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Aquaculture: a development opportunity for Pacific islands

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Aquaculture: a development opportunity for Pacific islands

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Background

A major problem facing Pacific island nations is the limited number of opportunities to earn income. In most countries, tourism and the sale of access rights to fish for tuna account for the majority of gross national product, although the larger nations (Papua New Guinea, Fiji and Solomon Islands) also benefit greatly from agriculture, forestry and mining.

Inshore fisheries resources should also provide relatively important economic benefits to island nations because the ratio of coastline to landmass is much greater than for continental countries. However, the inshore fisheries sector is not yielding its full potential. This is not due to lack of development. On the contrary, the problems facing inshore fisheries have been caused by overharvesting of the valuable species of fish and shellfish, with the result that there are now too few adults to replenish stocks. In other words, the natural supply of juveniles of valuable species each year is often well below the carrying capacity of the coral reef habitats. This situation is analogous to having a large farm with only a few breeding cows, when the pasture is capable of supporting hundreds of cattle.

The problem of overharvesting has been compounded in some places by destructive fishing methods. The most notorious of these is the use of sodium cyanide to collect coral reef fish for the live reef fish trade and the aquarium market. The sodium cyanide, which is released in solution by divers to stun the fish, kills corals and small invertebrates. In addition, the coral is often broken apart to reach stunned fish hiding inside. The result is that the habitat and food on which the target species depend is damaged, limiting future harvests (akin to poisoning the soil and grass on a farm).

Part of the solution to the current lack of productivity from coral reefs in the Pacific is to raise awareness of the need to allow stocks to recover to productive levels, and to implement community-based management. These measures are particularly important in the region because inshore fisheries resources are often under customary marine tenure (Lam 1998). Consequently, governments have little control over the areas harvested, although they can impose size limits and export restrictions to limit total catches. This ‘awareness-participation’ approach is currently being applied in Samoa with assistance from AusAID and many coastal communities there have established protected areas to allow restoration of valuable inshore species (M. King, pers. comm.). However, improved awareness and protection will not necessarily result in rapid recovery of stocks, and will not deliver increased levels of production compared to historical catches. Both these outcomes are essential for the increased well-being of the rapidly growing human populations in the Pacific.

How can aquaculture help?

Potentially, aquaculture is the other part of the solution to the problem of low yields from inshore marine resources. Aquaculture involves producing juvenile fish and invertebrates in hatcheries, or collecting juveniles from the wild and nursing them through to a larger size. It also involves the farming of algae. Aquaculture can be used to produce greater yields from valuable inshore species in three ways.

1. Cultured juveniles can be released into the wild to restore stocks to levels where they provide substantial, sustainable yields. This process is known as 'restocking'.

2. Cultured juveniles can be released into the wild to increase stocks compared to historical, unexploited levels. This process is known as 'stock enhancement' and is designed to overcome the common phenomenon of 'recruitment limitation'. This phenomenon occurs when the natural supply of juveniles fails to reach the carrying capacity of the habitat, even when there are great numbers of breeding adults. Recruitment limitation is the rule rather than the exception among tropical marine animals and arises for several reasons. For example, the floating (pelagic) larval stages of fish and shellfish may perish *en masse* in the plankton due to lack of suitable food, or be swept away from coral reefs during storms. Mass mortality of larvae can also occur when they cease their pelagic phase and settle on coral reefs. At such times, the majority of these juveniles may be eaten by predators. The result of recruitment limitation is that (even unexploited) coral reef habitats do not produce as many valuable fish and shellfish as they could. Stock enhancement redresses this situation by supplying as many juveniles as the habitat can support. Stock enhancement is not without pitfalls, however, and the factors that need to be considered for responsible implementation of such programmes, and transfering the technology to the Pacific, are described by Blankenship and Leber (1995), Munro and Bell (1997) and Bell (1999a).

3. Cultured juvenile fish and invertebrates, or propagules of algae, can be grown in captivity to increase productivity independently from the management of wild fisheries. This process is usually referred to as 'farming'.

Benefits of aquaculture

Restocking, stock enhancement and farming enterprises can deliver benefits to island nations through increased generation of income, employment opportunities and food security, and through conservation of biodiversity. Increased income will be generated through greater catches from restocked and enhanced wild fisheries, and by farming additional quantities of valuable species. Such income will be distributed to fishers and small-scale farmers at the grass roots level (see examples below); to larger farming ventures; to distributors of marine products; and to Governments through increased sales tax and export duties.

Small-scale farming enterprises will provide more opportunities for self-employment, and diversify the ways money can be earned in rural areas, whereas larger farms will create new jobs. For example, the farming of pearl oysters has provided livelihoods for 300 people on Manihiki Atoll in Cook Islands (J. Lyons, pers. comm.).

Although the focus of aquaculture in the Pacific will need to be on high-value products for export (see below), establishment of the infrastructure and skilled workforce needed for successful enterprises will make diversification into food production for local consumption relatively straightforward. Thus, development of aquaculture will lay the groundwork for improved food security.

Responsible restocking programmes, i.e., those that maximise the genetic diversity of restocked individuals, will reduce the risk that over-exploited species will become locally extinct. Giant clams are a case in point: restocking programmes are re-establishing species in areas of the Pacific where wild stocks have been eliminated (Munro 1993a, Bell 1999b).

Is aquaculture likely to be successful in the Pacific?

For restocking and stock enhancement, the success of programmes will depend on identifying valuable species that prove easy to propagate and release into the wild at high rates of survival (Blankenship and Leber 1995, Munro and Bell 1997). It will also depend on the willingness of development assistance agencies to support such programmes until the costs of operating hatcheries can be covered by levies on the revenues generated through the increased production from improved stocks (Bell 1999a). For farming, success will depend on whether the private sector can make a profit culturing those species demanded by the marketplace under the conditions that exist in the Pacific. The features of the region that favour successful development of aquaculture are:

1. *A high diversity of species*: Inshore habitats in the Pacific support a great variety of marine organisms in demand from seafood markets (e.g., groupers, sea cucumbers, spiny lobsters), the aquarium trade (e.g., clownfish, angelfish, giant clams, hard corals, soft corals), as ornaments (e.g., pearl oysters, trochus, green snail) and for pharmaceuticals (e.g., algae, sponges, soft corals). Importantly, many of these species are low in the food chain and can be grown without the addition of food. This means that aquaculture in the Pacific can be developed without the adverse environmental effects that attend the rearing of shrimp in Asia and carnivorous fish in Europe (Naylor et al. 1998). At a time when intensive aquaculture is receiving much 'bad press' elsewhere, this feature alone is a great advantage to the region.

2. *Location*: The relatively short flight times from Pacific nations to the major seafood markets in Asia allows many species to be shipped alive, which results in premium prices.

3. *Suitable grow-out sites*: Coral reef lagoons provide the calm conditions essential for culture of many species. The pristine nature of these habitats also helps to market edible and ornamental products.

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. *Inexpensive and appropriate workforce*: The cost of labour is relatively low in many Pacific countries. In addition, coastal communities have a tradition of working with marine resources, which should facilitate the acquisition of skills for husbandry of animals in aquaculture.

Although the attributes listed above confer many advantages on the region for development of aquaculture, there are also several constraints (Munro 1993b, Adams 1998, Bell and Gervis 1999). These constraints include:

1. *Limited domestic markets*: Local markets for the fresh products of aquaculture in the Pacific are small and usually offer low prices. Large-scale aquaculture in the Pacific will depend heavily on export markets.

2. *Transport problems*: The high price of airfreight and shipping in the Pacific adds to the cost of producing and exporting the products of aquaculture. Poor internal transport services also 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 nonperishable, e.g., beche-de-mer (processed sea cucumbers), or frozen, so that they can be shipped by sea.

3. *Socioeconomic conditions*: Many island nations lack the infrastructure, capital and skilled workforce to implement aquaculture, particularly where hatcheries are involved.

4. *Fragile habitats*: Many coral reef ecosystems have evolved in a nutrient-poor environment. This will rule out the farming of carnivorous fish in many places because the addition of nutrients that occurs through uneaten and undigested formulated diets can be expected to change the ecosystem in favour of algae and herbivores. Such changes will be unacceptable, particularly to the tourist industry. This constraint may not apply to rare locations that have good flushing to the open ocean and low exposure to strong winds.

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

What has been achieved so far?

The potential benefits of aquaculture to the Pacific have been deemed to outweigh the constraints and during the past two decades development has occurred along two paths. First, large-scale, commercial enterprises have transferred technology from elsewhere in the world to establish profitable aquaculture farms in the territories of France and the US State of Hawaii. Such enterprises include the farming of pearl oysters in French Polynesia, shrimps in New Caledonia and microalgae (Spirulina) in Hawaii (see Bell and Gervis 1999 for a summary of the value of this production). Culture of black pearls has also been established in Cook Islands, where it had an export value of ~ AUD$7.5 m in 1998 and was exceeded only by tourism as a source of foreign exchange. Farming of shrimps is also underway in Fiji and Solomon Islands.

Second, national fisheries institutions assisted by organisations such as the Australian Centre for International Agricultural Research (ACIAR), EU, FAO, the International Centre for Living Aquatic Resources Management (ICLARM), the Japanese International Cooperation Agency (JICA), the Secretariat of the Pacific Community (SPC), and the University of the South Pacific (USP) have laid the groundwork for development of restocking, stock enhancement and small-scale aquaculture in the region.

Restocking and stock enhancement programmes are still at the experimental stage due to the long leadtime required to: a) produce juveniles in captivity, b) develop strategies to release the juveniles into the wild so that they survive in large numbers, c) minimise the potentially deleterious effects on wild stocks, and d) assess the benefits of pilot-scale releases. The longest running programmes involve giant clams, where restocking has been underway in 10 Pacific island nations since the mid 1980's (Bell 1999b). Giant clams have proved particularly difficult to restock, however, because they remain vulnerable to predators until they are four years old. Unfortunately, the costs of such prolonged husbandry for the large numbers of giant clams needed for effective restocking has proved to be beyond the capabilities of many island nations. As a result, many of these restocking programmes are in demise. On the brighter side, it is now evident that the costs can be reduced drastically by linking restocking to the farming of giant clams (Bell 1999b). Under this model, the giant clam farmers (described below) rear a small proportion (2-5%) of their 'seed' clams through to the size where they escape predation, and then place them on reefs under their customary marine tenure. Other restocking projects in the region are summarised by Bell and Gervis (1999). They involve sea cucumbers in Solomon Islands and Kiribati; trochus in Vanuatu and Solomon Islands, and green snail in Tonga and Solomon Islands. Recent research by ICLARM and ACIAR has shown that some sea cucumbers are particularly suitable for restocking (Battaglene and Bell 1999, Lawrence 1999).

Small-scale aquaculture of giant clams, pearl oysters, seaweed (Eucheuma cottonii), milkfish and bath sponges has now deveoped to the point where coastal villagers are deriving benefits and several countries are exporting products (Bell and Gervis 1999). For example, giant clam growers in Solomon Islands, who rear 'seed' clams for sale to the aquarium trade, have made profits equivalent to a fulltime labouring wage, and have used the proceeds to diversify into other opportunities to earn income (Hart et al.1998, Lawrence 1999). Giant clam farming has also proved to be popular because it takes only 2 – 3 mornings per week and leaves farmers with ample time to pursue their traditional activities, such as gardening and fishing. Farming of Eucheuma cottonii seaweed (used to produce the food additive, carrageenan) is another good example: it has now been adopted by 12% or rural households in Kiribati, and rivals the production of copra as a source of cash in many cases (Bergschmidt 1997). This form of aquaculture is also increasing rapidly in Fiji.

What has been learned?

An important lesson to emerge from small-scale aquaculture ventures in the Pacific is that benefits cannot be delivered at the 'grass roots' level without the aid of the private sector. In the case of giant clam farming, villagers cannot grow and sell the clams unless they can purchase the 'seed' from a hatchery, and unless there is someone to distribute, market and export their products to the marine aquarium trade. It is now clear that development of giant clam farming will depend not only on training and assistance for village farmers; support is also needed for establishment of private sector hatcheries, and perhaps for exporters of tropical marine aquarium products. A complicating factor with the development of some aquaculture enterprises, e.g. giant clam farming, is that the size of the market may not be large enough initially to support the operation of a commercial hatchery dedicated to producing 'seed' for out-growers. To be commercially viable, hatcheries in the Pacific may need to propagate several species (e.g., giant clams, pearl oysters, trochus and coral reef fish). The enterprise may also need to supplement its revenue by coordinating the distribution of the farmers' produce to exporters.

The establishment of small-scale seaweed and pearl oyster farms by coastal villagers also illustrates the dependence of such ventures on assistance from other sectors. In Kirribati, The Atoll Seaweed Company organises the shipment of seaweed from distant islands to the capital, Tarawa, where it is pressed into bales for shipping to Denmark. In the early years, the company needed assistance from development agencies to overcome the problem of insufficient production. In Cook Islands, the smaller black pearl farmers depended on larger enterprises to cover the costs of bringing in technicians to implant nuclei in the oysters for the cultivation of pearls.

Overall, aquaculture in the Pacific has passed an important milestone in that many communities now appreciate that relatively high levels of income can be generated sustainably by farming marine organisms. The stage is now set for development of aquaculture through increased production by hatcheries and out-growers using existing technology, and through development of viable methods for 'new' species.

Prospects for Further Development

Some of the best opportunities for development of aquaculture in the Pacific are in the aquarium trade, live seafood markets and the pharmaceutical industry (Bell and Gervis 1999). In all cases, the products are of high value and can be grown in small areas with relatively simple technology.

Opportunities for aquaculture of tropical marine aquarium animals have arisen because it is now difficult to obtain some of the species from coral reefs. There is also a strong trend among consumers to protect wild populations by purchasing cultured products. The greatest demand is for hard and soft corals, and a variety of fish. Preliminary trials indicate that a wide range of corals can

be produced by small-scale farmers, simply by removing tips from colourful colonies and attaching them to small concrete discs. The attraction of this form of aquaculture is that it can be done in shallow water close to coastal villages using the same materials required for giant clam farming. In addition, the mechanisms for marketing to the aquarium trade are already in place in many Pacific countries (Mercier and Hamel, 1998). The potential for using simple, village-based aquaculture to rear coral reef fish for the marine aquarium trade is described below.

Prospects for the live seafood trade include tropical abalone, groupers and crabs. Tropical abalone, are smaller than their temperate counterparts, but are in demand for the "cocktail" abalone market in Asia. Methods for culturing these species are now well documented (Bell and Gervis 1999 and references therein) and so existing hatcheries in the region have potential to supply 'seed' for grow-out by local farmers.

Live groupers fetch high prices in Hong Kong, Singapore and Taiwan, ranging from US$25-50 per kg depending on species. The live reef fish industry is currently supplied by fish of market size from coral reefs, or by catching wild juveniles and shipping them to southeast Asia for grow-out in sea cages. The capture of wild juvenile reef fish has potential for aquaculture in the Pacific because the postlarvae can be caught in simple traps, grown-out for several weeks, and then shipped alive to growers in southeast Asia or sold to the aquarium trade. This concept is currently being tested by ICLARM in Solomon Islands with funding from ACIAR. The project is also expected to shed light on the feasibility of producing some coral reef fish in hatcheries.

One of the main issues confronting the capture and culture of larval fish is the concern that removal of juveniles may affect replenishment of wild stocks. However, this form of aquaculture should have negligible impact because the juveniles will be caught before the severe natural mortality at the time of settlement to reefs. Indeed, the capture and culture of larvae is expected to improve productivity by nursing the juveniles through the period when the majority of recently settled fish perish.

The other group of species with potential for aquaculture as a live seafood products are the 'mangrove' or 'mud' crabs in the genus *Scylla*. Methods for propagating species within this genus have been developed and three of the four species in the genus occur in the Pacific (Bell and Gervis 1999 and references therein).

The production of pharmaceuticals promises to be a lucrative new form of aquaculture for the Pacific because a number of coral reef organisms contain complex, biologically active compounds of use to medical science. For example, saponins from the body wall of sea cucumbers kill molluscs harbouring larval worms that transmit the tropical disease schistosomiasis (Sotheswaran, pers.comm.), and sponges produce compounds that inhibit tumours (C. Battershill, pers. comm.). However, natural availability of these invertebrates is not sufficient to produce commercial quantities of the desirable compounds. Opportunities exist, therefore, to grow tropical marine invertebrates for pharmaceutical use. This is confirmed by related research in New Zealand, which shows that aquaculture is a viable way of producing sufficient biomass of sponges for the extraction of compounds (Duckworth et al. 1997).

Pre-requisites for further development of aquaculture

The imperative for the continued expansion of aquaculture in the Pacific is to provide better methods of production for species currently under cultivation, and techniques for propagating and growing the 'new' species described above. This requires research. It is vital, however, that the outputs of such research are not limited simply to the production of manuals for the culture of species. The research must also extend to grow-out trials at the pilot commercial scale to test and

demonstrate the economic viability of the methods, and to assess the impact of the technology on the well-being of coastal communities. Otherwise, it will be difficult to encourage entrepreneurs with scarce capital to invest in aquaculture. It may also be hard to convince people at the grass roots level that embarking on a new form of enterprise is in their best interest.

Appropriate research alone will not be sufficient to ensure further development of aquaculture in the Pacific. Education and training of the workforce at all levels of aquaculture production, and dissemination of information about new methods and opportunities for aquaculture, will be needed to instigate and implement new businesses. In due course, it will also be necessary to support development of aquaculture through marketing of products, drafting of suitable legislation, assessment and regulation of environmental impacts and quarantine risks, and regular analysis of production and market trends, regional competitive advantage and overall direction of the industry.

The role of international and regional organisations

The size of many Pacific island nations prevents them from allocating the resources necessary for development of aquaculture. In particular, many of them lack scientists to do the required research, and institutions capable of providing appropriate education and training. Consequently, these nations must rely on other organisations and their larger neighbours for the technological 'building blocks' needed to implement or expand aquaculture.

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.

How can development agencies assist?

Development assistance agencies can expedite the expansion of aquaculture, and the benefits that it will deliver to the Pacific, by supporting the main components of the 'Regional Strategy for the Development of Aquaculture'. The four main areas that require support are: 1) research to complete projects on species currently under investigation and to assess the potential of 'new' species; 2) the application of research, e.g. establishment of restocking projects or farms using proven technology; 3) education and training of the workforce needed to implement aquaculture enterprises; and 4) the overall co-ordination and planning of the expansion of aquaculture.

The support required for aquaculture should not be confused with that needed by agriculture: proven technology already exists for many agricultural products whereas production methods for aquaculture are still under development and need sustained support to bring them to fruition. In general, it takes 10-15 years of research before basic methods for propagating and rearing marine species are suitable for adoption by farmers. Restocking and stock enhancement programmes may require an even greater commitment. As mentioned earlier, support for these applications of aquaculture is needed until levies on increased harvests can maintain the operation of hatcheries.

Support for the four areas listed above needs to be distributed across regional organisations, governments and the private sector. The principal groups requiring assistance to develop aquaculture in the Pacific are:

1. The three major organisations collaborating to implement the 'Regional Strategy for Development of Aquaculture' (multilateral aid).

2. National governments proposing to implement restocking and stock enhancement programmes based on proven technology resulting from the regional strategy (bilateral aid).

3. Private sector hatcheries providing 'seed' and small-scale farmers of marine species (business support schemes).

Conclusions

Restocking and stock enhancement programmes for valuable inshore marine species, and establishment of aquaculture farms, are some of the most exciting opportunities for improving the well-being of people in the Pacific. These three forms of aquaculture can revitalise the inshore marine sector by generating more income, creating new jobs, improving food security and conserving biodiversity. Increased business activity, and a better understanding of the marine environment, is already occuring in several Pacific island nations through the culture of black pearls, grow-out of shrimps, and farming of giant clams and seaweed. These benefits can be expanded greatly by developing and implementing sustainable aquaculture methods for additional species. International and regional organisations are now collaborating under the umbrella of a 'Regional Stratgey for Development of Aquaculture' to do the research, training, education and planning needed to deliver these methods. Development assistance agencies can expidite the process by supporting this strategy, which is co-ordinated by the Secretariat of the Pacific Community (SPC). Support for governments to implement restocking and stock enhancement programmes, for the private sector to operate hatcheries, and for small-scale farmers, will also assist the people of the Pacific to realise the opportunities available through aquaculture.

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