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Aquaculture Potential in Fiji and Other Pacific Island Countries

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Abstract—Examples of aquaculture ventures in the Pacific Islands show that reasonable development has occurred. While some earlier and ill-planned projects failed, recent initiatives have shown good results. Future prospects look good for pearl oyster, seaweed, marine and freshwater shrimps, and tilapia. A number of pitfalls must be avoided, however, for aquaculture to reach its potential for economic development in the islands.

Introduction

The trend in global marine and inland capture fisheries production over the last fifty years indicates that most of the world's fishing areas have reached their maximum potential, with the majority of the stocks being fully exploited (FAO 2000a). Between 1950 and 1970 the rate of production of capture fisheries increased on average by 6% (FAO 2000a). In the 1970s and 1980s, the rate of production had decreased to 2% and by the 1990s the production had leveled off (Chiu Liao 1996, Pillay 1999, FAO 2000a).

However, the total world production of fisheries products has continued to increase due to aquaculture production. Aquaculture has become the world's fastest growing industry in recent years (Williams 1999, FAO 2000a). Inland and marine aquaculture production grew by 5% per year between 1950 and 1969, by 8% per year in the 1970s and 1980s and has been increasing at the rate of 10% per year since 1990 (FAO 2000a,b). In 1988, the aquaculture production of all aquatic animals and plants stood at around 15.54 million tonnes, increased to 36.05 million tonnes in 1997, and to 39.4 million tonnes in 1998 (FAO 2000a,b) (Table 1).

The Asian region has become the dominant producer of all aquaculture products, with China and India supplying about 74% of the total production (FAO 2000a). With the inclusion of Japan, Philippines, Indonesia and Thailand the total contribution from Asia jumps to 84% (FAO 2000a) (Table 2).

Aquaculture production worldwide is expected to continue growing for several reasons, including the provision of food security for a growing world population, increasing demand for fresh seafood products, demand for jewellery derived from aquatic animals, demand for aquatic animals for aquarium trade, diversification of primary industries, rehabilitation of over-exploited stocks, and derivation of economic benefits from aquaculture such as employment and trade. New initiatives and developments are occurring all over the world, and

Table 1. World aquaculture production and value from 1989 to 1998.

Year	Quantity (Metric tonnes)	Value (US$'000)
1989	16 490 362	25 616 572
1990	16 834 786	27 599 508
1991	18 287 324	29 944 462
1992	21 253 006	33 168 488
1993	24 547 061	36 476 812
1994	27 753 856	41 280 890
1995	31 340 192	45 091 256
1996	33 991 826	48 001 843
1997	36 031 129	50 703 628
1998	39 430 834	52 458 185

(Source FAO 2000b)

Table 2. Major aquaculture producers in 1998.

Country	Quantity Produced (thousand tonnes)	% of Total
China	27072	68.6%
India	2030	5.0%
Japan	1290	3.3%
Philippines	955	2.4%
Indonesia	814	2.1%
Korea Republic	797	2.0%
Bangladesh	584	1.5%
Thailand	570	1.4%
Vietnam	538	1.4%
Other countries	4782	12.1%

(Source: FAO 2000b)

there has been tremendous advancement in aquaculture technology over the last two decades.

Aquaculture in the Pacific Islands

The Pacific region is generally considered to be that region encompassing Micronesia, Melanesia and Polynesia (Wright 1993). All the independent island nations, and Australia, Palau and New Zealand are members of the South Pacific Forum and its sub-organization South Pacific Forum Fisheries Agency (Wright 1993).

The Pacific island countries (PICs) consist of different types of islands ranging from volcanic origin to atolls. The total area is approximately 526,000km^2 but 87% of this area is accounted for by Papua New Guinea (Wright 1993). The smallest countries in terms of land area are Nauru and Tuvalu, 21km^2 and 26km^2 respectively. PICs are estimated to have a population of 5.25 million, but 67% of

Table 3. Land and sea areas and recent population estimates of the island countries and territories of the Pacific region.

Country	High Islands	Low Islands	Atoll Islands and Cays	Land Area (km^2)	EEZ Area ('000km^2)	1990 Population ('000km^2)
American Samoa	5	–	1	200	390	46.8
Cook Islands	6	>200	9	237	1,830	16.9
Palau	18	>350	–	488	629	15.2
Federated States of Micronesia	16	>250	36	701	2,978	101.2
Fiji	113	>350	12	18,272	1,290	725.0
French Polynesia	26	>100	82	3,521	5,030	196.3
Guam	1	–	–	541	218	133.4
Kiribiti	–	>100	23	690	3,550	71.8
Marshall Islands	–	>50	29	181	2,131	46.2
Nauru	–	1	–	21	320	9.3
New Caledonia	4	>18	11	19,103	1,740	167.6
Niue	–	1	–	259	390	2.2
Northern Mariana Islands	16	4	–	471	1,823	44.2
Papua New Guinea	83	>350	47	462,243	3,120	3,528.5
Solomon Islands	37	65	2	27,556	1,340	324.0
Tokelau	–	124	3	10	290	0.2
Tonga	16	>150	–	747	700	96.3
Tuvalu	–	4	5	26	900	10.2
Vanuatu	25	43	–	12,190	680	146.4
Wallis and Futuna	1	22	–	255	300	13.7
Western Samoa	3	2	–	2,935	120	157.7

Source: Wright, 1993.

this number are in Papua New Guinea (Wright 1993). Population growth is relatively high at an average of 2.1% annually for all countries and territories in the region (Wright 1993) (Table 3).

Although it is difficult to accurately ascertain the annual harvest of fisheries products in PICs, many of these nations would rank highly in per capita consumption. According to Wright (1993), in some atoll nations fisheries products consumption may be up to 250 kg per person per year. In Fiji, consumption has ranged from about 38 kg per person per year to 62 kg per person per year between 1986 and 1998 (Fiji Fisheries Division 1998).

Aquaculture has been practiced in the PICs for quite some time, although many of the PICs have no aquaculture tradition (Uwate & Kunatuba 1984). In 1986, the Food and Agricultural Organisation of the United Nations (FAO) launched a regional aquaculture development project entitled the South Pacific Aquaculture Development Project (SPADP) (Tanaka 1997). In the ensuing years many aquaculture initiatives have been undertaken, both within the project and outside the project. However, apart from pearl oyster aquaculture in the Cook Islands and French Polynesia (Sims 1993, Fassler 1995, Southgate 1995), production levels of most other species have been insignificant on a global scale.

In many instances aquaculture development programs have been geared towards stock enhancement of those species that have been overexploited and are severely threatened. Other ventures have been conducted mainly at subsistence level with only a few medium scale commercial farms.

Fiji

There is little history of indigenous aquaculture in Fiji. However, there are records of the introduction of oysters for aquaculture in the 1880s and in 1910 (Gulick 1990). Any notable attempt to develop aquaculture in Fiji began in the 1970s. A wide variety of species of seaweed and animals have been trialled since then, of which a large number were exotic species (Table 4).

The Fijian national government played a major role in trying to establish aquaculture through the fisheries and agriculture divisions. The establishment of Naduruloulou Research Station, Raviravi Prawn Farm, Makogai Clam Hatchery, and recent additions of Galoa Prawn Hatchery facility and Savusavu Pearl Farm are examples of the Fiji government's effort to promote aquaculture.

Although results of some past trials have been very promising (Popper 1977, Navakaloloma 1982, Chagi & Dawai 1992, Beckmann 1998), aquaculture still has not become an industry of any significance in Fiji. At the present time, only tilapia, *Oreochromis niloticus*, freshwater prawn, *Macrobrachium rosenbergii*, marine shrimp, *Penaeus monodon* and seaweed, *Eucheuma* sp. are being farmed on a noteworthy level (FAO 2000b).

Tilapia–Fiji's tilapia production stood at 243 metric tonnes in 1998 (FAO 2000b, Fiji Fisheries Division 1998). This is a significant increase from 10 tonnes produced in 1989. The 'chitralada' strain of *O. niloticus* is the preferred fish for

Table 4. Aquaculture attempts of some species in Fiji.

Species Cultured	Year Started
Aquatic angiosperm, *Ipomoea reptans*	1953
Seaweeds:	1985
Eucheuma striatum	
E. alvarezii	
E. dendiculatum	
E. spinosum	
Fishes:	
Smallmouth bass, *Micropterus dolomieus*	1962
Largemouth bass, *M. salmoides*	1962
Common Carp, *Cyprinus carpio*	1937 (second 1968)
Grass carp, *Ctenopharyngodon idellus*	1968
Bigehead carp, *Aristichthys nobilis*	1968
Silver carp, *Hypophthalmiothys molitrix*	1968
Milkfish, *chanos chanos*	1970s
Mullet, *Mugil* sp.	1970s
Rabbitfishes, *Siganus* sp.	1970s
Molly, *Poecilia mexicana*	1983
Perch, unknown sp.	1910
Swordtail	–
Tarpon, *Megalops cyprinoides*	1949
Tarpon, *Elops hawaiiensis*	1949
Tawes, *Puntius gonionotus (P. japonicus)*	1968
Tilapia, *Oreochromis mossambicus*	1954
Tilapia, *Oreochromis niloticus*	1968
Brown trout, *Salmo trutta*	1920
Crustaceans:	
Marine shrimps, *Penaid* sp.	1973 (survey), 1977
Freshwater prawn, *Macrobrachium* sp.	1980
Crab, *Scylla serrata*	1983
Spiny lobster, *Panulirus versicolor*	1974?
Molluscs:	1974
Freshwater clam, *Batissa violacea*	1971
Manilla clam, *Venerupis semidecussata (Tapes japonica)*	1987 1975
Marine giant clams, *Tridacna* sp.	1988
Philippine green mussel, *Perna viridis*	1880, 1901, 1960s
Salt water mussel, *Anadara* sp.	1968
Oyster, *Saccostrea glomerata (S. commercialis)*	1977
Pacific oyster, *Crassostrea gigas*	1975
European oyster, *Ostrea edulis*	1966
Philippine oyster, *Crassostrea iredalei*	1966
Pearl oyster, *Pinctada margaritifera*	
Winged Pearl oyster, *Pteria penguin*	
Turtles: Hawksbills turtle, *Eretmochelis imbricata*	1974

Source: Gulick 1990.

aquaculture in terms of ease of culture and acceptance by consumers (Beckmann 1998, B. A. Costa-Pierce unpublished). In total there were 12 commercial and 250 subsistence farms in operation and the fish fetched a price of $3.00–$6.00 (Fiji dollars) per kg in local markets (Fiji Fisheries Division 1998).

Although Fiji does not have an export market for its tilapia at this stage, there is room for further expansion of tilapia aquaculture. Fiji has "superb natural resources for growing tilapia" and further development should occur (B. A. Costa-Pierce unpublished).

Freshwater prawn–According to FAO (2000b), Fiji produced 40 metric tonnes of *Macrobrachium rosenbergii* in 1998. The fisheries division has established three farms to gauge the full potential of freshwater prawn farming. Although there is much interest in prawn farming among locals, it is unclear how many privately owned farms are in existence at the present time. Freshwater prawns are a much sought after food item among the local population. A large proportion of the prawns currently available on sale are wild captured. Freshwater prawn farming is quite likely to gain more prominence once natural sources decline. Freshwater prawn farming is quite likely to gain more prominence once natural sources decline. Freshwater prawns, both, farmed and wild capture fetch a price of $14.00–$18.00 (Fiji dollars) per kg (Satya Nand Lai, Fiji Fisheries Division, personal comm.).

Marine Shrimp–Marine shrimp, *Penaeus monodon*, production in Fiji increased from 7 tonnes in 1989 to 35 tonnes in 1998 (FAO 2000b). Currently, there are three commercial farms (Anonymous 2001a). Prices range between $25.00–$40.00 per kg and the market is entirely local (White 1992, Koroiwaqa 2001).

Marine shrimp are regarded as a commodity which can provide the highest economical return compared to other cultured animals (Fiji Fisheries Division 1998). One of the privately owned and operated commercial farms, has achieved great success in producing a crop from post larvae to harvest weight (25–35g) within 16–20 weeks (White 1992).

Koroiwaqa (2001) suggests that a huge potential exists in Fiji to expand the shrimp farming industry. In Fiji's tropical environment, 150,000 prawns could potentially be cultures in a 5000 m^2 pond.

Seaweed–Seaweed farming has seen great development in Fiji in the recent years. In 1989 Fiji produced 600 tonnes of *Eucheuma* sp. seaweed but production increased tremendously to 10,000 tonnes in 1998 (FOA 2000b). Due to the establishment of an overseas market for the dried product, and active support of the Government, seaweed farming has become a success.

Fiji has vast areas of coastline suitable for seaweed farming, and there is substantial potential for further expansion. However, further development is largely dependent on market prices (South 1993).

Giant Clams–The giant clam project in Fiji was initiated in the early 1980s mainly to repopulate over-exploited reefs. As a result of assistance from Australian Centre for International Agricultural Research (ACIAR) and parallel

research by other institutions such as the International Centre for Living Aquatic Resources Management (ICLARM), there has been a great deal of technological advancement in artificial propagation of giant clams (Munro 1993). Fiji is now capable of, and has produced giant clam larvae and juveniles in hatcheries. Juveniles produced in hatcheries have been transplanted on several reefs to replenish stock.

However, no commercial aquaculture of giant clams has been undertaken. This is largely due to the time it takes for giant clams to attain harvesting size (Okada 1997). This may change, however, due to the recent interest in giant clams for the aquarium trade. The aquarium trade needs only small clams 4–10 cm in size (Okada 1997).

Provided that suitable markets are identified, Fiji has good prospects of developing giant clam aquaculture for the aquarium trade.

beche-de-mer–Fiji produced 250 tonnes of beche-de-mer worth $5 million (Fiji dollars) in 1998 (Fiji Fisheries Division 1998) but none of it was through culture. With the decline in production level down from 800 tonnes in 1989, the industry faces a bleak future. Attempts have been made to breed beche-de-mer in the hatchery (Fiji Fisheries Division 1998) and the potential exists to develop culture technology and establish commercial culture.

Trochus–Trochus shells have been harvested from the wild for quite sometime for button manufacture. Natural production was estimated to be 75 tonnes annually (Fiji Fisheries Division 1998) but natural stocks are declining. Successful attempts have been made to breed trochus in the hatchery at Makogai. There are no plans for commercial culture as of yet.

Pearl oyster–Pearl oyster culture in Fiji has existed since 1966 (Gulick 1990), largely through the efforts of one single privately owned farm, but it has never gained industry status. Recently, the Fiji Fisheries Division established a pilot study farm at Savusavu on the island of Vanua Levu with an initial stock of slightly over 3000 blacklip pearl oysters, *Pinctada margaritifera.* The oysters came from natural populations in Fiji, mainly from the northern side of Vanua Levu (Galoa) (Tevita Taumaipeau, Fiji Fisheries Division, personal comm.). By 1999 there were 10,000 oysters on the farm (Frazer 1999). The oysters were seeded two years ago and the first batch of pearls have been harvested (Tevita Taumaipeau, Fiji Fisheries Division, personal comm.). The pilot project received major financial and technical assistance from ACIAR. The Fiji blackilip pearl oyster project is part of the ACIAR Pacific Island Pearl Oyster Resource Development project which also involves Kiribati and the Solomon Islands (Southgate 1995, Southgate 1996). In the third phase of collaborative research Tonga has also been included in (Paul Southgate, James Cook University, personal comm.). The results obtained during the project have been very promising.

An American company, Taylor Shellfish, has shown keen interest in pearl farming in Fiji and has, reportedly, started a farm in Savusavu alongside the Fiji Fisheries farm (Anonymous 2001b). They are also involved with the Fiji Fisheries Division in establishing a hatchery.

Fiji has a number of outer islands, as well as sites on the larger islands, which would be very suitable for pearl oyster aquaculture. There is, therefore, a very good potential to expand the pearl culture industry in Fiji. The same sentiments are echoed by Justin Hunter, manager of Taylor Shellfish (Anonymous 2001b)…"Fiji has the potential for pearl farming."

French Polynesia

French Polynesia is involved with the aquaculture of Barramundi, *Lates calcarifer,* freshwater prawn, *Macrobrachium rosenbergii* and marine shrimp, *Penaeus stylirostris,* producing 1 tonne, 2 tonnes and 48 tonnes respectively, in 1998 (FAO 2000b).

Preston (1990) reported on the different aquaculture activities being pursued by agencies and private individuals in French Polynesia. The French Institute for Ocean Research (IFREMER) was providing support to many of the projects. However, no exact figures and data could be obtained to show the status of aquaculture in French Polynesia at present.

The success story of French Polynesia is, of course, the black pearl industry. French Polynesia has become the largest producer of black pearls in the Pacific region. In 1999, earnings from pearl exports stood at $US 200 million (Anonymous 2001c).

Cook Islands

The Cook Islands is another Pacific nation where pearl oyster aquaculture has been a success. In 1993, the Cook Islands produced 150 kg of black pearls worth $US 4.5 million (Fassler 1995). By 2000, the black pearl export had risen to $US 7.4 million (Anonymous 2001d). The pearl culture farms are concentrated mainly in the northern islands of Cook Islands group, on the islands of Manihiki and Penrhyn (Anonymous 2001d).

US-Affiliated Pacific Islands

The nations in this region include the Republic of Palau, the Federated States of Micronesia, the Northern Mariana Islands, the Republic of Marshall Islands and American Samoa.

The Republic of Palau has the largest giant clam hatchery in the world and is reported to be involved with the production of seven species of giant clams, as well as trochus, marine groupers, turtles, soft corals and an assortment of other marine creatures (Lindsay 1993). The giant clams are the main culture species with production around 200,000 clams annually. These are sold for food, aquarium market, aquaculture and stock replenishment (Lindsay 1993).

In the Federated States of Micronesia, aquaculture has centered around giant clams, although culture of seaweed and rabbit fishes have also been attempted (Lindsay 1993). In Pohnpei state, sponge culture has been in operation, but there is no commercial production (Lindsay 1993).

The Marshall Islands were reported to have two successful aquaculture operations involving giant clams and pearl oysters (Lindsay 1993).

A recent report shows that there has been progress made towards pearl culture. There were three farms in operation in 1999 in the Marshall Islands and in the Federated States of Micronesia (Regional Notes 1999).

Kiribati

Aquaculture production data from Kiribati shows that 180 tonnes of milkfish, *Chanos chanos* and 6868 tonnes of seaweed *Eucheuma* were produced in 1998 (FAO 2000b).

Kiribati is one of the countries in the Pacific region where the agricultural land is very sparse and marine resources play an important role in the sustenance of the population and provide export earnings. Kiribati has, therefore, been actively involved in the development of aquaculture activities such as pearl production (Southgate 1996). After the initial phase of technology development under the ACIAR project in Kiribati, black pearls farms have now been established (Paul Southgate, James Cook University, personal comm.).

New Caledonia

New Caledonia is the biggest producer of marine shrimp, *Penaeus* sp. In the Pacific region (FAO 2000b). Production level in 1998 was 1569 tonnes (FAO 2000b). In 1992, there were six farms in New Caledonia which could grow shrimp to marketable stage and prospects of expansion have been predicted (Galinié 1992).

New Caledonia is also the only country in the region that is successfully producing edible oysters. Production of Pacific oyster, *Crassostrea gigas*, was 45 tonnes in 1998 (FAO 2000b).

Tonga

The kingdom of Tonga, which lies east of Fiji, has also been involved with the development aquaculture for several years (Cheser 1987, Fa'anunu et al. 1995). With assistance from the Japanese International Cooperation Agency (JICA), the Fisheries Research Centre was established at Sopu, Nuku'alofa in the late 70s. The center now houses a modern hatchery, where considerable research has been conducted towards artificial propagation of giant clams, trochus and green snails. These three species were bred mainly for stock enhancement, but there are prospects of trochus and green snails being exported and fetching prices of $3.00–$4.00 per kilogram and $9.00–$10.00 per kg respectively (Anonymous 1999).

Tongan Fisheries has also actively sought to develop pearl culture. Experimental farms have been established on the northern island of Va'vau. According to Yamamoto and Tanaka (1997), there is good potential in Va'vau for the establishment of 'Mabe' pearl culture using the winged oyster, *Pteria penguin.* The prospects for developing pearl oyster hatchery facilities on Va'vau has also been explored (Ito 1999).

Discussion

Only a few examples of aquaculture development and production in the Pacific region have been covered in this paper. A detailed exploration of all aquaculture activities currently being pursued would be a daunting task.

Nevertheless, the examples considered above show that reasonable development in aquaculture has occurred in the Pacific region. While some earlier and ill-planned projects have failed, recent initiatives have shown good results. Future prospects for some aquaculture ventures such as the pearl oyster, seaweed, marine shrimps, freshwater shrimps, tilapia look good. The success of black pearl industries in the Cook Islands and French Polynesia are good indicators of what can be achieved, provided there is proper management and persistence.

Unemployment and poor income is a major problem in almost all of the PICs. The lack of major industries and the wide geographical area over which the population of each PIC is distributed are the main contributing factors. Aquaculture is one industry that can be taken to the scattered population, as has been demonstrated by pearl farming in the Cook Islands and seaweed farming in Fiji.

Moreover, there are many other advantages of aquaculture, such as food security, stock replenishment, decreased pressure on natural fisheries, etc. PICs should therefore encourage well-planned and environmentally safe aquaculture practices.

Although the prospects for aquaculture development in the PICs look extremely promising, utmost caution is necessary in the selection of the type of aquaculture. For example, there would be limited scope for inland aquaculture in the small island nations where land and freshwater is scarce. Attempts to develop such aquaculture projects would lead to conflicts over land and water usage. An assessment similar to Tanaka (1997) on the suitability of the culture species for different PICs would be useful.

One of the other problems that is often not given much early thought is the provision of feed for the aquaculture animal. In many instances there would be no availability of the correct feed from local sources. Importation of feed would most certainly raise the cost of production and eventually affect marketing of the product. Therefore, herbivorous and filter feeding animals may be more suited for aquaculture in the PICs.

There is another major requirement in the region that would very much contribute to the success of aquaculture, and that is the need for qualified personnel. Personnel should have a good scientific background as well as training in the appropriate aquaculture technology. The personnel in-charge should also have suitable management skills. Currently, in most of the PICs the personnel involved with aquaculture projects are those who have moved up the ranks after starting as fisheries assistants, and often have limited tertiary level academic qualification.

To assist the PICs in the development of aquaculture, it may be appropriate to consider the Kyoto Declaration (FAO 1997). In the plan of action it was agreed that states and FAO in cooperation with IGOs and/or regional fisheries management organizations and arrangements, should (among others):

- Access and monitor trends in the demand and supply of fish and their effects on food security, employment, consumption, income, trade and sustainable production;
- Strengthen national and international coordination to stimulate environmentally sound aquaculture and stocking programme;
- Provide and coordinate technical and financial assistance for developing countries, in low income food deficit countries (LIFDCs) and small island developing states and encourage cooperation among these countries in order to allow fisheries to contribute to food security through such means as the rapid transfer of technology and expertise in enhancement in inland fisheries and marine waters, upgrade and increase the capabilities needed to minimize post-harvest losses, and ensure improved control of fishing activities within areas under national jurisdiction.

All of the PICs fall in the category of developing countries. All of them, though some more than others, are heavily dependent on marine resources for food and income. It is, therefore, vital to give consideration to aquaculture ventures that may improve the economic status of these nations,

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