial operation and ownership has been in place since 2005. This is a private company, but employs several locals and assigns 2.5% of profits to local communities. Despite good infrastructure, the enterprise is presently constrained by security issues, poor community relations, and poor market conditions.

FRESHWATER FISH FARMING

A trout farm was established in the early 1970s in the highlands by a company associated with Air Niugini and another regional airline. It was set up as a partnership with locals and produced around 20 t pa. It was subsequently passed to local management and went into decline.

A JICA funded freshwater aquaculture project was established in Aiyura (Eastern Highlands) between 1996 and 2000 which resulted in significant capacity building for aquaculture development (especially with regard to carp and tilapia), including training of two of the current staff in the aquaculture department of the National Fisheries Authority. This project has been followed up through the late 1990s and 2000s with a series of ACIAR funded projects, including some targeted specifically at local feed development. The production from freshwater aquaculture is very difficult to estimate but may amount to more than 2000 t from as many as 8000 farmers – although this is not reflected in official figures (roughly 200 t in 2007[2] and 180 t in 2009[3]).

Growth is being constrained by limited skills, poor seed quality (Edwards 2009), and (in the case of cage culture and more intensive pond culture) expensive feed. Nonetheless the

[2] Ponia, Ben 2010. A review of aquaculture in the Pacific Islands 1998-2007: tracking a decade of progress through official and provisional statistics / Ben Ponia.
[3] FAO fishstat

opportunity for tilapia culture is significant, and it is likely to be more suited than mariculture to the needs of food security.

MARINE FINFISH

A barramundi cage culture project was started in Madang in 2001 by a local fish farming company with support from the European Union. The project engaged locals to manage cages. The project failed for a variety of reasons, including personal circumstances of the hatchery owners, basic economics (high feed cost, low sales value), inadequate husbandry, and lack of training/understanding.[4]

More recently (2009) a barramundi hatchery has been developed in Daru *(Western Province Sustainable Aquaculture [WPSA])*, primarily for restocking the Fly River but also offering the possibility of cage culture in the river. Funding has been mainly from PNG Sustainable Development Program. Target production is 500,000 fingerlings per annum, although they have experienced some initial technical and environmental problems. To date the hatchery has produced more than 18,000 fingerlings. The plan is to operate a nucleus estate type production company (provide partial grant and credit; buy fish) in partnership with a local fish processing company. Formulated feed is being imported from Australia, but local sources (e.g. herring from Lake Murray) are also being explored.

The economics of production have not been thoroughly analysed, but our own rough analysis suggests that margins are likely to be slim, and risks for inexperienced farmers may be significant.

SHRIMP FARMING

A hatchery, 10 ha of ponds, and a processing factory were built between 2005 and 2007 near Rabaul by a large local multi-sector company.

The existing enterprise was successful initially, with a good crop produced in 2008, but is now constrained by lack of broodstock. However, there are wild stocks of *Penaeus monodon* (for example in Milne Bay), and it may be possible to source broodstock from the wild. The logistics and financial feasibility need to be explored more thoroughly.

There is a significant national market for shrimp, prices are good and the economics of production appear to be favourable. There is also the opportunity for export if sufficient scale and efficiency can be achieved.

SEAWEED FARMING, MILNE BAY PROVINCE

A new venture was established by a Malaysian Company in 2010 in Milne Bay Province. There were initial problems with rapid temperature change at one site, but the venture is now located

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4 http://www.islandsbusiness.com/islands_business/index_dynamic/containerNameToReplace=MiddleMiddle/focusModuleID=17758/overideSkinName=issueArticle-full.tpl

Also a range of persons offered their views on this project

at Suau Island and in the Trobriand Islands, and the seaweed is growing well and being replanted. There have been no sales as yet.

The company has invested significant money in supplying materials and providing technical assistance to farmers through the provision of Malaysian technicians living on site.

The economics of seaweed culture appear to be favourable at the present time, although the costs of local freight (i.e. from growing site to local collection/shipping centre) are relatively high.

MARINE HATCHERY, NAGO ISLAND

This is an ongoing government (NFA) funded initiative to establish both research/training and potentially commercial mariculture hatchery operations. The hatchery is presently under construction. It is intended to breed sandfish, *Trochus*, corals, clams and possibly marine finfish. A commercial fish processing company based in Kavieng is interested in collaborating to produce finfish seed and promote small scale marine finfish cage culture with a view to meeting current unsatisfied demand for quality whitefish fillet. Possible species include cobia, milkfish, and barramundi.

Government run hatcheries in the Pacific Islands have generally underperformed and suffered from a lack of strategic direction and sustained funding of key functions. As discussed in the overview report, it is essential that each country, and the region as a whole, develop a clear strategy and financing mechanism for hatchery development and operation.

MARINE ORNAMENTALS

A company called Ecoaquariums is currently being established, focusing on sustainable aquarium fish sourcing, with potential mariculture for some species in the future. The company is 75% American owned; 15% is owned by the local community; and 10% is owned by local individuals. A previous highly capitalised venture failed in 2010 (mainly through poor financial management and possibly excessive capital investment).

OPPORTUNITIES AND CONSTRAINTS

The following is not meant to be comprehensive – there are many other species/possibilities. This analysis focuses on those with greatest potential and/or greatest current interest.

Opportunities	Constraints
Markets	
- There is strong local demand for marine finfish and prices are reasonable (5–10 kina/kg; US$2.25–4.5/kg first hand sales) even in coastal areas. - There is strong national demand for frozen whitefish fillets (and to a lesser extent other products such as prawns and molluscs), mainly to supply catering trade especially in support of mining camps and urban growth. Current wholesale prices for frozen fillet are 25–30 kina/kg ($11.25–13.5/kg), but supply is limited. - The volume of this market is several hundred tonnes per annum at the present time and likely to grow. Current supply of reef fish is inadequate (volume, consistency of product and supply, quality)[5] to meet this demand. Processors are prepared to pay 5–10 kina/kg (US$2.25–4.5/kg) for mixed good sized (600 g+) reef fish, and would probably pay similar rates for high quality farmed fish such as barramundi or cobia. - There is a good but modest national market for prawns. Prices in New Britain range from 19 to 40 kina/kg depending on size and as much as 65 kina/kg in Port Moresby for large prawns. The size of the market is unclear but probably in excess of 100 t per annum. The disease- and antibiotic-free status of the prawns suggest good export opportunities and some comparative advantage in discerning markets. - There is a good but modest international market for ornamental fish, corals and giant clams, and Port Moresby area is relatively well placed to service this market. Ecoaquariums is currently setting up a trading centre on Fishermen's Island and this effectively creates a local market for a range of ornamental products.	- There is good local supply of finfish from marine capture fisheries, which are not overexploited except close to major towns and cities. Increased fishing effort and the use of more energy efficient fishing boats could result in increased supply at lower costs and lower risk than from mariculture. - An increasing proportion of tuna is landed and processed in PNG, offering potential to meet emerging demand for food security and nutritional needs. The prime tuna catch from the longline fleet is exported to Japan, with lesser grades and catch of non-tuna species sold domestically. - It will be difficult to produce high quality finfish from mariculture operations for less than US$3/kg – and would depend on a combination of high quality, reasonably priced feed, good food conversion efficiency, high quality of husbandry and high water quality. - The rapid recent growth in tilapia farming might result in more commercial medium scale production (possibly contract farming on the Asian model) and meeting a significant proportion of the demand for white frozen fillet. Tilapia is significantly cheaper to produce than marine finfish (cheaper seed, cheaper feed, less demanding husbandry, options for fertilised only systems).
Sites	
- Environmental conditions are favourable for mariculture in many locations around the coast with generally stable seawater temperatures, shelter, and unpolluted waters. PNG is not usually subject to cyclones.	- As with many Pacific Island nations, marine tenure can be complex and sensitive – and without clear and equitable arrangements marine resource development initiatives can easily founder.

[5] FAO fishery and aquaculture country profile 2010

Logistics

- Small scale inshore transport in open boats with outboards is ubiquitous and convenient.
- Air freight is regular and well established between most provincial centres and the major city ports of Port Moresby and Lae.
- Access to international supplies (e.g. feed) and markets are relatively good compared to other Pacific countries, with direct flights to Australia and Singapore and with the prospect of direct flights also to the US. The ports of Moresby and Lae are significant trading centres, with reasonably priced shipping access to Australia and major Asian markets. Many private companies also have direct shipping links, especially with Indonesia and Malaysia.
- The high cost of petrol for outboards represents an increasing constraint
- Road infrastructure within the country remains limited, and existing roads are largely related to mining activity. Transportation between coastal areas and the more highly populated highland and urban areas is limited and costly and effectively restricts domestic demand for seafood products, despite high prices in inland areas.
- Development of the cold chain network is limited.
- Internal air freight costs are significant (>7 kina/kg) and freight capacity limited.
- Outside of Lae and Port Moresby, both domestic and international sea freight costs may also be high.

Commercial networks and skills

- There are significant commercial relations between PNG and Asian countries, and in particular Malaysia, Indonesia and the Philippines. This facilitates the transfer of investment capital and skills for commercial developments.
- Mobile telephone use is increasing rapidly and driving a shift towards a cash economy even in remote rural areas. Phones also facilitate marketing and financial transactions.
- There is very little tradition of commercial or entrepreneurial activity in coastal areas, and traditional use rights constrain incoming entrepreneurial activity, and/or government efforts to promote enterprise. Transaction costs associated with drawing up local agreements may be high and misunderstanding/ misinterpretation common.

Feed

- Significant quantities of fish meal are already produced (and exported) as a side product of tuna processing (Lae and Madang), and could underpin the development of national fish feed manufacture, which might in turn underpin the development of a range of mariculture enterprises. Other locally produced feed ingredients might include coconut meal, fermented coconut, seaweed, rice bran, freshwater herring, meat meal, blood meal and feather meal.
- An animal feed manufacturer is already established in Lae supplying the chicken industry, which has seen rapid growth.
- High fuel costs are a major factor that will increasingly favour aquaculture over wild fish production, although this depends on limiting energy input into feed production/supply and developing energy efficient aquaculture systems.
- Both shrimp and finfish culture may be constrained by the lack of a national feed manufacturer. This relates primarily to lack of current demand to make production viable, and possibly limited supply of other high protein feed ingredients available locally. However, given the fact that:
  a. fish feeds are an internationally traded commodity, and PNG is relatively well serviced by container vessels from Asia; and
  b. prices are relatively high for finfish and prawns, and will remain so until supply is no longer constrained;

  it should be possible to absorb the extra costs of imported feed (at least while product supply remains constrained), until demand for feed reaches a level where national feed manufacturers will be prepared to start production.

Seed	
- The new NFA/NFC barramundi hatchery in Dauru and the marine hatchery facility at Nago Island will be well placed to operate a commercial unit which could also produce a range of species. The operation of such a unit on a commercial basis would also greatly enhance the value of the facility for practical operational training. - The Pearl Hatchery at Samarai Island is underutilised (pearl seed production is largely confined to Feb-April each year) and could also produce a range of mariculture seed.	- Seed is commonly cited as a constraint to mariculture development and current supply is limited. - Inadequate broodstock management practices and broodstock availability have been cited as constraints – though we consider them significantly less critical than market/cost of production constraints.
- There is a significant opportunity for sourcing marine shrimp broodstock within PNG – this is probably a matter of initiative, education and facilitation. Given the lack of competition for broodstock in the country it should be possible to source indigenous breeders at reasonable price.	- Broodstock for commercial shrimp farming is not currently readily available despite significant tiger shrimp stocks and trawl fisheries. The only shrimp farm developer is therefore seeking to import seed from Australia (sourcing from Asia has been refused by the government because of the high risk of bringing in disease).
Financial investment	
- Copra and palm oil prices are currently relatively high, and increased mining means that investment capital is likely to be available.	- It will always be hard to finance new aquaculture ventures – it is a high risk activity. However, a lack of take up of existing finance schemes suggests that this is not the main constraint. - A 10% tax is levied on imported seafood products, which together with transportation costs should favour domestic production.

Table 2: Mariculture opportunities

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	**Site availability**	**Local markets**	**National markets**	**International markets**	**Comparative advantage and disadvantage**	**Production and market risks**
Seaweed	good	none	none	good	fair	L;M
Marine/BW finfish (cobia, barramundi)	good	limited	fair	poor	fair	MH; M
Marine shrimp	good	limited	fair	fair	fair	H;M
Pearls	good	poor	limited	fair	fair	H;H
Coral	good	poor	poor	Fair	high	M;M
Giant clam	good	poor	poor	fair	high	H;M

Table 3: Potential contribution to development objectives

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Commercial viability	Import sub-stitution	Livelihoods & poverty alleviation	Food security
Seaweed	good	low	fair	low
Marine/BW finfish (cobia, barramundi)	worth exploring	fair	low	low
Marine shrimp	fair[6]	good	low	low
Pearls	low	low	low	na
Coral	fair	none	fair	none
Giant clam	fair	none	fair	none

[6] Assumes that broodstock constraint can be overcome

RECOMMENDATIONS TO PAPUA NEW GUINEA GOVERNMENT/SPC

- Offer technical/advisory services as required to the commercial sector to underpin the current development in seaweed farming.
- Undertake more thorough analysis of the domestic finfish market and realistic production costs before promoting finfish mariculture, including production of barramundi, cobia and milkfish.
- Explore opportunities for supporting commercial giant clam and coral farming for the aquarium trade, building on current commercial initiatives in ornamental fish exports.
- Facilitate sourcing and supply of wild broodstock to the existing commercial shrimp hatchery/farm.
- Develop a coherent strategy for government and private sector engagement in hatchery development, maintenance, and seed production, and put in place sustainable financing mechanisms.
- Undertake more thorough market and financial feasibility studies before engaging in any mariculture R&D activity.

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APPENDIX D

OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

COUNTRY REPORT: REPUBLIC OF THE MARSHALL ISLANDS

Report by Hambrey Consulting in association with Nautilus Consultants

www.hambreyconsulting.co.uk

To the Secretariat of the Pacific Community

November 2011

THIS REPORT

This brief report was prepared in support of a wider study on Opportunities for the Development of the Pacific Islands' Mariculture Sector for the Secretariat of the Pacific Community (SPC), and forms one of a set of five country case studies undertaken between early August and September 2011. Reports were prepared for the following countries:

- Cook Islands
- Fiji
- Papua New Guinea
- Republic of the Marshall Islands
- Solomon Islands

Roughly one week was spent in each country, including site visits and discussions with stakeholders. Thanks are due to all those who spent time talking with us (see list of consultees on page 107) and especially to especially to Clyde James for his help and site visits, Candice Guavis for arranging meetings as well as Glen Joseph, Florence Edwards, Manoj Nair, Provan Crump and Simon Ellis for their time and insights.

An overview report was also prepared drawing on the case studies, published information, and desk based analysis.

SUMMARY

RMI is small and relatively remote, with substantial logistical challenges for internal and external communications. Despite rich marine resources mariculture potential is modest compared to offshore fishing and limited coastal fisheries.

- Opportunities for mariculture for food security in rural coastal areas are limited, since there remain significant coastal fisheries resources, coastal population density is not generally high, and local entrepreneurial activity is limited.
- There are some opportunities for cash generation for poverty alleviation or income diversification (giant clam growout, seaweed), but these have yet to demonstrate potential beyond rather spasmodic and insecure production of pearl and aquarium clam for international markets.
- There is strong national demand in the urban centres of Majuro and Kwajalein for fish, but demand is greatest for relatively low priced products, with sales particularly sensitive to price. Without substantial economies of scale, finfish aquaculture is unlikely to be commercially viable.
- The one commercial venture exporting cultivated ornamental fish, giant clam and coral shows that success is possible, but the large number of broadly unsuccessful (and costly) public interventions in this sector suggests that the immediate constraints have less to do with markets and more to do with entrepreneurship, organisation, commitment and management skills. Furthermore, it is arguable that as a small and peripheral producer, RMI is at a commercial disadvantage, particularly at a time when increasing levels of supply and flat or falling demand in markets for aquarium giant clam, live coral and pearls further emphasise the need for strong business skills and economies of scale.
- RMI has relatively good access to research and technical advice from the national College of the Marshall Islands and also from Hawaii, USA, and neighbouring countries. However, advice on markets and economic feasibility seems to have been limited, and clearly identifiable transport constraints have overcome several trial ventures.
- Attempts at engaging the private sector have met with mixed success. The private clam hatchery doubles as an exporter and has proven to be a sympathetic supporter of community clam farming. Attempts at privatising the government clam hatchery failed, and the private sector involvement in pearl farming ended after the ventures found that they were not able to rely on the government run pearl hatchery or, ultimately, to compete with it.
- The potential of seaweed and *Trochus* do not appear to have been adequately explored, though there seem to be strong concerns over biosecurity, which need to be addressed.

COUNTRY CHARACTERISTICS

Land area: 181 km^2 EEZ : 2,131,000 km^2	Population density 304/ km^2
Length of islands coastline: 370.4 km	
Population[1]: 54,999 Population growth rate 2000–2009:	Estimate for 2030: 62,414
Percentage urban population 65%	
GDP 2008: US$160 million	Per capita GDP[2]: US$2,300
GDP growth rate 0.7%	GDP fisheries 2007: US $0.68 – 42 m
Fisheries production (2007): 80,046 t	National minimum wage: US$2/hr indicative
Local market fish price: US$2.75 – 4.95/kg	Currency: US$

HISTORY AND CURRENT STATUS OF AQUACULTURE AND FISHERIES DEVELOPMENT

Reports of aquaculture activities in RMI date back to before World War II under the Japanese administration of the islands. Black-lipped pearl oyster mariculture was carried out on a small scale at Ebon Atoll in a joint venture between the Japanese government and a private firm. Some live oysters were reportedly transplanted from Namdrik Atoll as part of this operation, and during this period a sponge farm was reportedly operating in Ailinglaplap Atoll. Recent information suggests that it was in fact white lipped pearl oysters that were introduced and farmed at Ebon by the Japanese and that no transplants took place until at least the 1970s.[3] All mariculture activities ceased after the war.[4]

Renewed interest in pearl oysters in the 1980s (including a Japanese survey of pearl oyster shell in 6 atolls) led to support from SPC and the development of pilot black lip pearl farming in Namdrik Atoll supported by local government ordinance. The 1980s also saw the emergence of interest in giant clam farming, initially for food and subsequently for the aquarium trade. Local species *Tridacna maxima*, *T. squamosa, T. gigas* and *Hippopus hippopus* were farmed, as well as *T. derasa,* introduced from Palau in 1985 and 1990. By 1990 a giant clam hatchery had been established in Wau Island, Majuro, and by 1993 small scale giant clam farming activities had been tried in the outer islands of Ailuk, Aur, Jaluit, Likiep, Maloelap, Ujae, Wotje and Kwajalein.

The 1990s saw increased activity in black lip pearl oysters and giant clam cultivation with the emergence of the first commercial companies, though with only one currently remaining successful. The last decade has seen the development of government/private partnerships and exploration of new approaches and species for RMI aquaculture.

Current aquaculture production in the RMI consists of relatively steady but small production of tridacnid clams for the aquarium market as well as small amounts of hard and soft corals for the

[1] SPC 2011
[2] http://data.un.org 2008
[3] Manoj Nair, personal communication, January 2012
[4] Dashwood 1991, Clarke et al. 1996, Mariculture Working Group 2005

same aquarium trade and sporadic production of black pearls. Annual revenues to RMI are on the order of a few tens of thousands of dollars, but this varies greatly between years. A fair proportion of this is to community growers, though much of the value chain is located outside RMI (pearl auctions, aquarium trade consolidators) and thus added value revenues are captured by others in the supply chain.

GIANT CLAMS

The main giant clam facility is operated by Ocean Reefs and Aquariums Inc. (ORA) based in Miami. The ORA operations in RMI are the Marshall Islands Mariculture Farm (MIMF) and result from the purchase of giant clam operations operated by local company Robert Reimers Enterprises Inc. (RRE) in the early 2000s. MIMF expanded RRE's Majuro-based hatchery and land-based growing facility and continues to be the major producer and sole exporter of tridacnid clams, hard and soft corals and occasionally other aquarium species.

MIMF concentrates on the production of various species of giant clams for export, primarily to the ORA main facility in Florida but also to buyers in Asia and Europe (e.g. Hong Kong and Italy). Hard and soft corals are also produced by fragmenting second generation mother colonies held in the tank systems. There are 24 concrete raceway tanks covering some 500 m^2, and another 24 smaller fiberglass tanks all supported by redundant electric pumps and a backup generator.

T. maxima and *T. derasa*, as well as limited amounts of *H. hippopus* and *T. squamosa*, are grown in tanks until they reach an acceptable size at which, depending on demand, they are shipped via Continental Airline to their markets. The growing period takes approximately 3–4 years in the case of *T. maxima* and 2–3 years for *T. derasa.*

MIMF also purchases clams from local farmers in Arno and Likiep atolls. These farmers are provided with spat from hatcheries run by the government in those atolls. The Arno hatchery also serves as an intermediary for the Arno farmers. MIMF has also reportedly provided some cage materials and training to village based farmers in at least five locations around Majuro Atoll.

The government, through the Marshall Islands Marine Resources Authority (MIMRA), operates two rural giant clam hatcheries established with Japanese aid from the Overseas Fisheries Cooperation Foundation (OFCF) to provide spat for community farmers. The hatchery at Likiep Atoll is associated with a functioning fisheries station and ice plant which defrays some of the operational costs and shares a staff member. The hatchery is reportedly producing spat regularly and comprises 12 large tanks with a total area estimated at 100 m^2. Clams are distributed to farmers, drawn from the local population of less than 500, who grow them in cages for 1–1.5 years in the lagoon. When MIMF requests a shipment and air transport allows, clams are harvested and shipped directly to MIMF.

The Arno hatchery occasionally produces spat, with the last major spawning undertaken in 2009 and the next expected in the near future. The facilities were constructed with Japanese assistance and comprise ten concrete tanks totaling some 60 m^2 and various buildings located some distance from the sea. The small size of the tanks and cost of running the large pumps required result in elevated production costs and the exposed location of the hatchery restricts ocean nursery operations. MIMRA entered into agreement with MIMF/ORA to run the Arno Hatchery, but this arrangement has been discontinued.

The farm scheme initially agreed in community meetings envisaged farmers paying back the cost of cages and snorkel equipment (2.25m^2 cages at $100) and allowing MIMRA to partially

recoup hatchery costs through a 10% charge on sales deducted by MIMF and refunded to MIMRA. MIMRA also sells some clams (around 20% in 2010) directly to MIMF, which also helps ensure regular supplies.

Production figures are potentially confusing: MIMRA annual reports and interview data produced for SPC (Ponia 2010) suggest around 30,000 and up to 90,000 clams are sold per year. However, export permit records, CITES records and, most crucially, the sole exporter's own records, suggest the most accurate estimate would be considerably lower – in the region of 6,000–15,000 per year (Table 1).

All sources concur that at least half the clams produced are *Tridacna maxima*, with smaller quantities of *T. squamosa* and *T. derasa*. Small amounts of *Hippopus hippopus* and *T. gigas* are also mentioned, as well as *T. crocea* (~4%), but these are not produced nationally and may indicate that re-exports from Pohnpei are included in the national figures. The slight discrepancy between MIMF and CITES figures may be indicative of limited re-exports. Community farmers may produce between 20% and 90% of exports, depending on the year.

Table 1. Data available on export or production of tridacnid clams for the aquarium market in RMI.

	2005	2006	2007	2008	2009	2010
MIMF export figures	26,000	17,000	8,119	10,137	6,116	15,192
CITES database (live tridacnids)	14,582	20,690	9,159	11,200	7,142	
Export permits (granted to MIMF)[a]				19,836[b]	10,078	
ALL aquaculture production (pieces)[c]	28,000	28,000	34,000			
MIMRA farmers sales to MIMF[d]	22,142	4,121	1,751	5,548	5,881	3,129
MIMRA Annual Reports	46,924	77,525	47,250	87,900		

a: Source: MIMRA data
b: 3 months' data
c: Source: Ponia 2010
d: Produced in MIMRA hatchery, grown by community farmers then sold to MIMF

The farm gate prices offered by the sole buyer and exporter, MIMF, are currently $2.75, $2.20 and $1.40 for the most frequently purchased size grade (4–5cm) of *T. maxima*, *T. derasa* and *T. squamosa*, respectively. The value of production to rural giant clam farmers in recent years is likely to be between $15,000 and $40,000, with an additional proportion to the exporter.

HARD AND SOFT CORALS

MIMF produces small amounts of live hard corals for the aquarium trade by fragmenting second generation mother colonies and growing them in tanks. Production is estimated at around 1,500 pieces a year with a value around $13,000.

PEARLS

Early research carried out under the auspices of Hawaii Black Pearls Inc. (BPI) determined that oyster spat could be collected at Namdrik and grown; half-shell (mabe) pearl was produced there in 1994, and some of the 200 adults that were seeded produced quality pearls. BPI also piloted the removal of broodstock to their hatchery operation in Hawaii and returned spat for augmentation of natural stocks in Namdrik, as well as testing hatchery operations in Majuro

from 1997. The BPI initiative led to a joint venture with MIMRA and local businessmen (Black Pearls of Micronesia [BPOM]), but hatchery operations continued to be fraught with difficulties and growout was moved to Arno in 2002.

A local company, Robert Reimers Enterprises Inc. (RRE), began pearl farming at Arno Atoll in 1995 using shells collected from Jaluit Atoll. This resulted in a number of small harvests, but overall production was limited by the availability of spat. From 2000 to 2005 RRE managed to produce small amounts of pearls, which it sold on the local market loose and as part of jewelry-making initiatives. The supply of spat continued to be a major limitation and collaborative spat collection trials with the Center for Tropical and Subtropical Aquaculture (CTSA) and the University of Hawaii Sea Grant Program led RRE to commence operations in Jaluit Atoll in 2001. At the same time it phased out operations in Arno, which, though located close to Majuro, could not access spat through local collection or from the hatcheries in Majuro, which struggled to meet demand.

Spat production needs identified by industry and MIMRA led to the College of the Marshall Islands renovating its Arrak campus hatchery under the Land Grant Program and commencing trial production. Later, in 2002, semi-commercial spat production was undertaken with a view to filling needs until the much larger MIMRA sponsored hatchery in Woja could become operational. The main purpose of the Arrak hatchery was research and training, but the Land Grant Program managed to supply two commercial farms – BPOM (Arno) and RRE (Arno and Jaluit) – with spat until 2004. In late 2005 the Land Grant Program initiated community pearl farming in five atolls (Maleolap, Bikini, Rongelap, Ebon, and Likiep). Unfortunately the MIMRA supported Woja hatchery never overcame high mortality and operational problems and large scale spat production was never sustained. After reportedly successful sales from 2003 to 2005, industry led black pearl operations had ceased in 2007 when the RRE operation officially closed, citing the lack of availability of hatchery produced spat as the main reason. In 2009 the Arrak hatchery received renewed funding and support and in 2010 it produced 1.7 million spat with the intention of continuing production and supply to the community farms. This process continues.

The Community Based Black Pearl Farm Project of Rongelap Atoll and the Black Pearl Project of Namdrik Atoll Local Government harvested pearls in 2010, ending a five-year lapse in RMI pearl production. Spat and extension services were provided under the College of the Marshall Islands (CMI) Land Grant Program and collaboration from staff at the Marine and Environmental Research Institute of Pohnpei (MERIP) and from a University of Hawaii Sea Grant Aquaculture Extension Agent.

Pearl production in RMI generally lacks substantiated figures. Those most commonly cited refer to the estimated value, such as pearls harvested by RRE with a value of US$50,000 in 2001[5] and a personal communication from Manoj Nair cited by Gillett (2009) suggesting that 2,000–3,000 pearls were harvested in 2005 with a proposed farm-gate value of $50 each. The only recent reports refer to the pearl harvests carried out by the Rongelap and Namdrik atoll governments in 2010. These were estimated to be worth 'close to US$100,000',[6] though the harvest from Rongelap Atoll of 1,300 pearls was valued at about $20,000[7] and the pearl auction and sale of pearl necklaces, earrings, and rings produced 'a net profit of over $31,000.[8]

More precise figures are provided by Fishery Manager Reuben Ranay of Rongelap Atoll Local Government, cited in a CMI press release, reporting that 1,368 pearls were harvested in August

[5] CTSA 2002
[6] PINA 2010
[7] Marshall Islands Journal 2010
[8] YokweOnline, 2011

2010 in Rongelaap.[9] S. Ellis (pers. comm.) reports that 517 pearls harvested at Namdrik were valued after grading at around $22,000, suggesting an average price of US$43 per piece (which is towards the top end of market prices, paid for pearls of particularly high quality).

The best estimate for the pearl harvest in 2010 is therefore 1,885 pearls with a farm gate value of $82,000 and potentially up to $100,000 allowing for grading differences. The amount actually sold so far, however, seems to be $31,000 at the one-day auction and some additional sales to interested parties. These figures do not account for hatchery costs accrued by CMI or production and grafting costs of the community farms.

Pearl production can be best described as sporadic, with significant harvests over the last decade only in 2001, 2005 and 2010. These harvests likely amount to under 2,000 pearls with a potential farm gate value of just under $100,000 and recorded sales (local) of just over $30,000. These figures do, however, appear rather on the high side, with more realistic average farm gate prices on the order of US$15 per piece (particularly given that fewer than 10% of pearl production is likely to be of gem quality).

Looking to the future, after modification and expansion, the Arrak multi-purpose hatchery produced a trial run of spat in 2009 and 1.7 million spat in 2010, of which 600,000 were distributed to Rongelaap and Namdrik Atolls. Further harvests and grafting are scheduled for early 2012 and local and national political statements suggest interest in a revival of the industry.

For strategic management purposes, more accurate figures on volume, price and quality would be useful, alongside figures on capital and recurrent costs. The inference from the above information is that whilst useful revenues are generated from pearl cultivation, it is very likely that these are far outweighed by the construction, maintenance and operating costs of the hatcheries and growout facilities, and the costs of seeding technicians. Further, a lack of continuity of spat production rather undermines the idea of pearl farming from a commercial perspective, with the inference that facilities funded and managed by non-commercial operators lack the rigor and commercial discipline required by this sector.

POTENTIAL AND PLANNED MARICULTURE ACTIVITY

Aquaculture of a number of other potential species has been discussed, but the most notable trials have been for cage fish culture and seaweed. From 2008 to 2009 an Australian company reportedly invested more than US$3 million dollars in establishing cage culture of barramundi cod and cobia for live export to Asia and USA. The venture gained partial approval from the RMI Environmental Protection Authority (EPA) but ceased operations, reportedly because of uncertainty over export logistics and the high cost of live fish shipment from Majuro. Farming of the introduced seaweed *Eucheuma cottonii*, initially using seed from Fiji and Kiribati, commenced with the training of staff and community members and establishment of trial farms in several atolls. The initiative was cancelled after running into a variety of problems including biosecurity concerns, king tides, high levels of grazing, and undesired impact on sharks of grazing prevention measures.

CMI is preparing for renewed rabbit fish culture trials at the Arrak hatchery with financing from the Land Grant Program, and an expert is due to arrive in the near future. The aim is to restock a favourite food fish perceived to be under pressure in Majuro. The hatchery is gearing up for trial production, and should be capable of carrying out trials of other species provided manpower and operational costs are secured.

[9] YokweOnline, 2011

A Technical Cooperation Programme project is awaiting final approval under the FAO Food Security and Sustainable Livelihoods Programme. The two-year, $389,000 project includes the identification of viable aquaculture projects and the enhancement or establishment of community based aquaculture. No indication has been given of priority species.

As with most other previous mariculture activities, little attention appears to be given to addressing the commercial and economic case for development. Projects tend to be technology driven, and almost totally dependent on grant funding. Some financial benefits have been derived by community farmers on a number of atolls, but this is insignificant in relation to the scale of grant funding used to set up central facilities and trials. To move beyond the idea that development would have been better served by simply handing out cash to every household in the country rather than using it to build mariculture facilities requires a much more rigorous and considered evaluation of the commercial and economic issues involved.

Table 2: Mariculture opportunities and constraints

Opportunities	Constraints
General	
RMI has many potential aquaculture sites in the atoll lagoons, especially in the lee of the atoll islands. Major storm activity is rare.	The downwind side of lagoons tends to be excessively exposed to wave action for low-technology mariculture growout. Land availability is limited and lease arrangements can be a burden.
International port and airport in place as well as airfields on most islands.	International air freight expensive, limited and unreliable. Domestic air and sea transport, plagued by maintenance and logistical issues, is unreliable.
Government run fish collection service from island Fishbases provides an opportunity for piggy-backing operations in terms of transport and on-site support (e.g. hatchery facilities).	Local interests may hinder promotion of aquaculture ventures as reflected in demands for business taxes or selection or exclusion of particular beneficiary groups.
Few income generation options are available for outer islanders, and alternatives to fishing and copra are in demand. Potential to slow urban migration.	Logistical support of even the most low-technology ventures is challenged by transport issues in almost all islands.
Significant history of diverse mariculture initiatives in private, government and academic sectors resulting in a pool of expertise and experience.	Little, if any, track record of assessments of overall viability and markets before proceeding with technical and pilot projects. Little evidence of 'learning lessons'.
Presence of College of Marshall Islands and good connections to other academic and technical service providers.	Little emphasis on skills relating to the business planning and financial assessment of mariculture ventures.
Conservation NGO and Coastal and Community Fisheries section of MIMRA promoting mariculture as an environmentally friendly alternative use of coastal resources.	Biosecurity concerns have relatively strong influence over planned mariculture development and processes for approving experimental or commercial ventures.
Modest but burgeoning demand for seafood in two main urban centres of Majuro and Ebeye and potential for sales of jewellery to small numbers of tourists and workers at the Kwajalein military base.	Locally available seed restricted to tridacnids, with a need for hatchery production or import of seed of other species.
Four atolls have trust funds for administering compensation from nuclear fallout claims which provide a source of funds for local government investment.	Relatively limited access to start-up capital, soft loans and subsidies for business entrepreneurs. Little success (with one exception) in generating successful public/private partnership and some perceptions of government out-competing the private sector. Far from encouraging commercial development, the high levels of grant funding and government managed activity can act as a significant disincentive to commercial development.
Commercial clam hatchery and exporter with access to US market collaborating with government and community farmers.	Project driven mariculture R&D has led to expectation that farmers will receive seed and equipment up front with risk of unfair subsidies and reduced commitment of farmers.
Investment incentives exist, though not for small-scale mariculture targeting local markets. No export taxes and no tariffs in the US market.	Government- and college-run hatcheries not appropriate for the reliable production of seed necessary for commercial investment.

Giant clam (ornamental) and coral farming

Over two decades of experience in hatchery and ocean culture of giant clams with experienced personnel and understanding of habitat and husbandry requirements.	Government supported hatcheries still unable to produce reliable and regular supplies of seed. Poor site selection and lack of commitment continues to be a problem with community farmers.
Commercial hatchery producing spat and continuing growout in land-based system also willing to buy directly from rural farmers and cover transport costs.	Government hatchery production of spat would not be commercially cost effective and results in heavily subsidised spat and unpredictable clam production. The subsidy reduces the incentive for new players in commercial production (though it may reduce the risk of a monopoly over spat).
Unmet market demand, especially for *T. maxima* and *T. derasa*. Fluctuations in supply from community farmers may be buffered by steady production from private hatchery and injections of stock held at government hatcheries.	History of unpredictable and underperforming supply from community farms. Estimates of 5–10 times the market capacity may lack sufficient reliability for major investment by community or private sector.
Some demand for cultured corals, which are relatively easy to grow with a far lower investment.	Potential of cultured coral for community farmers is reduced as demand may be most reliably met by commercial hatchery which can control quality and meet CITES requirements.

Pearl

Available sites and tried and tested methods for growing.	Production extremely irregular and reportedly high spat losses occur.
Technical feasibility of large scale production of spat proven at research hatchery.	No guarantee (funding and manpower) that research hatchery can produce regular large quantities of spat over the long term and so far no clear opportunity to privatise or ensure long term running.
Existence of small local market from tourists and temporary workers in Kwajalein and Majuro, particularly for locally made jewellery.	Unlikely to be competitive with larger operations in the region on international markets.
Political support and investment at the atoll level with funds from the compensation claims and some support between atolls.	Operations are highly subsidised from hatchery to harvest, and political importance of being seen to produce local benefits may be hard to reconcile with measures to increase cost effectiveness.
Technical support available at CMI and regionally. Skilled technicians can be brought in from French Polynesia.	Reliance on overseas technical support, particularly for nuclear implanting, as local skills not available. Vulnerable to changes in local leaders' political support.
	Major local investor disenchanted with pearl farming after previous experiences and reluctant to re-enter the industry under current circumstances.

Finfish

Coastal fish stocks under pressure close to urban centres and concerns expressed on impact of commercial fishing in remote atolls.	Local market prices and demand inadequate for maricultured finfish.
Cage culture of finfish (cobia and barramundi cod) proved technically viable.	Significant investment required (cages, security, broodstock and/or fry, feed).
	Transport constraints: export of product and import of feed and fry.
	No economic feasibility studies yet carried out for rabbitfish (about to be cultured) or other finfish.

Seaweed	
Recent trials suggest a number of locations present adequate conditions for farming.	A number of technical issues to be resolved in terms of site selection and husbandry, including control of grazing and impact on sharks affected by grazing control measures.
Dried produce not so susceptible to unreliable shipping.	Biosecurity concerns relating to the introduction of seed for proven commercial species.
Simple, low-cost technology, relatively suited to rural farmers.	Comparative disadvantage relative to large scale and well organised production in places like Indonesia.
There is an established international market for dried seaweed for processing into a range of natural gels.	RMI production would be minute on an international scale, and it may be difficult to ensure that a reasonable market value is paid for relatively small volumes of local product.
Restocking	
Community based marine resource management and conservation area initiatives could be enhanced by restocking depleted invertebrates.	The viability and sustainability of restocking and/or ranching remains to be demonstrated, and will require very particular conditions for success. The cost-effectiveness of restocking will have to be compared to other potential resource management interventions.

Table 3: Mariculture opportunities

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Site availability	Local markets	National markets	International markets	Comparative advantage	Production and market risks
Giant clam	good–fair	poor	poor	Fair	Low–medium	medium
Pearls	fair	poor	medium–good	Low	low	medium–high
Seaweed	fair	none	none	good??	low	low; medium
Marine finfish	fair	low	low	Fair	low	high

Table 4: Potential contribution to development objectives

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Commercial viability	Import sub-stitution	Export earnings	Livelihoods & poverty alleviation	Food security
Giant clam	fair	none	Fair	fair	none
Pearls	Local sales	low	Low	low	none
Seaweed	good?	none	Fair	fair	low
Marine finfish	unclear	low	Low	unclear	unclear

RECOMMENDATIONS TO MIMRA/SPC

- Complete strategic analysis of experience to date, including financial and technical feasibility analyses. Correlate with national policy to define the degree of subsidisation (if any) appropriate to produce desired policy outcomes.
- Define medium term focus of MIMRA support, reducing to one or two key species with best potential and appropriate government interventions over a 10 year term – both direct support and in terms of creating an enabling environment for the private sector.
- Examine biosecurity constraints and develop or further define procedures.
- Provide business skills and feasibility assessment (economic/financial as well as technical) training for government and research staff.
- Improve and simplify data recording for hatchery and ocean production, including yearly training/support from computer staff.
- Explore specific feasibility studies for trochus and seaweed.

CONSULTEES

Marshall Islands Marine Resources Authority

- Glen Joseph, Director
- Florence Edwards, Chief of Coastal
- Clyde James, Aquaculture specialist
- Candice Guavis, Coastal specialist
- Export permitting
- Staff, MIMRA Fish market

College of the Marshall Islands

- Don Hess, CMI Head of Science Dept. and Dean of Academic Affairs
- Puma Samson, Dean of Land Grant
- Julius Lucky, CMI Arrak Hatchery

Robert Reimers Enterprises Inc.

- Ramsey Reimers, Chairman and CEO

Ministry of Transport and Communications

- Phil Philoppo, Secretary
- Carl Alik

MI Shipping Corporation

- Wally Milne

Ministry of Resources and Development

- Theresa Kitchener, Trade and investment officer

Marshall Islands Conservation Society

- Albon Ishoda

MI Mariculture Farms/ORA

- Provan Crump, Manager (via email)
- Staff x 2

Arno Atoll stakeholders

- Akjen, Clam farmer
- Turrak Anton, Clam farmer
- Clam farmer #1
- Frances Reimers, Rural business entrepreneur, ex-pearl farmer

Continental Airlines

- Carlson– Air Freight (via telephone)

SPC Coastal Fisheries

- Ian Bertram

Marine and Environmental Research Institute of Pohnpei

- Simon Ellis, Director

Other stakeholders

- Paul Alee, Government employee
- Manoj Nair, Ex- Land Grant Aquaculture Scientist, CMI Arrak (via email)
- Maria Haws, University Hawaii – Sea Grant (via email)
- Antoine Teitelbaum, Ex-SPC aquaculture (via skype)

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Appendix E

OPPORTUNITIES FOR THE DEVELOPMENT OF THE PACIFIC ISLANDS' MARICULTURE SECTOR

COUNTRY REPORT: SOLOMON ISLANDS

Report by Hambrey Consulting in association with Nautilus Consultants

www.hambreyconsulting.co.uk

To the Secretariat of the Pacific Community

November 2011

THIS REPORT

This brief report was prepared in support of a wider study on Opportunities for the Development of the Pacific Islands' Mariculture Sector for the Secretariat of the Pacific Community (SPC), and forms one of a set of five country case studies undertaken between early August and September 2011. Reports were prepared for the following countries:

- Cook Islands
- Fiji
- Papua New Guinea
- Republic of the Marshall Islands
- Solomon Islands

Roughly one week was spent in each country including site visits and discussions with stakeholders. Thanks are due to all those who spent time talking with us (see list of consultees on page 122) and especially to Wesley Garofe for arranging meetings and site visits.

An overview report was also prepared drawing on the case studies, published information, and desk based analysis.

SUMMARY

Solomon Islands represent an intermediate type of Pacific Island nation with significant inland areas rich in timber and minerals, and a long coastline rich in marine resources.

- **Air and sea connections** with major overseas markets and suppliers from Honiara are fair, and potentially good, with significant existing international trade in palm oil, copra, timber and tuna, and an emerging mining sector.
- There is a long **history** of mariculture development initiatives underpinned by the research work of World Fish Center at Nusa Tupe in Western Province.
- Prices for **seaweed** are relatively good, and artisanal seaweed farming is clearly economically beneficial at the present time, with potential to make a significant contribution to poverty alleviation, GDP and foreign exchange. Good sites are available in the islands (access, shelter, good water exchange, lack of grazers), but testing of new sites is a time consuming and risky activity. Switching between seaweed, bêche-de-mer, other fishery products, and copra according to price and availability is a characteristic of coastal village economies, and mechanisms are needed to maintain seaweed stock during periods of relatively lower prices and reduced activity.
- **Sponges** have several attractive characteristics from the perspective of artisanal production and poverty alleviation: low seed costs; limited growout risks; and a stable, easily stored dry product with a high value/weight ratio. However, the relatively long growout period is a significant disadvantage. Nonetheless, this possibility deserves further examination with a focus on markets, growout risk, labour and other input requirements, and beach price.
- **Coral and giant clam** farming have the potential to be economically viable on a modest scale *if well sited and well managed,* and could make a modest contribution to employment, GDP and livelihoods. The cost of hatchery produced giant clam seed is, however, a significant constraint to artisanal production, and implies either significant subsidy or high levels of risk to producers. A larger scale, well located, more commercially driven enterprise, possibly with semi-independent or contract farmers, is worth exploring. Past initiatives in this area have been disrupted/constrained by ethnic tensions and internal logistics.
- **Commercial shrimp** farming has been successful in the past, but was disrupted by ethnic tensions. Given access to a suitable site, this could be restarted, and so long as disease can be avoided it should be economically viable. It has the potential to make a modest contribution to GDP and export earnings.
- Although fish supply per capita is high, and beach prices low, internal logistics constrain marine finfish supply to the main urban centre, Honiara, resulting in locally high fish prices, especially for the preferred reef fish species. Although current prices suggest that **milkfish** culture may be viable if undertaken close to market, the existing supply of this species is limited, and there is a range of cheaper substitutes and partial substitutes. If supply were to increase significantly, it is likely that price would drop rapidly below production cost. More thorough market analysis should be undertaken before significant resources are diverted to R&D or trials with this species or other marine finfish species.
- There is currently a JICA supported initiative to produce **sea cucumber** seed in a new hatchery at the Ministry of Fisheries and Marine Resources on the outskirts of Honiara. It is too early to be able to assess the economic viability of this activity (for reseeding/stock enhancement or for 'ranching') and there are as yet no clear examples of success elsewhere in the world. The main constraint is the space and protection required during the nursery phase.

COUNTRY CHARACTERISTICS[1]

Solomon Islands is classed by the UN as a least developed country due to its poor social indicators and low per capita income.

Land area: 28,000 sq km	Population density: 21/km sq
Coastline: 4,270km (main islands?)	
Population: 0.54 m Population growth rate: 2.6%	Population estimate for 2030: 0.88 m
18% urbanised (UNICEF)	Rural 67% 80% subsistence farming/fishing
GDP 2009: US$546 m	Per capita GDP 2009 (current US$): US$ 1,014
GDP Fisheries 2006: 27.4 m	
GDP growth rate (2009): 1 %	Exchange rate v US$ 7.36 General decline – especially during ethnic tensions
Poverty (% below PL): na	Adult literacy: 77%
Life expectancy: 67	National minimum wage: US$0.2/hr[2]
Fisheries production (2007): 142,000tonnes[3]	Fisheries exports: 17,280 tonnes
Per capita fish consumption: 34 kg[4]	
Local wholesale fish price US$0.7[5]–3/kg	Prices higher inland
Mariculture production 150 t (seaweed)	Fishing contribution to GDP (formal): 6–7%; 12% of exports; 12% of formal jobs (5000)

HISTORY AND CURRENT STATUS OF AQUACULTURE AND FISHERIES DEVELOPMENT

Mariculture has been supported in Solomon Islands through a number of projects over the last 30 years. However, apart from some success with shrimp and seaweed, aquaculture activity has so far made no significant contribution to GDP, livelihoods, or food security.

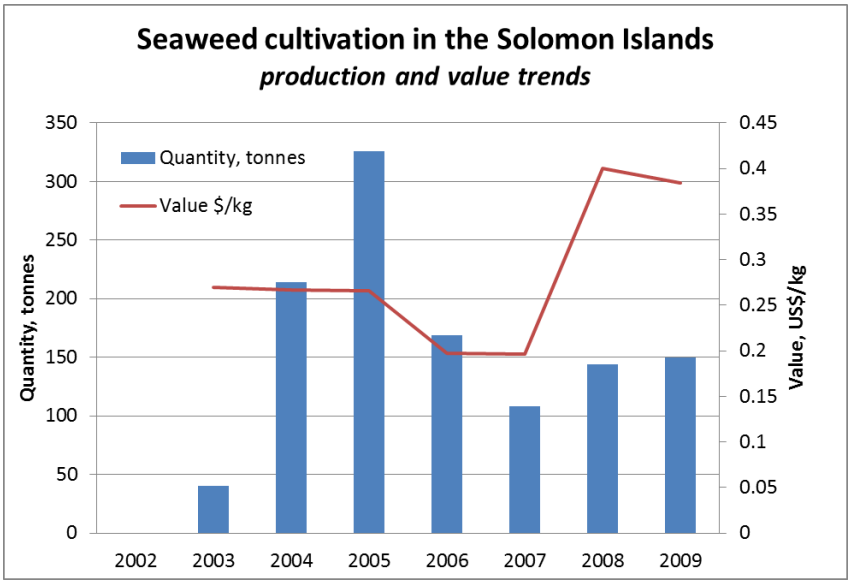
SEAWEED *(KAPPAPHYCUS)* CULTIVATION

Seaweed farming was trialled by UK ODA in the late 1980s (Munda, Vona Vona and Rarumana Islands) but suffered from rabbit fish grazing and low prices/low volume and was abandoned in the early 1990s. At that time, the product was shipped to Fiji and then shipped on to the Philippines. Under the EU Rural Fisheries Development project in the 1990s and early 2000s, fisheries centres were upgraded in several locations and opportunities for diversification and

[1] FCO Country Profile; BBC country profile; SPC socio-economic data; Gillett 2010; FAO country profile, fisheries
[2] Wikipedia
[3] FAO fishery and aquaculture country profile 2010 and Gillett 2010. Comprises: close to 100,000 t mainly tuna caught by foreign vessels, 23,600 t local offshore (mainly tuna for export), 15,000 t (estimated) coastal subsistence, 3250 coastal commercial (bêche-de-mer, shark fin, trochus, lobster etc.) 200 t freshwater and 165 t aquaculture (seaweed).
[4] Much higher locally
[5] Estimated value of coastal subsistence fisheries Gillet 2010.

increased use explored. As a result, seaweed production was restarted at Rarumana using residual stocks from the previous initiative, and 19 tonnes was produced in 2001–2002. This aroused the interest of a local trading company[6] (traditionally engaged mainly in collecting copra), which began to buy and export seaweed with an exclusive license. Production was then extended to Wagina – supported/facilitated by the Fisheries Department, the Nature Conservancy, and the private sector traders.

Figure 1: Evolution of seaweed cultivation in Solomon Islands



Recently, four other trading companies have obtained licenses to export seaweed, and this, along with more favourable international markets, has led beach prices to rise significantly during the last year (from S$3–4/kg to S$5–6/kg), generating significantly increased interest and activity in several locations. Seaweed cultivation is now relatively well established at Wagina, with smaller amounts also being produced in Rarumana, Buena Vista (Sandfly Group). Production in 2010 amounted to several hundred tonnes. This represents significant income to the communities and individuals involved.

GIANT CLAM AND OTHER MOLLUSCS

Research and development effort was originally targeted at production of giant clam (for meat) in the late 1980s/early 1990s with funding through ICLARM (now World Fish Center) and UK ODA working closely with Solomon Islands Government. These were innovative projects with a focus on improved livelihoods for people in relatively isolated coastal communities. Unfortunately, the focus was on developing the technology and engaging villagers in village trials, rather than on economic feasibility. Neither the production risks nor the costs of shipping product to market were fully appreciated, and activity declined rapidly in the early 1990s. Trials were undertaken on other species including sea cucumber, black, gold and whitelip pearl, *Trochus* and greensnail, but none have taken off, and were in any case disrupted by the ethnic tensions which began in the mid-1990s and lasted until the mid-2000s.

[6] Lee Kwok Kuen Company

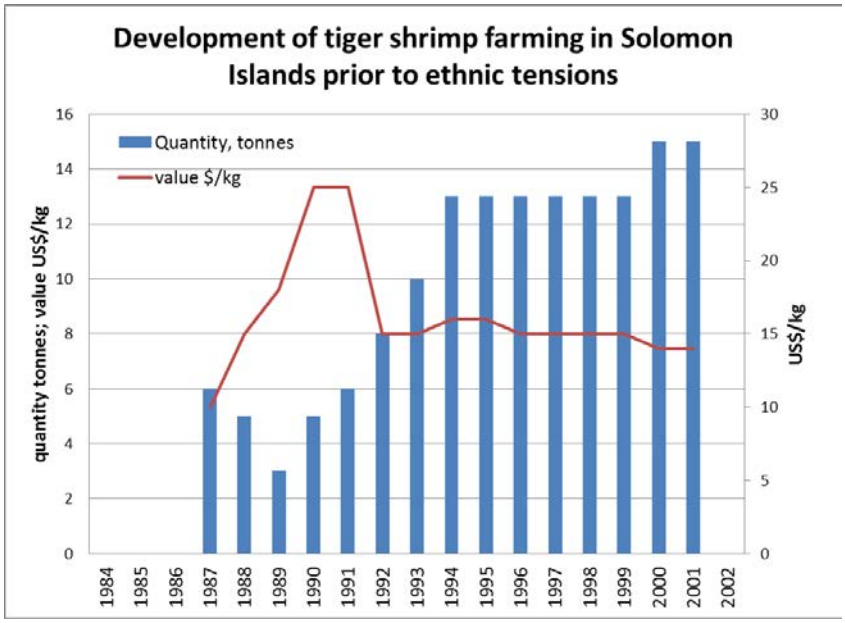
PEARL FARMING

There has been periodic interest in pearl farming since the early 1990s, with some trials (spat collection, hatchery production, growout – mainly of blacklip, but also some on goldlip) supported by the EU and ICLARM, and some commercial interest from Japan and Fiji. However, the high investment, long payback and significant risk mean that this is not suitable as an artisanal livelihood enhancement project. Resource use/access issues for foreign companies have probably restricted opportunities for more commercial development.

COMMERCIAL SHRIMP FARMING (BLACK TIGER SHRIMP)

Shrimp farming was developing well prior to the ethnic tensions, reaching 15 tonnes in 2001 worth US$210,000, and may be restarted if land issues can be resolved. Production was for both domestic and export markets. Broodstock of black tiger shrimp (*Penaeus monodon)* is available in Solomon Islands waters, and there is therefore the opportunity to develop high quality disease-free enterprises.

Figure 2: Tiger shrimp (*Penaeus monodon*) farming in Solomon Islands



MARINE ORNAMENTALS

The skills developed by ICLARM/World Fish Center were built on through a New Zealand Aid Programme project (2005–2010) that focused on creating rural livelihoods in Solomon Islands through environmentally-friendly aquaculture and trade of marine ornamentals. This focused on giant clams, cultured corals and post-larval capture and culture (PCC).

A total of 90 individuals (75 men, 15 women) and three community groups were trained in clam, coral and PCC techniques. According to the New Zealand Aid Programme final project

report, 39 individuals and 2 community groups were still active in June 2010, with highest rates of sustained activity for giant clams (80%). However, since that time the picture has changed. According to World Fish Center there are now 10–20 active coral farmers in Western Province, about 20 in Marau Sound, and a few in the Sandfly Group. Of the original 35 farmers trained in giant clam farming, there are less than 10 remaining. Recently, World Fish Center has decided to cease production of giant clam seed. Seed costs are high (at least US$0.6/pc), implying high investment costs for growout farmers, and high risk; however, beach prices are low in many locations. The logistical complexity and costs associated with product aggregation and shipment to the exporters in Honiara is a major constraint.

PCC of shrimp and lobster for the aquarium trade has not been successful, apparently because of the effort involved in feeding during growout, and the low prices received.

CORAL FARMING

Coral farming for the ornamental trade has been promoted heavily since 2005, primarily under the New Zealand Aid Programme funded project with World Fish Center and World Wide Fund for Nature (WWF). The Foundation of the Peoples of the South Pacific (FPSP) and Solomon Islands Development Trust were also closely involved in implementation. The beach price was originally set by the project, and was unrealistically high, as transport to a collection depot was subsidised by a project-funded collection boat. The subsequent necessary reduction in this price was a blow to many producers and numbers engaged have declined. A key problem here is that wild collection is also allowed, and is easier and quicker.

SPONGES

There is some current interest in sponges, with preliminary work undertaken by World Fish Center. Sponges appear to be more suited for artisanal production given that seedlings can be sourced sustainably from wild stock, are relatively easy to grow, can be processed and stored locally and have a high value/weight ratio. However, growout takes between one and three years (compared with six weeks for seaweed) making it less attractive from a cash flow perspective and significantly increasing production risks. Prices as high as NZ$5/pc have been secured in the beauty market, though thorough studies on market volume and characteristics have not yet been done.

MILKFISH

World Fish Center and ACIAR are now working on a project to trial the feasibility of milkfish and tilapia farming, primarily in support of food security. Tilapia culture is currently constrained by a ban on import of Nile tilapia, though this is under review. In the case of milkfish it is assumed that native seed would be sourced from the wild.

SEA CUCUMBER

A Japanese funded and supported hatchery has been established at the Ministry of Fisheries and Marine Resources near Honiara with the aim of producing the high value peanut fish. The institutional/organisational/commercial mechanisms for future restocking and/or stock enhancement/ranching have not been worked out.

INSTITUTIONAL STRENGTHENING

Since 2006, New Zealand has funded the Solomon Islands Marine Resources Organizational Strengthening Project, focusing on the Ministry of Fisheries and Marine Resources.

PLANNING

Government aspirations with respect to aquaculture development are set down in the Solomon Islands Aquaculture Development Plan 2009–2014, and the Solomon Islands Tilapia Aquaculture Action Plan 2010–2015. The former plan identifies 16 types of aquaculture with some potential for Solomon Islands. Seaweed, tilapia, sea cucumber and marine ornamentals are singled out as priority commodities for development.

OPPORTUNITIES AND CONSTRAINTS

The following is not meant to be comprehensive – there are many other species/possibilities. This analysis focuses on those with greatest potential and/or greatest current interest.

Table 1: Mariculture opportunities and constraints

Opportunities	Constraints
General	
Solomon Islands has an exceptional diversity and abundance of marine sites suitable for a range of mariculture activities.	Traditional ownership of reefs constrains commercial development and may also constrain smaller scale local individual or entrepreneurial activity. Partnership agreements may be difficult and costly to enter and unpredictable in outcome.
Weather patterns are relatively stable and predictable, with potential for year round production of a range of species.	
There is a long tradition of trading in bêche-de-mer, pearl shell and copra, with corresponding communications/transport infrastructure.	When resources are abundant there is limited incentive to nurture mariculture organisms.
There is a ban on sea cucumber harvest, and copra prices are low, resulting in strong demand for alternative income generating activities.	Coastal villagers have always been opportunistic in trading behaviour, shifting between commodities according to price. Mariculture may therefore be exploited as a temporary opportunity only.
Honiara is reasonably well placed; its container port has global connections and its international airport has direct flights to Brisbane, Papua New Guinea and Fiji, allowing access to most markets at reasonable cost/time.	Internal logistics for aggregation/transportation of mariculture products is limited and relatively costly at the present time.
	Those in greatest need of income generating activities typically have the worst transport/distribution infrastructure.
	Internal and international air freight capacity is very limited. This is already a constraint on marine ornamental exports.
There is a long history of mariculture in the country related to the work of the World Fish Center.	R&D and mariculture trials have a poor track record related mainly to inadequate financial viability and market assessment.
Many fishery staff have been engaged on or with aquaculture projects so that significant skills exist in both hatchery production and growout for a range of species	Education levels are generally poor, and understanding of market trends and needs limited.
	Repeated project framed development interventions have created a 'project driven' economy.
	Understanding of basic development economics, and basic feasibility assessment is very limited amongst researchers, NGOs, development professionals and government fishery officers.
A number of strong NGO organisations are active in supporting rural development, and the Ministry of Fisheries has a strong aquaculture department.	Monitoring of financial performance and return on labour of IGAs promoted in the islands has been very limited.
Wild seed is available for many species, including blacklip pearl, lobster (*Panulirus*), and milkfish. Broodstock for tiger prawn is also available.	Knowledge about location and status of wild seed opportunities is very limited.
Tourism has been slow to develop, but potential is now high with a more stable political situation, creating additional local	There is potential for conflict between tourism interests and development of any high input or intensive mariculture.

demand for high value marine products.	
Mobile phones, television and other electronic good are beginning to drive a more cash orientated economy with increased appetite for income generating activity. There is increasing interest in partnership arrangements with incoming investors.	Limited entrepreneurial spirit, and a subsistence work ethic.
Labour costs (US$0.2/hr) are very low by regional and global standards.	Many mariculture projects in the past have provided startup materials and seed inputs and there is now a widespread expectation that these costs will always be covered.
A dynamic local-Chinese trading community has good links to Asian markets, expertise, etc.	Ethnic tensions and mistrust remain between Solomon Island communities, and between these communities and the Chinese community.

Finfish

Coastal fish stocks are under pressure close to growing urban centres and high costs of aggregation and transportation have resulted in locally high price of finfish (especially in Honiara). Also a projected supply shortage implies local opportunity for milkfish culture, for example.	Significant investment would be required in ponds or cages; there are cheaper and potentially abundant partial substitutes from capture fisheries (large and small pelagics); tilapia culture would probably be cheaper and easier if appropriate species/strains are imported.
Abandoned shrimp ponds might be developed for milkfish farming.	Abandoned shrimp ponds might be better redeveloped for shrimp farming, which has been successful in the past.
Solomon Islands has produced/exported fishmeal as a byproduct of tuna processing and there may be future opportunities for developing lower cost local feeds. Two new canneries are planned.	*Catch 22.* Need sufficient demand to stimulate production of fish feeds, but demand is constrained by the lack of cheap feed. There is limited production of other feed ingredients.

Shrimp farming

A successful shrimp farm was in operation prior to the ethnic tensions, and ponds/infrastructure might be reinstated and historic expertise drawn on.	Significant land use issues remain.

Giant clam (ornamental) and coral farming

Long track record and experience growing giant clam, especially *T. derasa.*	World Fish Center decision to pull out of hatchery production of giant clams, and no initiative to privatise production.
There is an existing exporter of marine ornamentals based in Honiara with storage/conditioning facility and good links with American importers.	Single exporter implies some monopoly powers over price to suppliers. The costs of new entry to the export business is high (facilities, importer links).
Good current market demand for *T. maxima* and *T. derasa;* good prices paid by importers; importers are prepared to pay freight costs.	Total size of market is not known. Potential supply significant from many hatcheries with *Tridacna* expertise across the region. Market access to Asian/Chinese ornamental trade is not well established.
Probably an opportunity for a well located commercial development (hatchery + growout) possible with some contract/satellite farmers.	Strict World Organisation for Animal Health (OIE) regulations in Europe constrain aquarium/live product movements. Regulations into the US are less demanding.
Fair demand for cultured corals, which are relatively easy to grow and require far lower investment.	Wild corals can be collected more easily/cheaply, and there is little if any premium on cultured corals as yet.

Restocking

Marine protected areas have proven surprisingly popular, and reef owners are keen to use them. Coral farming or restocking with sea cucumber, *Trochus*, giant clam etc. may be a good way to enhance these areas and strengthen stocks more widely.

The viability and sustainability of restocking and/or ranching remains to be demonstrated; these will require very particular conditions for success.

Table 2: Mariculture opportunities

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	**Site availability**	**Local markets**	**National markets**	**International markets**	**Comparative advantage**	**Production and market risks**
Seaweed	good	none	none	good	high	low; medium
Marine/BW finfish (milkfish)	fair	limited	fair but limited at present fair	fair	low	medium; medium–high
Marine shrimp	good	poor	fair	fair	fair	medium–high; medium–low
Coral	good	poor	poor	fair	low–high[7]	medium
Giant clam	good	poor	poor	fair	low–high[8]	medium
Pearls	fair	poor	poor	fair	high	high

Table 3: Potential contribution to development objectives

Deep red = unfavourable; deep green = favourable; yellow = neutral or unknown

Species, system	Commercial viability	Import sub-stitution	Export earnings	Livelihoods & poverty alleviation	Food security
Seaweed	good	low	high	good	low
Marine/BW finfish (milkfish)	unclear	low	low	unclear	fair
Marine shrimp	fair[9]	limited	high	low	low
Pearls	unclear	low	high	low	none
Coral	fair	none	fair	fair	none
Giant clam	fair	none	fair	fair	none

[7] Depends critically on location, enterprise structure and logistics
[8] Depends critically on location, enterprise structure and logistics
[9] High if original ponds could be re-opened

RECOMMENDATIONS TO SOLOMON ISLANDS GOVERNMENT/SPC

- Offer technical/advisory services as required to the commercial sector to underpin the current development in seaweed farming.
- Undertake more thorough analysis of the domestic finfish market and realistic production costs before promoting finfish mariculture, including milkfish.
- Explore new business models for the development of giant clam and coral farming, probably building on historic initiatives around Marau Sound. Undertake in depth study of global market for cultured corals and clams.
- Facilitate re-establishment of commercial marine shrimp farming.
- Develop a coherent strategy for government and private sector engagement in hatchery development, maintenance, and seed production; and put in place sustainable financing mechanisms.
- Undertake more thorough market and financial feasibility studies before engaging in any mariculture R&D activity.

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