

# Current Status of Aquaculture in the Pacific Islands

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## ***Introduction***

This review covers the Insular Pacific as defined by the work-area of the Secretariat of the Pacific Community (Figure 1).

### **Figure 1.** Work-area of the Secretariat of the Pacific Community

Compared to fishing, aquaculture is currently of little commercial significance in the insular Pacific with one important exception – black pearl farming, and this is virtually confined to eastern Polynesia. Elsewhere in the Pacific considerable development is needed before aquaculture can be considered economically sustainable. Shrimp (*Penaeus* spp.) farming has been a focus of commercial development in several islands over the past 30 years, with varying degrees of success; Tilapia (*Oreochromis niloticus*) aquaculture has entered the subsistence economy in some areas, and seaweed (*Kappaphyces* spp.) is considered a future commercial export prospect by the region. But the culture of other marine and freshwater species is, generally, still at the experimental or "backyard" stage.

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Aquaculture is a relatively new phenomenon in the region and in most Pacific Islands where it has been attempted, its history goes back less than 30 years. There is no fund of traditional knowledge for culturing fish and shellfish, just catching them, except in very specialised instances and areas, and thus no great resource of aquacultural skill or infrastructure. This steep development path has perhaps not been taken into account in some development projects, which have often had unrealistic short-term aims and lacked followup.

Despite the comparatively minor penetration of aquaculture into Pacific Island economies, and despite the loss of interest by most of the international development community after many short-term project failures, several Pacific Island governments have accepted the challenge, recognising that expansion in capture fisheries is limited, and made substantial investments in freshwater aquaculture and mariculture, often in concert with external sources of development assistance.

Pacific Islanders cannot turn away from the sea. It is the greatest resource they have.

### ***The Potential Importance of Aquaculture to Pacific Islands***

A major problem facing most of the island nations in the Pacific is that they have relatively few opportunities to generate income (Adams, 1998). The economies of most Pacific countries are limited due to small landmasses, few terrestrial resources and low numbers of inhabitants. To ensure further development, island nations must make the most of the one important resource they all have - the sea. Through the joint efforts of the Forum Fisheries Agency (FFA) and the SPC Oceanic Fisheries Programme, island nations are deriving major inputs to their economies by fishing for tuna, or by selling access rights to tuna, within the large maritime zones under their control. However, valuable, sustainable harvests are also possible from inshore waters and coral reefs.

The potential for increased well-being of coastal communities from the wise use of their inshore marine resources arises because the inshore habitats surrounding Pacific nations support a great diversity of economically important species (Wright and Hill 1993, Dalzell et al. 1996, Bell and Gervis 1999). Traditionally, these animals were harvested at subsistence levels. More recently, however, development of export markets has provided coastal communities with opportunities to earn income from the inshore fisheries species. Unfortunately, the transition from a subsistence to a market economy has usually been far from ideal: chronic overfishing has occurred in some areas. In such places, there are now too few of the prized animals to sustain reasonable harvests. Destructive fishing methods have compounded the problem by degrading some habitats to the point where they cannot support the valuable species (McManus 1996). Pacific Island countries now recognise that aquaculture provides one of the few long-term, sustainable, ways of deriving benefits from inshore fisheries resources (Williams 1996). This view of aquaculture as a priority area for continued sustainable development was reinforced as part of a consensus member country statement arising from the 2nd SPC Fisheries Management Workshop in 1998:

*“...Regional fisheries managers have focussed on establishing regimes to sustain inshore fisheries. This is supported by a strategy to divert demand and fishing pressure to alternative activities, mostly to offshore fishing and into aquaculture. Development of fisheries management varies from country to country reflecting the differing stages of economic development and levels of need. In some countries the need is to encourage*

*economic activities and to generate income for rural villages; in other countries the need is to restrict or limit fishing. Yet in other countries the need to involve all stakeholders in the management system has evolved into community-based decision-making and control. There is now broad acceptance that marine resources cannot be managed in isolation from other users, or by one government agency so that an integrated and co-ordinated approach should be taken. In many circumstances, because of the smallness of the islands, an island system-management approach is the desirable option.*

*Aquaculture, as an alternative activity, is still at a preliminary stage of economic development in most PIC, but is of enormous future significance. For aquaculture to realise its full potential to the economies of PIC in a sustainable way will require a considerable degree of international support. PIC have endorsed a strategy to harness and prioritise such support at the regional institutional level. Several PIC already devote significant national resources to this subsector and this trend will continue as benefits are realised...”*

### **Advantages of Pacific Islands for Aquaculture**

Pacific island nations have many attributes that favour development of aquaculture and stock enhancement in the coastal zone. These include:

1. A great diversity of species associated with coral reefs that are in high demand for: a) the aquaculture and seafood markets in Asia (e.g., napoleon wrasse, groupers, sea cucumbers, spiny lobsters, trochus, pearl oysters, giant clams, green snail), b) the marine aquarium trade (e.g., clownfish, angelfish, hard corals, soft corals, giant clams), and c) the pharmaceutical trade (e.g., algae, sponges, soft corals, sea-horses).
2. Proximity to the major aquaculture and seafood markets of Asia - flight times are short enough to ensure that many species can be shipped alive to Asia.
3. Availability of suitable grow-out sites in pristine habitats - coral reef lagoons create the calm conditions essential for culture of many species. The favourable environmental conditions should be the opportunity to develop green label products to get better prices on the international market.
4. Geography that favours restocking and stock enhancement - most Pacific countries are small islands, or groups of small islands, surrounded by deep water. Cultured juveniles released into the inshore waters of island ecosystems cannot emigrate, and are therefore relatively easy to recapture.
5. A relatively inexpensive labour force - expectations for financial return on labour are low in many Pacific countries relative to developed countries.
6. A tradition of working with marine resources - coastal communities are already familiar with the basic biology of many species.

### **Constraints to Aquaculture in Pacific Islands**

Although the attributes listed above confer many advantages on the region for development of aquaculture and stock enhancement, there are also several constraints to such enterprises in the Pacific. Many of these have been identified previously by Uwate and Kunatuba (1983), Munro (1993a) and Bell and Gervis (1999). They include:

1. *Limited domestic markets.* Local markets for the fresh products of aquaculture in the Pacific are small, and with the exception of very limited opportunities in the restaurant trade, usually offer low prices. Thus any large-scale aquaculture development in the Pacific catering to the trade in seafood will depend heavily on export markets.

2. *High added value export markets targeted.* These are most often regional and fluctuating markets (e.g. live reef fish). Thus any aquaculture development will depend on the capacity to follow the market trends, and to fulfil the demand in time.

3. *Transport problems.* The high cost of shipping in the Pacific adds considerably to the cost of producing and exporting aquaculture products. Poor internal transport services restrict opportunities to grow perishable products in remote locations, and limited international air connections inhibit continuity of supply to export markets. Transport arrangements dictate that species cultured for export need to be of high value and low weight. Alternatively, the products must be non-perishable, e. g. *bêche-de-mer* (processed sea cucumbers), or frozen, so that they can be shipped by sea.

4. *Socioeconomic factors.* Many of the smaller island nations lack the infrastructure, capital and skilled labour required to implement aquaculture, particularly where hatcheries are involved. Sustained assistance from developed countries is needed to implement and operate stock enhancement programmes until they become self-funding (Bell 1999a). The traditional marine tenure systems in place in many countries (Ruddle et al. 1992) also add complexity to the process of negotiating access and tenure to sites for aquaculture.

5. *Fragile habitats.* Coral reef ecosystems on many of the smaller island nations have evolved in a nutrient-poor environment. Additions of nutrients, e.g., through uneaten and undigested formulated diets for carnivorous fish in cage culture (Beveridge 1987; Landesman 1995; Stewart 1997), can be expected to change the ecosystem in favour of algae and herbivores. Such changes are likely to be unacceptable, particularly to the tourist industry. This constraint is particularly relevant to lagoonal habitats, but would not apply to locations that have good flushing to the open ocean.

6. *Freshwater is limited,* except for the large islands of Melanesia, which have extensive river systems. Prospects for freshwater aquaculture are thus limited. Even in areas with significant fluvial development, the indigenous freshwater ichthyofauna is generally unfavourable for economic culture and species for freshwater aquaculture have been imported.

7. *Cyclones.* Countries in the cyclone belt can expect aquaculture installations to be damaged intermittently by large swells and strong winds.

## Current Status of Aquaculture in the Pacific Islands

### Aquaculture systems

Profitable aquaculture of penaeid shrimps and blacklip pearl oysters has now been established in some areas of the Pacific by commercial interests. Stand-alone enterprises producing penaeid shrimps for export markets are firmly established in New Caledonia, Fiji and Solomon Islands. These enterprises are applying technology developed originally in Japan, Taiwan and France, and now common place throughout the tropics.

A large, sustainable, industry for culturing pearls using the blacklip pearl oyster (*Pinctada margaritifera*) has been established in the Tuamotu Archipelago, French Polynesia, and on a couple of atolls in the Cook Islands (Fassler, 1995). In French Polynesia, the value of cultured pearls exceeds US\$150 million p.a. In Cook Islands, the industry is currently worth US\$5 million and is the second largest source of revenue for the country after tourism.

Black pearl farming in French Polynesia and Cook Islands, and shrimp aquaculture in New Caledonia represented more than 98% of the total value of aquaculture production estimated in 1996 (Table 1).

**Table 1.** Values (US\$ 000) of aquaculture productions for coastal species cultured in tropical Pacific countries and territories in 1996 (from Bell and Gervis, 1999).

Country/Territory	Species									Total
	Pearl oysters	Penaeid shrimps	Micro-algae	Various finfish	Macro-algae	Table oysters	Giant clams	Milkfish	Sponges	
American Samoa	-	-	-	-	-	-	30	-	-	30
Cook Islands	4,500	-	-	-	-	-	-	-	-	4,500
Fiji	-	180	-	-	20	-	-	-	-	200
French Polynesia	140,000	398	-	50	-	-	-	-	-	140,448
Guam	-	121	-	13	-	-	-	100	-	234
Kiribati	-	-	-	-	114	-	-	95	-	209
Marshall Islands	75	-	-	-	-	-	60	-	-	135
New Caledonia	-	10,062	-	-	-	675	-	-	-	10,737
Palau	-	-	-	-	-	-	55	-	-	55
Fed. States of Micronesia	-	-	-	-	-	-	-	-	5	5
Solomon Islands	-	170	-	-	-	-	65	-	-	235
Tonga	-	-	-	-	-	-	-	-	-	-
Total	144,575	10,931	0	63	134	675	210	195	5	156,788

Indicates that there was small production of unknown value.

The initiatives by FAO, ICLARM, CTSA and bilateral donors, have concentrated on establishing the culture of pearl oysters in other countries, developing small-scale aquaculture enterprises for other species, and providing basic training in aquaculture and stock enhancement to fisheries staff in several of the countries. The proceedings of the workshop entitled "Present and Future of

Aquaculture in the Pacific” organised jointly by SPADP and JICA in Tonga in November, 1995 (Anon, 1996) presents the status of aquaculture in the region. A summary of recent progress in initiatives by FAO, ICLARM, CTSA and bilateral donors is given below.

*Blacklip pearl oysters*: Small-scale culture of the pearl oysters is under way in Fiji, Marshall Islands, the Federated States of Micronesia, Solomon Islands, Kiribati and Tonga.. In some places, e.g., Kiribati, development is based on spat produced in hatcheries, whereas in others, e.g., Solomon Islands, development is geared towards finding ways that coastal villagers can catch and grow wild spat (Friedman et al. 1998). Current research is concentrating on assessing the economic viability of pearl farming in Solomon Islands, Fiji and Kiribati, and comparing growth, survival and pearl quality of oysters derived from wild and hatchery-reared spat.

*Giant clams*: Small-scale enterprises in Solomon Islands, Palau, Marshall Islands, Cook Islands, Tonga and American Samoa supply five species of giant clams (*Tridacna crocea*, *T. derasa*, *T. gigas*, *T. maxima* and *T. squamosa*) to the marine aquarium trade (Foyle et al. 1997, Hart et al. 1998). Production of giant clams for enhancement of wild stocks is also under way in Solomon Islands, Fiji, Cook Islands and Western Samoa (Bell et al. 1997a, Bell 1999b). Several of these countries also have the capacity to produce giant clams for the sashimi market in Okinawa, and as a live product for markets in Hong Kong and Taiwan (Bell et al. 1997b). ICLARM is currently conducting large-scale grow-out trials to test and develop these markets for *T. derasa*.

*Sea cucumbers*: Research has commenced to assess the viability of producing sea cucumbers in hatcheries for enhancement of wild stocks. There are three steps in this process: developing methods for cost-effective mass production of juveniles, learning to release the cultured juveniles in ways that maximise their survival, and evaluating the economic impact of releasing cultured juveniles into existing fisheries.

Currently, the focus is on development of methods for the mass rearing of *Holothuria scabra*, *H. fuscogilva* and *Actinopyga mauritiana*, three of the most valuable sea cucumbers in the region. To date, ICLARM has demonstrated that *H. scabra* is relatively easy and cheap to rear (Battaglione and Bell 1999), and that *A. mauritiana* grows relatively rapidly at high densities (Ramofafia et al. 1997). Initial research on *H. scabra* indicates that this species has much potential for stock enhancement.

*Other species*: Technology for propagating and releasing cultured juveniles of green snail and trochus has been transferred to the Pacific through projects in Tonga (JICA) and Vanuatu (ACIAR). OFCF is also implementing a stock enhancement programme for both species in Solomon Islands. Production of the marine alga, *Eucheuma*, is well established by coastal villagers in Kiribati and Fiji, and sponges are being cultured in the Federated States of Micronesia. Milkfish are being cultured as live bait for the tuna industry in Guam, and there is considerable interest in this activity by several other countries.

## Policy and institutional framework

The independent Pacific Islands (Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu) generally lack any specific provision for aquaculture in the legislation, but many include a statement about aquaculture in national development plans.

Whilst prospects for inland aquaculture are limited by geography, the custom of communal tenure of coastal marine areas may be incongruous with private sector farm ownership in many areas, unless the development is carefully managed. Tonga, is currently developing a comprehensive legislative basis for future aquaculture development, whilst the Cook Islands has adapted traditional systems into a legal basis for pearl farm management. Other countries are taking a more ad-hoc approach and trying to adapt land-based systems of state leases for mariculture development, or encouraging development only by traditional reef custodians.

### Status by island group

Production statistics for aquaculture, as might be expected from what is currently a minor, semi-subsistence activity, are almost nonexistent for the Pacific Islands. The exceptions are for black pearl farming in eastern Polynesia, shrimp aquaculture in New Caledonia, and a few other islands. The following summary is mainly non-quantitative.

**American Samoa (US)** - Aquaculture currently focused on giant clams (*Tridacna derasa*, *T. maxima*, and *Hippopus hippopus*). In 1996, 30 subsistence level farmers participated to a programme of growing-out 500 clams each provided by a public sector-supported hatchery (Clarke, 1997).

**Cook Islands** - Few freshwater bodies but small lakes on three islands contain introduced eels and tilapia (not cultured though). Blacklip pearl (*Pinctada margaritifera*) culture started early 1970's at Manihiki - 50 farms in 1988 and over 90 in 1998. First full-scale commercial harvest in 1990 for US\$0.8 million, \$4 million by 1995 to become Cook Islands most valuable visible export. Farming now expanded to Tongareva & government hatchery there. Government hatchery for giant clam & trochus on Aitutaki for 10 years, but not currently commercially sustainable. (Matutu, 1999)

**Federated States of Micronesia** – In spite of numerous trials and projects from the years 1930's, there has not been any sustained commercial or subsistence aquaculture operation at present (Itimai, 1999).

**Fiji** - First aquaculture 1953 when Tilapia introduced as protein source for pig-farming. First directed efforts after Japanese JICA project developed freshwater aquaculture methods in 1970s. Varied success with shrimp, euclidean, oyster, mussel, macrobrachium, carp & tilapia, but now major investment subsidised by government through Commodity Development Fund. Currently 3 shrimp farms + hatchery - 20 Milkfish ponds for longline bait - Tilapia 1 industrial, 7 commercial and 215 subsistence farms + 6 hatcheries, 243 t production in 1998 - Euclidean (cottonii) 182 farms est 1,500 t production 1999 - experimental pearl farming (+ 1 commercial farm for 2 decades), giant clam hatchery - Naduruloulou government freshwater aquaculture research station - Makogai government mariculture research station - USP aquaculture teaching - school teaching ponds (Ledua, 1999).

**Guam (US)** - Increasing trend of the annual aquaculture production between 1990 and 1995 (Clarke, 1997). In 1995, the aquaculture production was 205 metric tons (valued at US\$

1.6) farming mainly tilapia, marine shrimps, Chinese catfish, and milkfish. Potential of other species (giant clams, top shell, striped mullet, and groupers) explored by Guam-based research facilities.

**Kiribati** - 80ha Milkfish ponds originally set up to provide livebait for tuna pole-and-lining, operating several decades - *Eucheuma* (*cottonii*) in Phoenix, Line & Gilbert groups for 15 years - OFCF project on sea cucumber rearing - ACIAR project on pearl farming (Tekinaiti, 1999)

**Marshall Islands** – Farming of giant clams, seaweed, and pearl-oysters (Te, 1999)

**Niue** - currently no aquaculture, but have investigated the feasibility of a giant clam & trochus hatchery

**Nauru** - Milkfish been farmed for at least 1 century, but competition from introduced Tilapia (*O. mossambicus*) in Buada lagoon & lapsed. Revived recently with *O. niloticus* & milkfish. 11 ponds (Alefaio, 1999)

**Northern Marianas** (US) – Aquaculture limited to penaeid shrimp and tilapia (Clarke 1997). Annual production estimated to 1,250 kg for marine shrimp, 200 kg for fresh water prawns, and 4,200 kg for tilapia. Less than three commercial farms. Total estimated value of products estimated to US\$25,000 in 1996.

**Nouvelle Calédonie** (Fr) 1,500 t shrimp production achieved for the first time in 1998 (Labrosse et al., in prep), after disease problems in early 1990s. Value of marine shrimp production is about US\$10 million. About 45 metric tons of oysters (*Crassostrea gigas*) produced for local market. Experimental of local oyster and giant clam also (Etaix-Bonnin, 1999).

**Palau** - Pioneered giant clam culture at Micronesian Mariculture Demonstration Centre plus trochus, soft corals.

**Papua New Guinea** - Started 40 years ago with several aquaculture stations along coast and highlands to encourage subsistence culture - mainly *Cyprinus carpio* - 300 carp farms in operation approx 10.5 ha. Trout introduced 1940s & Kotuni trout farm 1973-84 - 3 newer farms but only 2 currently operating for 15 t yield - hatchery started in 1996. Barramundi (*Lates calchifer*) in Madang on site of failed redclaw (*Chierax quadricarinatus*) 9 ha pond - not yet producing (Wani, 1999).

**Pitcairn, Henderson, Ducie & Oeno** (UK) - no aquaculture

**Polynésie Française** (Fr) - *Pinctada margaritifera* farming for black pearls is major industry. Successful in the past with Mussel, Shrimp, Barramundi & Oyster culture.

**Samoa** - Farming trials tilapia in 1954 by SPC and Macrobrachium 1971 by FAO did not develop - seaweed, giant clam, green mussel, redclaw farming also tried - new national economic strategy promotes aquaculture & being actively developed by current AusAID village fisheries extension project (Tilapia, Mullet & Giant clam (Mulipola, 1999)

**Solomon Islands** - 2 shrimp farms - 50 village-based giant clam farms - ICLARM Coastal Aquaculture Centre - University of the South Pacific Institute of Marine Resources - OFCF Project greensnail & trochus (Oreihaka, 1999)

**Tokelau** (NZ) - no aquaculture

**Tonga** - Tilapia/milkfish polyculture 1968 was first aquaculture attempt - 1973-79 various trials on shellfish (oyster, mussel, pearl shells) lapsed but *Pteria penguin* established in wild & basis for later mabe pearl culture. Japanese mariculture project with Ministry of Fisheries on Tongatapu recently finished. Currently - government hatchery for giant clam, greensnail (introduced) & trochus (introduced). Planning trials on extensive *Cladosiphon* farming. (Fa'anunu, 1999)

**Tuvalu** - interest in trials of Tilapia culture in borrow-pits at Funafuti



**Vanuatu** - *Crassostrea gigas* introduced 1920s Santo - shortlived *Macrobrachium Rosenbergii* farm 1978-83 Efate - Tilapia from New Caledonia early 1980s Efate. Trochus hatchery 1985-present started up by ORSTOM & continued by SPADP & ACIAR. - giant clam spawning just started. No commercial aquaculture (Pakoa, 1999)

**Wallis et Futuna (Fr)** – no aquaculture

### ***Prospects for Further Development***

Some of the best opportunities for development of aquaculture in the Pacific are in the aquarium trade live seafood markets (e.g., napoleon wrasse, groupers, sea cucumbers, spiny lobsters, trochus, pearl oysters, giant clams, green snail, abalone, crabs, clownfish, angelfish, hard corals, soft corals), and the pharmaceutical industry (e.g., algae, sponges, soft corals, sea-horses) (Bell and Gervis, 1999 ; Bell, 1999c). In all cases, the products are of high value and can be grown in small areas with relatively simple technology.

The continued expansion of aquaculture in the Pacific will depend on providing better methods of production for species currently under cultivation, and techniques for propagating and growing the 'new' species described above (Bell, 1999c). These methods and techniques should be simple and flexible for being adapted to the context of the Pacific Islands environment, and to the market constraints (local and export markets). This approach should favour culture systems based fisheries integrating mariculture (with low investment, operating costs and technicity processes of production). This should associate to pilot commercial scale operations to test and demonstrate the economic viability of the methods proposed. This will need a research effort coupled to assistance, training and education programmes.

In recognition of these needs, three organisations (SPC, ICLARM and USP) have recently joined forces to produce a 'Regional Strategy for the Development of Aquaculture'. Under this strategy, SPC will be to provide the focal point for decision-making about the development of aquaculture. This will be done by convening regular meetings of island nations, stakeholders and other organisations to identify needs, determine priorities and allocate tasks in a way that maximises the use of the region's resources. ICLARM will undertake the long-term research to devise and test economically and environmentally sustainable methods for restocking, stock enhancement and farming; whereas USP will provide all levels of university education and vocational training, and contribute to research through higher degree programmes. The other functions necessary for the expansion of sustainable aquaculture in the region, e.g., marketing, legislation, environmental protection and quarantine, will be co-ordinated progressively by SPC.

This 'Regional Strategy for the Development of Aquaculture' represents an opportunity to reinforce an inter-regional cooperation based on research, training and information exchanges (such as cooperation with NACA for South East Asia countries) and also being more investment from Asia and thus to get better conditions of access to Asian market.

### ***References***

**Adams, T. J. H. 1998.** Coastal fisheries and marine development issues for small islands. *In: A roadmap for the future for fisheries and conservation.* (Ed. Meryl J. Williams) ICLARM Conference Proceedings 56. pp 40-50. (World Conservation Congress Workshop papers)

- Adams, T., P. Dalzell and E. Ledua. 1999.** Ocean Resources. *In* The Pacific Islands: Environment and Society (Ed. Moshe Rapaport); 366-381. The Bess Press, Honolulu.
- Alefaio, F. 1999.** Aquaculture Resource Development Country Statement: Nauru. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Anon. 1996.** Present and Future of Aquaculture Research and Development in the Pacific, Proceedings of the International Workshop, Ministry of Fisheries, Tonga, 20-24 November 1995. JICA, Nuku'alofa, Tonga.
- Battaglione, S. and J.D. Bell. 1999.** Potential of the tropical Indo-Pacific sea cucumber, *Holothuria scabra*, for stock enhancement. In Stock enhancement and sea ranching. First International Symposium on Stock Enhancement and Sea Ranching, Bergen, Norway (Eds. B. R. Howell, E. Moskness and T. Svasand). Blackwell Science, Oxford.
- Bell, J.D. 1999a.** Transfer of technology on marine ranching to small island states. Proceedings of the International Symposium on Marine Ranching, 13-16 September 1996, Kanazawa, Ishikawa Prefecture, Japan.
- Bell, J.D. 1999b.** Restocking of giant clams: progress, problems and potential. *In* Stock enhancement and sea ranching. First International Symposium on Stock Enhancement and Sea Ranching, Bergen, Norway (Eds. B. R. Howell, E. Moskness and T. Svasand). Blackwell Science, Oxford.
- Bell, J.D. 1999c.** Aquaculture: a development opportunity for Pacific islands. ICLARM (in press).
- Bell, J.D., P.J. Doherty and C.A. Hair. 1999.** The capture and culture of postlarval coral reef fish: potential for new artisanal fisheries. SPC Live Reef Fish Information Bulletin (in press).
- Bell, J.D. and M. Gervis. 1999.** New species for coastal aquaculture in the tropical Pacific - constraints, prospects and considerations. *Aquaculture International* (in press).
- Bell, J. D., A. M. Hart, T. P. Foyle, M. H. Gervis and I. Lane. 1997a.** Can aquaculture help restore and sustain production of giant clams? *In* Developing and sustaining world fisheries resources: the state of science and management. 2nd World Fisheries Congress Proceedings, Brisbane 1996. (Eds. D. A. Hancock, D. C. Smith, A. Grant and J. P. Beumer). CSIRO, Melbourne, pp 509-513.
- Bell, J. D., I. Lane and A. M. Hart. 1997b.** Culture, handling and air transport of giant clams from the South Pacific. In Marketing and Shipping Live Aquatic Products. (Eds. B. Paust and J. B. Peters). Northeast Region Agricultural Engineering Service, New York, pp 60-66.
- Beveridge, M. 1987.** Cage culture. Fishing News Books, Farnham, UK, 352 p.
- Capinpin, E.C. and K.G. Corre. 1996.** Growth rate of the Philippine abalone, *Haliotis asinana*, fed an artificial diet and macroalgae. *Aquaculture* 144:81-89.

- Clarke, R.P. 1997.** Status and Future of Aquaculture in the US territories of the Pacific. Draft paper of the National Marine Fisheries Service Pacific Area Office, USA.
- Dalzell, P., T.J.H. Adams and N.V.C. Polunin. 1996.** Coastal fisheries in the Pacific Islands. *Oceanography and Marine Biology: an Annual Review* 34:395-531.
- Duckworth, A.R., C.N. Battershill and P.R. Bergquist. 1997.** Influence of explant procedures and environmental factors on culture processes of three sponges. *Aquaculture* 156:251-267.
- Etaix-Bonnin, R. 1999.** Exposé national de la Nouvelle-Calédonie. Unpublished paper presented at the 1<sup>st</sup> Pacific Community Heads of Fisheries Meeting, August 1999, Noumea. [<http://www.spc.org.nc/coastfish/Reports/RTMF27/index.htm>]
- Fa'anunu, 'U. 1999.** Tonga Country Paper. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- FAO Fisheries Department. 1999.** The State of World Fisheries and Aquaculture 1998. Food and Agriculture Organisation of the United Nations, Rome. 112pp.
- Fassler, R. 1995.** Farming jewels: new developments in pearl farming. *World Aquaculture* 26(3):4-10.
- Foyle, T. P., J. D. Bell, M. H. Gervis and I. Lane. 1997.** Survival and growth of juvenile fluted giant clams, *Tridacna squamosa*, in large-scale village grow-out trials in the Solomon Islands. *Aquaculture* 148:85-104.
- Friedman, K. J., J. D. Bell and G. Tiroba. 1998.** Availability of wild spat of the blacklip pearl oyster, *Pinctada margaritifera*, from open reef systems in Solomon Islands. *Aquaculture* 167:283-299.
- Hart, A. M., J. D. Bell and T. P. Foyle. 1998.** Growth and survival of the giant clams *Tridacna derasa*, *T. maxima* and *T. crocea* at village farms. *Aquaculture* 165:203-220.
- Heslinga, G.A., T.C. Watson, and T. Isamu. 1990.** Giant clam farming. Pacific Fisheries Development Foundation (NMFS/NOAA), Honolulu, Hawaii, 179 pp.
- Itamai, I. 1999.** Aquaculture resource development in the Federated States of Micronesia. Proceedings of the 9<sup>th</sup> Pacific Islands Area Seminar in Hawaii, U.S.A. *Aquaculture Resource Development in Pacific Islands: Cultural and Community Influences, Sustainability, Technological Applications and Commercial Opportunities*. October 27-30, 1998. 9-10.
- Johannes, R.E. and M. Riepen. 1995.** Environmental, economic and social implications of the live reef fish trade in Asia and the western Pacific. Unpublished report prepared for The Nature Conservancy and the South Pacific Forum Fisheries Agency. 82 p.

- Labrosse, P., R. Fichez, R. Farman and T. Adams. (in press).** New Caledonia. *In Seas at the Millennium* (Ed. C. Sheppard). Elsevier.
- Landesman, L. 1995.** Negative impacts of coastal tropical aquaculture developments. *World Aquaculture* 25(2):12-17.
- Ledua, E. 1999.** Fiji Country Report. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Lewis, A.D.L. 1987.** Proceedings of the Fiji Aquaculture Symposium. Fiji Fisheries Division, May 1987. (Collection of abstracts)
- Lucas, J.S. 1994.** The biology, exploitation, and mariculture of giant clams (Tridacnidae). *Rev. Fish. Sci.* 2:181-223.
- Matutu, G. 1999.** Cook Islands Country Report. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- McManus, J. 1996.** Tropical marine fisheries and the future of coral reefs. *Proc. 8th Int. Coral Reef Symp.* (in press).
- Mulipola, A. 1999.** Aquaculture Development in Samoa with constraints and future requirements. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Munro, J.L. 1993a.** Aquaculture development and environmental issues in the tropical Pacific, p. 125-138. In: R.S.V. Pullin, H. Rosenthal and J.L. Maclean (eds.) *Environment and aquaculture in developing countries*. ICLARM Conf. Proc. 31, 359 p.
- Munro, J.L. 1993b.** Giant clams, p. 431-449. In: A. Wright and L. Hill (eds.). *Nearshore marine resources of the South Pacific*. Forum Fisheries Agency, Honiara.
- Munro, J.L. and J.D. Bell. 1997.** Enhancement of marine fisheries resources. *Rev. Fish. Sci.* (in press)
- Oreihaka, E. 1999.** Country Statement - Solomon Islands. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Pakoa, K. 1999.** Aquaculture Development in Vanuatu. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Ramofafia, C., T.P. Foyle and J.D. Bell. 1997.** Growth of juvenile *Actinopyga mauritiana* (Holothuroidea) in captivity. *Aquaculture* (in press).

- Ruddle, K., E. Hviding and R.E. Johannes. 1992.** Marine resources management in the context of customary marine tenure. *Mar. Res. Ecol.* 7:249-273.
- Stewart, J.E. 1997.** Environmental impacts of aquaculture. *World Aquaculture* 28(1):47-52.
- Te, F.T. 1999.** Marine resource development in the Marshall Islands: plans, issues and hopes. Proceedings of the 9<sup>th</sup> Pacific Islands Area Seminar in Hawaii, U.S.A. *Aquaculture Resource Development in Pacific Islands: Cultural and Community Influences, Sustainability, Technological Applications and Commercial Opportunities.* October 27-30, 1998. 31-35.
- Tekinaiti, T (1999)** Aquaculture Programmes in Kiribati. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Uwate, K.R. and P. Kunatuba. 1983.** Aquaculture development: the Pacific way? South Pacific Commission 15th Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 1-5 August 1983. 7 p.
- Wani, J. 1999.** Papua New Guinea Country Report. Unpublished paper presented at the 4<sup>th</sup> Technical Coordination Meeting of the FAO South Pacific Aquaculture Development Project Phase II. Nadi, Fiji, 18-19<sup>th</sup> March 1999.
- Williams, M. 1996.** The transition in the contribution of living aquatic resources to food security. *Food, Agriculture and the Environment Discussion Paper 13*, International Food Policy Research Institute. 41 p.
- Wright, A. and L. Hill (Editors). 1993.** Nearshore Marine Resources of the South Pacific. Forum Fisheries Agency, Honiara, Institute of Pacific Studies, Suva