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DRAFT PROPOSAL TO CONTINUE THE DEVELOPMENT OF AQUACULTURE IN THE PACIFIC

(Note: This draft document was circulated to Forum countries at the Forum Fisheries Committee Meeting in Honiara in November 1997. It is presented here for information only and will be superceded by a new proposal which incorporates the comments of member countries at this workshop, and which conforms to the draft Regional Aquaculture Strategy)

DRAFT

PROPOSAL TO CONTINUE THE DEVELOPMENT OF AQUACULTURE IN THE PACIFIC

Summary

The coastal communities of island nations in the Pacific have relatively few opportunities to generate income. Many countries in the region are now looking to aquaculture and stock enhancement to restore, and then increase, the productivity of their inshore marine resources. While the high value of many coral reef species, and the pristine nature of inshore waters surrounding many island nations, are strong incentives for aquaculture and stock enhancement in the Pacific, there are also a number of constraints. These include: infrequent and expensive international air links, fragile ecosystems, small economies, and limited capacity for research and development.

To overcome these constraints, Pacific island nations need viable, inexpensive methods to produce species that can be sold effectively using existing infrastructure. Because Pacific island nations have limited economies and human resources, they have difficulty in developing this technology on their own. The FAO established the South Pacific Aquaculture Development Project (SPADP) in 1986 to assist the region with the development of technology for aquaculture, and the marketing of aquaculture products.

The SPADP will terminate in 1999 and, despite the broad range of activities of the project, it is evident that aquaculture will only continue to develop in the Pacific if the following conditions are met:

i) methods for species already under investigation are completed,

ii) the completed methods are demonstrated to be economically viable and sustainable,

iii) methods for aquaculture of "new" species are developed and tested,

iv) information on viable methods is disseminated throughout the region,

v) training in the use of viable methods is provided for the public and private sectors, and

vi) products are marketed effectively.

The nations of the region continue to need support to accomplish these tasks. The International Center for Living Aquatic Resources Management (ICLARM) has a major research program on coastal aquaculture and stock enhancement based at its Coastal Aquaculture Centre in the heart of the region and is now well placed to develop viable and sustainable methods for aquaculture (Tasks i - iii). The South Pacific Commission (SPC) is in a strong position, through its Coastal Fisheries Program, to disseminate the methods to the region, to provide training, and to encourage other regional organisations to assist with marketing (Tasks iv -vi). Provided ICLARM and SPC can obtain the funding necessary to augment their operations, the two organizations propose to join forces to complete these tasks.

ICLARM is the most suitable organisation to do the research on behalf of the region because it has:

- established a Coastal Aquaculture and Stock Enhancement Program to increase the productivity of inshore marine resources,
- sustained core funding for the Coastal Aquaculture and Stock Enhancement Program, and the Coastal Aquaculture Centre, from the Consultative Group on International Agricultural Research (CGIAR), and partnerships with several donors,
- strong collaborations with advanced scientific institutions in the region,
- established projects on aquaculture or stock enhancement of coral reef species, including giant clams, pearl oysters and sea cucumbers,
- demonstrated its ability to establish viable small-scale farms; and
- a commitment to test the economic viability of research results.

Under this proposal, ICLARM will ensure that all research undertaken by the Coastal Aquaculture and Stock Enhancement Program is based on the needs of the region. These needs will be discussed and assessed at regular meetings convened jointly with SPC.

SPC is the most appropriate organisation to disseminate information on the methods produced by ICLARM, and to provide training for the public and private sectors in theses methods: SPC has the mandate and infrastructure for these functions, and the nations of the region have traditionally looked to SPC for such services in the fisheries sector.

Both ICLARM and SPC would require additional funding to provide their respective functions for the continued development of aquaculture in the region. The funds are needed to appoint and support professional staff. The budget required over five years is similar to that of phase two of the SPADP; i.e., US$ 2,243,400 over five years; $1,148,900 for ICLARM and $1,094,500 for SPC.

The joint SPC-ICLARM proposal would allow the nations of the Pacific to use their limited human and economic resources to focus on implementing viable methods for aquaculture, rather than spreading them between development of technology and establishment of enterprises.

Members of SPC are encouraged to endorse the proposal for SPC and ICLARM to join forces in an effort to secure funding for the research and training/advisory functions needed to continue the development of aquaculture in the region.

Introduction

In 1999, FAO will terminate the South Pacific Aquaculture Development Program (SPADP). This program has provided support for a wide range of aquaculture activities to some 15 countries in the region, particularly in the purchase of basic equipment, construction of pilot farms, training courses, visits by specialist advisors, study tours and workshops. The Pacific Island countries have appreciated the sustained support of SPADP, however, few of them can point to the establishment of viable aquaculture operations. At the 1996 Regional Technical Meeting on Fisheries of the South Pacific Commission (SPC), regional arrangements for the continued development of aquaculture were discussed in some detail. The meeting highlighted aquaculture as a potentially important component of fisheries development and asked representatives from SPADP, SPC and the International Centre for Living Aquatic Resources Management (ICLARM) to assess the aquaculture needs of the region and propose a suitable mechanism for continued development.

This paper is a response to that request. It has been prepared by senior staff from SPADP, SPC and ICLARM for consideration by the member countries of SPC. It outlines the importance of aquaculture to the region, the advantages and constraints to aquaculture in the Pacific, a brief history of developments, the current status of aquaculture, the prospects, and the pre-requisites for continued development. The paper also proposes a scheme of arrangements to achieve these prerequisites, summarises the capabilities of the regional organisations best suited to execute these arrangements and identifies the human resources and funding required to implement the plan.

Why Aquaculture is Important for Pacific Island Nations

Most of the island nations in the Pacific have relatively few opportunities to generate income. The economies of most Pacific countries are limited because they have small landmasses, few natural resources and low numbers of inhabitants. Island nations must make the most of the one important resource they all have - the sea. Through the joint efforts of SPC and the Forum Fisheries Agency (FFA), island nations are deriving major inputs to their economies through fishing for tuna, or selling access rights to tuna, within the large maritime zones under their control. However, valuable harvests are also possible from inshore waters and coral reefs.

The inshore habitats surrounding Pacific nations support a wide variety of economically important species (Wright and Hill 1993, Dalzell et al. 1996). 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).

Aquaculture provides a means of redressing the decline in productivity of inshore waters (Anon 1996, Bell 1996, Williams 1996). Increased numbers of animals can be produced by rearing the juveniles from captive broodstock and then growing them on "farms", or releasing them into natural habitats to restore and enhance wild stocks (Munro and Bell 1997). In fact, stock enhancement promises to lift productivity above historical catches by overcoming the phenomenon of "recruitment limitation". This phenomenon occurs for most inshore fisheries species in the tropics and arises because the number of juveniles recruiting to nursery habitats usually fails to reach the

carrying capacity of the system (see Munro and Bell 1997 and references therein for details). Recruitment limitation can be overcome by releasing cultured juveniles each year to supplement natural recruitment until the carrying capacity of the habitat is reached.

The increased productivity from aquaculture and stock enhancement can be used to achieve sustainable food security by providing additional income and food for the growing populations of the region.

Another advantage of successful aquaculture is that it raises the awareness of the value of wild marine resources and encourages coastal communities to manage their resources in a sustainable way. For example, since aquaculture has been practiced in Okinawa, Japan, residents have introduced their own regulations to protect the inshore marine resources on which aquaculture depends.

Advantages of the Pacific Region for Aquaculture

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

1) A wide variety of species associated with coral reefs and mangroves that are in great demand for: a) the aquaculture and seafood markets in Asia (e.g., napoleon wrasse, groupers, sea cucumbers, spiny lobsters, trochus, pearl oysters, giant clams, greensnail, octopus, algae), b) the marine aquarium trade (e.g., clownfish, angelfish, hard corals, soft corals, giant clams, ornamental shells), and c) the pharmaceutical, nutriceutal and cosmetic trades (e.g., marine bacteria, algae, invertebrates, 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.

4) Geography that favours 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 other regions.

6) A tradition of working with marine resources - coastal communities are already familiar with the basic biology of many species.

Constraints to Aquaculture in the Pacific

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 (1997). 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) *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 nonperishable, e.g., beche-de-mer (processed sea cucumbers), or frozen, so that they can be shipped by sea. Fiji is an exception.

3) *Socioeconomic factors.* Many of the smaller island nations lack the infrastructure, capital and skilled workforce required to research, develop and implement aquaculture, particularly where hatcheries are involved. Sustained assistance from developed countries is needed to implement and operate stock enhancement programs until they become self-funding (Bell 1996). 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.

4) *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.

5) *Lack of suitable feeds.* Fishmeal and other materials needed to manufacture high-quality feeds required to grow-out high-value species of marine fish and penaeid shrimp are not readily available in the region and must be imported at high cost.

6) *Vulnerability to cyclones.* Many countries within the region experience cyclones. Such adverse weather conditions can destroy aquaculture operations, or cause large financial losses.

7) *Absence of an aquaculture tradition.* Although coastal communities are familiar with the basic biology of species used for aquaculture, there is little tradition in farming species from the sea. Unless the people involved in aquaculture appreciate the need for strict and regular husbandry, aquaculture is unlikely to succeed.

History of Aquaculture Development in the Pacific

Developed countries and international organisations began to assist Pacific nations with aquaculture in the 1950's, 1960's and 1970's. Unfortunately, little progress had been made by the early 1980's (Uwate and Kunatuba 1983). The main problems were: a) the low success rate of projects organised by consultants, b) lack of tangible benefits to coastal communities and islands economies, c) a predominance of ill-conceived, unrealistic proposals and projects, and d) lack of transfer of viable technology developed in Asia to the Pacific.

Uwate and Kunatuba's study provided the impetus for a number of initiatives to develop sustainable aquaculture in the region. A summary of the major ones is set out below.

FAO South Pacific Aquaculture Development Project

In 1985, FAO offered to support development of aquaculture in the Pacific through a Japanese Government trust-funded position, and consideration was given to forming a lead centre, similar to the Network of Aquaculture Centres in Asia and the Pacific (NACA). The lead centre was to demonstrate opportunities and techniques applicable to the Pacific nations. However, the great variety of environmental conditions, and major differences in the economic and social factors affecting production, among nations augured against such a centre. Instead, FAO organised a mission to review the status of aquaculture in the region and to recommend an appropriate form of assistance.

The FAO mission concluded that a regional development project, that encouraged optimal use of existing capabilities, minimised duplication of effort and co-ordinated responsibilities for research, training and exchange of information, would be an effective way to advance aquaculture for the island nations of the Pacific. This concept was supported by the 12 countries visited by the mission. Consequently, the "South Pacific Aquaculture Development Project" (SPADP) was formulated by FAO and approved by the 11th Forum Fisheries Committee (FFC) in May 1986.

The work program for SPADP focused on evaluating the possibilities for aquaculture in the region. The objectives of the SPADP were:

- To raise living standards of the people of the participating countries by improving nutrition, generating income through sales in the domestic markets, providing employment opportunities, and is some cases foreign exchange earnings, through aquaculture production for export.

- To increase regional capability for self-sufficiency in aquaculture development, and to enhance national capabilities for preparation and appraisal of aquaculture plans and projects.

- To achieve sustainable utilization of selected reef resources through recovery/enhancement practices, including the eventual utilization of aquaculture techniques for seed production.

The SPADP commenced in December 1986, and included 15 countries: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu and Western Samoa. The project was based in Suva and funded for five years through a trust fund from the Government of Japan.

A major outcome of the project was the conclusion that there was little similarity in the potential for, and constraints to, aquaculture among countries. For example, the larger countries, especially Papua New Guinea and Fiji, had greater economic capacity to implement aquaculture, and a wider range of suitable species and habitats, including freshwater resources. Features common to all countries, however, were a similar range of species associated with coral reefs and, with the exception of Nauru and Niue, suitable sites for culturing a subset of these species.

In 1991, the 5th Technical Committee of the Forum Fisheries Committee (FFC) and SPC's 23rd Regional Technical Meeting on Fisheries, recommended the continuation of the SPADP into a second phase. In September 1991, a joint FAO - Japan mission evaluated the SPADP with a view to extending funding for a further five years. The mission found that the countries appreciated the

assistance provided by the SPADP, and that it raised awareness of the potential for aquaculture in the region. The second phase of the project began in May 1994.

Phase two of SPADP is due to conclude in 1999. The major activities of the project have been assistance with the development of commercial/export-oriented aquaculture, commercial/domestic-oriented and subsistence aquaculture, and resource enhancement. The main activities within each category are set out below.

Commercial/export oriented aquaculture

- Development of new seaweed commodities (Tonga and Fiji)
- Restoration of *Eucheuma* seaweed farming in Kiribati
- Demonstration of mabe pearl farming potential in Tonga
- Assessment of export potential of cultured giant clams to Japan (Solomon Islands and Tonga)
- Verification of export potential of cultured tilapia from Fiji
- Assessment of sponge farming development in FSM

Commercial/domestic-oriented and subsistence aquaculture

- Augmentation of tilapia farming in Fiji
- Assessment of tilapia potential in Nauru and Samoa
- Boosting of common carp farming in PNG
- Production of rainbow trout eggs in PNG
- Assessment of milkfish farming in Fiji, Kiribati, Nauru and Tuvalu
- Shrimp farming development in Fiji
- Assessment of triploid oyster farming in Samoa

Resource enhancement

- Trochus restocking practices developed in Vanuatu and FSM
- Potential of trochus and greensnail stock enhancement tested in Tonga
- Potential of greensnail introduction assessed in Samoa and FSM
- Fish stock enhancement assessed in Cook Islands (milkfish) and Tonga (mullet)

Center for Tropical and Sub-tropical Aquaculture

The Center for Tropical and Subtropical Aquaculture was established in 1986 by the US Department of Agriculture. It is jointly administered by The Oceanic Institute and the University of Hawaii, and overseen by a Board of Directors. The mission of CTSA is to support aquaculture research, development, demonstration and extension education to enhance viable and profitable aquaculture of tropical and subtropical species in the American Insular Pacific. Each year, the program is developed by CTSA's Industry Advisory Council and Technical Committee. Council members represent financial institutions, aquaculture and agriculture enterprises, government agencies and other business concerns. The Technical Committee includes researchers, extension agents and fisheries officers. Both committees include representatives from American Samoa, the Commonwealth of Northern Mariana Islands, the Federated States of Micronesia, Guam, Hawaii, the Republic of Belau and the Republic of the Marshall Islands.

Bilateral Initiatives

Australia and Japan have both funded bilateral initiatives in aquaculture in recent years. Through the Australian Centre for International Agricultural Research (ACIAR), Australia has supported work on giant clams in Cook Islands and Fiji, trochus in Vanuatu, and research on blacklip pearl oysters in Kiribati and Solomon Islands. Japan is delivering assistance through the Japanese International Cooperation Agency (JICA) and the Overseas Fishery Cooperation Foundation (OFCF). JICA is supporting aquaculture through: i) the development of the Marine Studies Centre at the University of the South Pacific (USP), ii) attachment of experts in aquaculture to USP, iii) projects on giant clams, trochus and greensnail in Tonga, and iv) production of carp and trout in Papua New Guinea. OFCF has projects on propagation of sea cucumbers in Kiribati, trochus and greensnail in Solomon Islands, and giant clams and trochus in FSM. The maximum term of the Australian projects is six years. The terms of the Japanese initiatives is usually five years, although the JICA project in Tonga may extend to 10 years.

International Center for Living Aquatic Resources Management (ICLARM)

ICLARM is part of the Consultative Group on International Agricultural Research (CGIAR) and is dedicated to improving the well-being of communities that use and depend on aquatic resources in the developing world. In the Pacific, ICLARM aims to improve the productivity of aquatic resources for the benefit of island nations through research to develop sustainable methods for aquaculture and stock enhancement.

In 1986, ICLARM established the Coastal Aquaculture Centre in Solomon Islands to serve the region. In 1995, ICLARM restructured its research programs and created a new program entitled "Coastal Aquaculture and Stock Enhancement" (see Appendix 1 for a summary of the new structure). The resources of the Coastal Aquaculture Centre are dedicated to supporting the Coastal Aquaculture and Stock Enhancement Program.

To meet the twin objectives of increasing income and food from inshore resources, and ensuring that the benefits are sustainable, ICLARM's research on aquaculture and stock enhancement in the Pacific is based on: i) species of high value, ii) species low on the food chain, iii) species yielding non-perishable products, iv) low-cost technology, and v) methods that maintain biodiversity by minimising changes to the genetic structure of wild populations, reduce the risk of transferring of diseases and limit deleterious effects on the environment.

In addition to maximising the potential to generate income, ICLARM strives to develop methods that reduce production costs, facilitate export from remote locations and minimise the impact of aquaculture and stock enhancement on wild stocks and natural habitats.

ICLARM tests the viability of the methods it develops for aquaculture and stock enhancement by: i) growing products in collaboration with coastal communities, ii) shipping them to export markets, and iii) assessing whether they can be sold at a profit. ICLARM then produces reports and manuals documenting methods for propagating, growing and shipping species suitable for aquaculture and stock enhancement in the region.

Current Status of Aquaculture in the Pacific

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 and Solomon Islands. These enterprises are applying technology developed originally in Japan and Taiwan, and now commonplace throughout the tropics.

An economically viable, and sustainable, industry for culturing pearls using the blacklip pearl oyster (*Pinctada margaritifera*) has been established in French Polynesia, and at a couple of atolls in the Cook Islands using technology developed for a related species in Japan (Fassler 1995). In French Polynesia, the value of cultured pearls now exceeds US$140 million p.a. In Cook Islands, the industry is currently worth US$6 million and is the second largest source of revenue for the country after tourism.

The initiatives by FAO, CTSA, bilateral donors and ICLARM, 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 JICA and SPADP in Tonga in November, 1995 (Anon 1996) provides the most recent report on the status of aquaculture in the region. A summary of recent progress in initiatives by FAO, CTSA, bilateral donors and ICLARM is given below.

Pearl oysters

Small-scale culture of blacklip pearl oysters is underway in Marshall Islands, Fiji, the Federated States of Micronesia, Solomon Islands and Kiribati. 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. 1997). In Fiji, there is one commercial farm holding 15,000 blacklip pearl oysters collected from the wild.

Current research on blacklip pearl oysters is concentrated on assessing the economic viability of village-based pearl farming, comparing growth, survival and pearl quality of oysters derived from wild and hatchery-reared spat, and developing methods to improve productivity of all aspects of pearl farming.

In Tonga, there is one farm culturing mabe pearls from winged oysters (*Pteria* sp.).

Giant clams

Small-scale hatcheries in Fiji, Solomon Islands, Palau, Marshall Islands, Cook Islands, Tonga, Samoa and American Samoa supply up to 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. 1997). Production of giant clams for enhancement of wild stocks is also underway in Solomon Islands, Fiji, Cook Islands and Samoa (Bell et al. 1997a). 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 is underway by ICLARM in Solomon Islands, and OFCF in Kiribati, 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. fuscogilvia* 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 (Battaglene and Bell 1997), and that *A. mauritiana* grows relatively rapidly at high densities (Ramofafia et al. 1997).

Initial research on *H. scabra* indicates that this species can be kept at high stocking densities and may therefore have potential to be farmed, perhaps in shrimp ponds (S. Battaglene, pers. comm.).

Other Species

Technology for propagating and releasing cultured juveniles of greensnail and trochus has been transferred to the Pacific through projects in Tonga (JICA) and Vanuatu (ACIAR). OFCF is also implementing a stock enhancement program for these species in Solomon Islands and FSM. Production of the marine algae, *Eucheuma*, is well established in Kiribati, 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.

Pre-requisites for Continued Development of Aquaculture in the Pacific

As the SPADP draws to a close, most governments are aware of the potential for aquaculture, and many of them have some of the basic infrastructure in place to apply technology. However, since viable aquaculture methods often take up to 15-20 years to develop, few of the countries have the resources to complete the research required to produce viable, sustainable methods for aquaculture.

It is now evident that aquaculture will only continue to develop in the Pacific if the following conditions are met:

i) methods for species already under investigation are completed,

ii) the completed methods are demonstrated to be economically viable and sustainable,

iii) methods for aquaculture of "new" species are developed and tested,

iv) information on viable methods is disseminated,

v) training in the use of viable methods is provided for the public and private sectors, and

vi) products are marketed effectively.

A summary of the issues involved in meeting each of these pre-requisites is set out below.

Completion of Existing Research

Bell and Gervis (1997) have pointed out that a feature of successful aquaculture outside the Pacific has been the persistent effort to overcome problems encountered in production and grow-out. In general, successful commercial aquaculture enterprises have been reluctant to culture additional species until they encountered intense competition for their produce and could identify alternative markets and products.

Coastal aquaculture in the Pacific is faced with similar considerations. The benefits of developing efficient industries based on relatively few species need to be weighed against the need to diversify and capitalise on new market opportunities. To make such judgements, the potential of a species for aquaculture must be assessed thoroughly. However, the temptation to evaluate too many new species, at the expense of completing studies on promising species already under investigation, should be avoided. This principle is particularly relevant to the Pacific where, with the exception of technology for the culture of penaeid shrimps and blacklip pearl oysters, none of the other aquaculture and stock enhancement developments are mature enough to stand on their own across a range of countries.

The emerging industry for cultured giant clams is a case in point. Although there has been considerable research into development of methods for propagating and growing giant clams (Heslinga et al. 1990; Munro 1993b; Lucas 1994; Bell et al. 1997a), and sales are now occurring to the aquarium market, there are few commercially viable giant clam farming operations in the region. With the prospect of a market for giant clams in the size range of 15-20 cm shell length in the live seafood trade in Asia (Bell et al. 1997b), it would obviously not be in the interests of the region if resources were now diverted from developing giant clam farming into other aquaculture initiatives. Research, development and government support for giant clam farming should continue until a thorough assessment of the viability of the industry is complete.

Demonstrating the Economic Viability of Aquaculture Methods

Development of reliable, sustainable technology for aquaculture and stock enhancement will not necessarily ensure the establishment of viable industries: investment is unlikely to occur unless the technology has been demonstrated to be profitable at the pilot commercial scale.

The viability of promising methods for aquaculture needs to be documented by: i) growing products in collaboration with coastal communities, ii) shipping them to export markets, and iii) assessing whether they can be sold at a profit. In the case of stock enhancement, the increase in value of the harvest due to stock enhancement must be shown to exceed the cost of producing and releasing the cultured juveniles into the wild. The process of verifying the viability of methods requires large-scale applied research.

New Species for Aquaculture

The challenge for countries in the Pacific is to determine which existing aquaculture initiatives need more time to mature, which ones should be abandoned due to limited potential and which "new" species should be investigated. Some of the best opportunities for aquaculture of 'new' species are to be found in the live seafood and aquarium markets (Bell and Gervis, 1997). In all cases, the products must be shipped alive. However, the additional costs of doing so are offset by the fact that most of the demand is for products of a small size and high value. Some of the products now in demand have the additional advantages that the animals can probably be grown in a small area with relatively simple technology.

Two apparently lucrative groups of species that could be cultured for the live seafood trade in Asia are tropical abalone (Haliotidae), and reef fish, particularly the humphead wrasse (*Cheilinus undulatus*) and several species in the family Serranidae (groupers). Methods for the culture of tropical abalone already exist (Capinpin and Corre 1996), so research will need to concentrate on developing inexpensive diets, improving rates of growth and survival, and optimising methods for live shipping.

The live reef fish industry is currently supplied by catching wild fish of market size from countries like Papua New Guinea, Solomon Islands, Indonesia and Australia, and sending them in boats to the Asian markets, or by catching wild juveniles and shipping them to southeast Asia for grow-out in sea cages (Johannes and Riepen 1995). The latter method has potential for aquaculture in the Pacific. The juveniles can be caught in light traps or in "crest" nets and grown-out for several weeks in simple enclosures until robust enough to ship alive to farmers in southeast Asia. The methods used to pack and transport fish for the aquarium trade should be suitable for this enterprise. Alternatively, the juveniles could be grown-out at sites in the Pacific where there is a supply of trash fish or fishmeal, and where the impact of cage culture can be controlled. The capture, holding and sale of juvenile reef fish caught from the wild will also provide the opportunity to evaluate the economics of rearing them in hatcheries. Research is needed to identify the species of reef fish that can be caught and reared efficiently.

Species with some of the best potential to be cultured for the tropical marine aquarium trade include soft corals, hard corals and gastropod "grazers". The apparent advantage of these species is that little extra expense may be needed to propagate and grow them where the infrastructure for farming giant clams already exists. The mechanisms for marketing to the aquarium trade are also already in place in many Pacific countries. Research is required to identify exactly which species of hard corals, soft corals and grazers can be grown profitably, and how best to grow each species.

Dissemination of Information and Training

Once viable aquaculture technology has been developed, the information must be transferred to governments, and the private sector must receive training in the methods. The public sector needs to be made aware of the technology so that they can plan adequately for development, issue appropriate licences and provide initial information for prospective investors. The private sector should be the focus for training because it will be investing in enterprises and implementing development.

Marketing

Marketing is an integral part of successful aquaculture. Most large-scale aquaculture and stock enhancement enterprises worldwide have been developed to meet shortfalls in the supply of marine products in high demand. Once the enterprises are established, marketing is needed to overcome perceived differences in cultured and wild products and to develop and promote new products arising from the basic commodity, thereby increasing overall demand. The aquaculture of Atlantic salmon in Europe is a good example of this process - the market share of Atlantic salmon continues to increase due to a great diversification of products (Harache and Paquotte 1996).

Marketing of aquaculture products is likely to be even more important in the Pacific. Although many of the inshore species in the region are sought-after, some of the aquaculture products differ from those traditionally in demand. The "black" pearls produced by blacklip pearl oysters, and cultured giant clams, are cases in point. The traditional market for pearls is for white gems. Skillful

marketing is needed to create a market of comparable size for black pearls. The traditional market for giant clams in Taiwan is for the adductor muscle of large specimens. This product is no longer available because wild stocks have been fished-out (Munro 1993b). However, giant clam farmers are not willing to grow *Tridacna derasa* and *T. gigas* for the 7 - 10 years it takes for their adductor muscles to reach the acceptable size. They are only prepared to grow clams for 2 -3 years. Thus marketing is needed to convert the traditional demand for the adductor muscle of larger clams into demand for smaller clams, and to create demand for other species of giant clams in the traditional market for *T. crocea* in Okinawa, Japan (Bell et al. 1997b).

A Mechanism for Continued Development of Aquaculture

Long-term research, and the dissemination of information and training, are separate and specialized functions. Fortunately for the region, two of the existing organizations in the Pacific are capable of fulfilling these functions, and completing the pre-requisites listed above to achieve the continued development of aquaculture. The two organizations are ICLARM and SPC. ICLARM is dedicated to long-term research on the development and testing of sustainable methods of aquaculture and stock enhancement, and SPC has traditionally provided services to the fisheries sector, including dissemination of information and training. SPC and ICLARM are proposing to join forces to continue the development of aquaculture in the Pacific at the conclusion of the SPADP in 1999. SPC and ICLARM will be signing a Memorandum of Understanding to achieve the following objectives:

1) Assess the status of aquaculture and stock enhancement in the region.

2) Consult with Pacific island nations to ascertain and prioritize their needs for aquaculture and stock enhancement.

3) Develop methods for viable and sustainable aquaculture and stock enhancement of species regarded as priorities by the region.

4) Liaise with other organizations undertaking research on aquaculture and stock enhancement in the Pacific to ensure that there is no duplication of research.

5) Collate and disseminate information on methods for aquaculture and stock enhancement from all research organizations in the Pacific.

6) Organize training in viable methods of aquaculture and stock enhancement.

7) Encourage other regional organizations to undertake marketing of aquaculture products.

The benefit of this proposal to members of SPC is that they will not have to use their scarce human and economic resources to develop viable technology for aquaculture. The expensive and time-consuming research needed to underpin successful aquaculture will be provided and transferred by stable organizations with a long-term commitment to the region. The resources of the nations themselves can then be directed towards implementing aquaculture, and servicing the aquaculture sector.

ICLARM's Capabilities for Research

ICLARM established the Coastal Aquaculture Centre (CAC) in Solomon Islands in 1986. The CAC is located on 32 ha of waterfront land, 25 km outside Honiara. The CAC is bounded by two permanent freshwater creeks and so ICLARM has the capacity to undertake research on tropical marine species, and the potential to study brackish and freshwater species. The CAC also has a field station near Gizo in the Western Province of Solomon Islands. ICLARM has 50-year renewable leases over both properties. The CAC has a hatchery and algal culture facility and extensive land-based and ocean nursery systems. The CAC has 11 professional staff, including internationally recruited research scientists, and several support staff dedicated to developing methods for aquaculture and stock enhancement. Thus, ICLARM has access to a wide range of species suitable for aquaculture and stock enhancement, the facilities to propagate juveniles, access to habitats to grow them to market size, and arrangements with coastal communities to test whether production methods are viable.

ICLARM is currently the only research organisation in the Pacific dedicated to developing methods for aquaculture and stock enhancement on behalf of all countries in the region. The ability of ICLARM to carry out long-term research to underpin the sustainable development of aquaculture is strengthened through active collaborations with advanced scientific institutions in neighbouring countries. In particular, ICLARM works closely with the Australian Institute of Marine Science (AIMS), James Cook University (JCU) and the University of the South Pacific (USP). The first stage of the Institute of Marine Research (IMR) within USP is due to be constructed next door to the CAC by 1998, and arrangements for the joint supervision of post-graduate students in aquaculture have been discussed. It is envisaged that postgraduate students from USP will make an important contribution to the development of aquaculture in the region by conducting research on discrete components of the long-term projects underway at ICLARM.

Although the focus of the CAC is the development of small-scale farms for species associated with coral reefs, and marine stock enhancement, ICLARM is also in a strong position to transfer technology for the improved methods of farming tilapia developed by ICLARM scientists in Asia.

ICLARM has sufficient space at the CAC to expand its operations to do the research needed to fulfill the pre-requisites for development of aquaculture in the region. ICLARM's Mid-Term Plan provides for taking research on giant clams, pearl oysters and sea cucumbers through to the point of economic analysis of viable methods. Provided the necessary funding can be obtained, ICLARM will appoint and equip additional research staff to develop viable aquaculture methods for those "new" species that are deemed to be a priority for research by the majority of members of SPC.

The Role of ICLARM

ICLARM's primary responsibilities under the proposed arrangements centre on the development of viable, sustainable methods for aquaculture and stock enhancement for use by the region. ICLARM will fulfill the following roles.

1) *Documenting the status of research* - ICLARM will prepare a review of research undertaken in the region to develop methods for aquaculture and stock enhancement. The review will summarize existing technology, identify when it will be ready for transfer by SPC and outline a range a "new" species that could be considered for aquaculture and stock enhancement in the Pacific.

2) *Develop methods required by the region* - ICLARM will seek responses to the review paper outlined above from members of SPC to ensure that its program on "Coastal Aquaculture and Stock Enhancement" addresses the priorities of the region, and does not result in unnecessary duplication. Feedback will be sought via written submissions and at the annual co-ordination meetings to be organized by the SPC's Aquaculture Section within the CPF (see below).

3) *Undertake research of an excellent standard* - ICLARM will employ research staff of the highest calibre to ensure that it can develop viable, sustainable methods for aquaculture efficiently. Research proposals will be reviewed by peers, research will be done in a way that produces unequivocal results, and will be submitted for publication in the best scientific journals.

4) *Test the viability of the methods it develops* - ICLARM will organize grow-out trials to test whether the aquaculture and stock enhancement methods it develops are economically viable. These trials will be done at the pilot-commercial scale in locations typical of the region. ICLARM will enlist the support of its economists from Head Office in Manila, and from other advanced scientific organizations in the region, including USP, for this research.

5) *Transfer of technology* - ICLARM will work with SPC's Aquaculture Section to produce manuals to simplify the transfer of viable technology to the countries of the region. ICLARM's scientists will also participate in training courses organised by SPC.

SPC's Capability to Disseminate Information and Provide Training

SPC's involvement in fisheries dates back to the early 1950's. The early work on fisheries carried out by the SPC was mainly restricted to gathering information, which then led to the establishment of national fisheries services in many of the 22 Pacific Island countries and territories that are members of SPC.

In 1972, the SPC Conference approved the convention of an annual Regional Technical Meeting on Fisheries (RTMF). For many years, the RTMF was the only forum for discussion of regional and national fisheries issues. Recommendations from successive RTMFs have shaped the SPC's fisheries work program over the years, and resulted in the formation of the Coastal Fisheries Program (CFP) during the mid 1970's. Initially, the CFP concentrated largely on assisting the members of SPC to develop their capacities in capture fisheries. During the 1980's, however, the range of services offered through the CFP increased substantially, resulting in a more balanced program of assistance. There are currently six Sections in the CFP (see Appendix 2). These sections address areas in fisheries identified by the members of SPC as requiring intervention at the regional level.

The CFP helps to develop the capacities of nations to survey, assess, harvest, and manage access to small- to medium-scale inshore fisheries. CPF does this through training by skilled fishermen, post-harvest specialists, entrepreneurs, scientists and planners. There is a strong emphasis on sustainable development of the region's inshore fisheries at the subsistence, commercial and industrial levels. The CFP is staffed by 11 professional and 4 support staff.

The work undertaken by the various Sections of the CFP is well integrated. Nevertheless, the 1996 RTMF requested an internal strategic review of the CFP by the SPC secretariat to ensure that its structure and work program continue to meet the wide range of expectations of its members. This

request, along with the imminent termination of the SPADP, has been the major impetus for examining how best to continue the development of aquaculture in the region.

There are no major constraints to establishing an Aquaculture Section within the CFP, provided the necessary funding can be obtained, On the contrary, establishment of an Aquaculture Section in the CFP will enhance the CFP's capacity to provide a full range of services to its members.

The Role of SPC

The Aquaculture Section within the CFP would be dedicated to disseminating information on viable aquaculture technology to the region, and to providing training in these methods. The Aquaculture Section would have the following functions.

1) *Establish a framework to meet aquaculture needs* - SPC will prepare an information paper detailing how the Aquaculture Section of the CFP will operate. The paper will explain the objectives of the Section, its proposed structure, strategies to achieve the objectives and a draft work program. Members of SPC will then be invited to comment on the paper to ensure that the Aquaculture Section will serve their needs.

2) *Networking* - The Aquaculture Section will ensure that all members of SPC are kept abreast of research in aquaculture relevant to the needs of the region. This will be done through an annual coordination meeting of members, SPC, ICLARM, and other organizations such as JICA, JCU and USP, involved in aquaculture research and development. The Aquaculture Section will also convene ad hoc meetings of aquaculture specialists to discuss technical issues of particular relevance to the region. These meetings will also provide the means for reviewing the progress and future direction of research.

3) *Collection and dissemination of information* - With assistance from the Fisheries Information Section, the Aquaculture Section would provide information on aquaculture to members of SPC. This information may be disseminated through the medium of a new Special Interest Group publication devoted to aquaculture.

4) *Training in aquaculture* - The Aquaculture Section would organise both short-term and long-term training. Short-term training, in the form of workshops or field attachments, would focus on specific topics. Long-term training, through attachments of up to 12 months with either the CFP or with ICLARM, would also be arranged for fisheries research staff within the region if required. The Fisheries Training Section and Fisheries Information Section will assist the Aquaculture Section in developing and conducting training courses, and assisting in information gathering, packaging and dissemination.

5) *Advisory services* - Members of SPC will be encouraged to seek advice through the Aquaculture Section on the technical and economic viability of proposed aquaculture projects.

6) *Short-term consultancies* - When members of SPC require specialist advice to implement aquaculture technology, the Aquaculture Section will arrange consultancies by appropriate experts to meet these needs. This may include exchange of experts among members of SPC.

7) *Integrating aquaculture with the CFP Work Program* - During country assignments, CFP staff will report on all fisheries activities in the countries and territories they visit, including initiatives and needs associated with aquaculture and stock enhancement. This will provide all Sections within the CFP with the means to keep abreast of aquaculture developments in the region.

The Role of Pacific Nations

Once viable methods for aquaculture and stock enhancement are available, the onus will be on island nations to implement the use of technology to increase the production of inshore marine resources.

In particular, island nations will need to:

1) Nominate individuals from the public and private sectors for training.

2) Establish infrastructure to facilitate aquaculture and stock enhancement. This involves: a) formulation of national policies to promote sustainable enterprises, b) establishment of licensing sections, c) certification of import/export procedures, and d) construction of national facilities to support aquaculture, e.g., holding tanks for quarantine (Humphrey 1995).

3) Provide appropriate incentives for investment in aquaculture by the private sector.

4) Seek long-term assistance from bilateral donors for hatcheries needed to produce juveniles for stock enhancement - such assistance will need to be sustained until increased returns from the enhanced fishery can be used to operate the hatchery. Bell (1996) outlines several reasons why the developed countries like Japan should be willing to provide such assistance. SPC and ICLARM will assist government officials with the submission of proposals to bilateral donors for such hatcheries by providing technical inputs.

5) Obtain assistance with the marketing of aquaculture products from other regional organizations. SPC will assist in this process by consulting with FFA, the Forum Secretariat and the Economic and Social Commission of Asia Pacific (ESCAP) to promote a regional mechanism to meet this important area of development.

Resources Needed by ICLARM to Implement this Proposal

Although ICLARM receives core funding for its basic operations from the Consultative Group on International Agricultural Research (CGIAR), the amount of money received is insufficient to support all the aquaculture and stock enhancement research needs of the region. ICLARM is helping to fill the gap in funding with grants from the Australian Centre for International Agricultural Research (ACIAR). At present, ACIAR provides funding for projects on giant clams, pearl oysters and sea cucumbers. ACIAR is expected to continue its support for research on these species until the year 2000, and beyond if necessary. However, it is unlikely that ACIAR will provide all the funding needed to finish investigations currently underway and to undertake for the research on 'new' species. ICLARM will need to obtain sustained funding (5 year cycle) to employ and support a Research Scientist for this purpose. The proposed duty statement for the Research Scientist is attached as Appendix 3.

Resources Needed by SPC to Implement this Proposal

SPC cannot establish an Aquaculture Section within the CFP from core funds. There is also little scope for SPC's traditional donors to cover the costs of this activity. SPC will need to obtain funds to appoint an Aquaculture Development Adviser (5 year cycle) to be responsible for the Aquaculture Section within the CPF. This person will be supported by an assistant and, as the need

arises, specialists under short-term consultancies. The proposed duty statement for the Aquaculture Development Advisor is attached as Appendix 4.

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Appendix 1. ICLARM's Research Programs

ICLARM's research covers both marine and fresh waters in important tropical ecosystems - coastal waters; coral reefs and freshwater waterbodies. The research is carried out through the following ten programs:

1. Biodiversity and Genetic Resources

Objectives: The characterization and evaluation of aquatic biota for their conservation and sustainable use by humans, and training in the methodologies used.

2. Germplasm Enhancement and Breeding

Objectives: Development of techniques for improving breeds of fish and training and dissemination of these techniques.

3. Aquatic Environments

Objectives: Assessing and managing coral reef degradation; facilitating decision making in coastal zone management; and improving multisectoral use of inland aquatic resource systems.

4. Fisheries Resources Assessment and Management

Objectives: Tropical fish stock assessment and management; the role of marine reserves in fisheries management and biodiversity conservation; and developing methods for acquiring data for aquatic resources management.

5. Integrated Aquaculture-Agriculture Systems

Objective: Improvement of small farm productivity through the introduction of multi-use waterbodies.

6. Coastal Aquaculture and Stock Enhancement

Objectives: Development of sustainable farming methods for valuable marine resources and improvement of fisheries production through release of hatchery-bred juveniles.

7. Policy Research and Impact Assessment

Objectives: Identification of broadly applicable government-community fisheries co-management models; assessment of aquatic resources research impact; policy analysis of the contribution of fish to food security.

8. Fish Health

Objective: Help prevent and manage future outbreaks of disease in African aquaculture and enhanced fisheries.

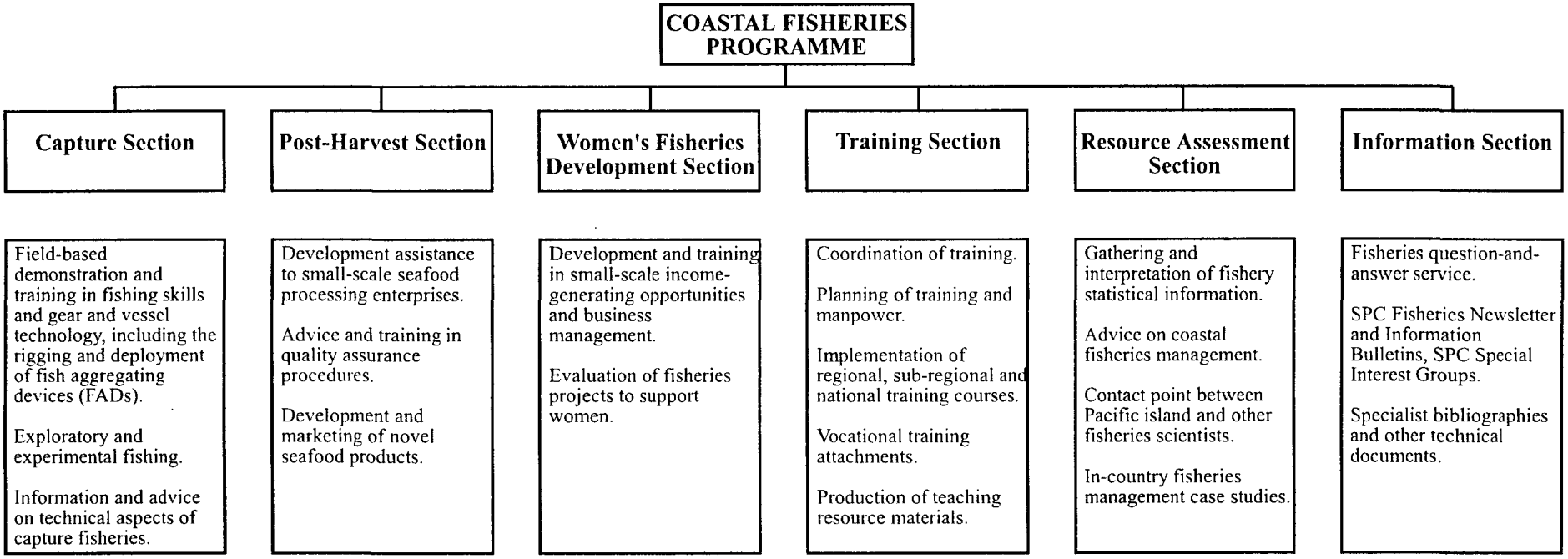
9. Information and Training

Objectives: Provide information services and access for staff and other scientists around the world; promote, in the public arena, aquatic resources issues and ICLARM's role in resolving them; and provide logistical support for the Center's training activities.

10. International Partnerships and Networks

Objectives: Strengthening of existing research and information networks and promotion of new networking activities.

Appendix 2. Structure of SPC's Coastal Fisheries Program



CFP Professional Staff

Capture Section: Fisheries Development Adviser, Fisheries Development Officer, Masterfisherman

Post-Harvest Section: Post-Harvest Fisheries Adviser

Women's Fisheries Development Section: Women's Fisheries Development Officer

Training Section: Fisheries Education and Training Adviser, Fisheries Training Officer

Resource Assessment Section: Fishery Resource Adviser, Inshore Fisheries Scientist, Integrated Fisheries Management Associate (x 2)

Information Section: Fisheries Information Adviser, Fisheries Information Officer, Fisheries Education and Training Associate

Appendix 3. Proposed Duty Statement for the Research Scientist

- Prepares a review of the status of aquaculture technology in the region, assesses when the technology is ready for transfer and recommends research needed to: a) complete the development of aquaculture of species currently under investigation, and b) assess the potential of "new" species for aquaculture.
- Undertakes research to develop reliable, sustainable methods for propagating and growing tropical marine species for the purposes of establishing viable small-scale aquaculture and stock enhancement enterprises of broad relevance to island nations in the Pacific.
- Organises large-scale grow-out trials in coastal villages to test whether aquaculture methods developed by ICLARM are economically viable.
- Ensures that sufficient broodstock are collected and maintained to achieve the research goals described above.
- Supervises research on the reproductive cycles and growth rates of selected species as the basis of achieving reliable production of gametes.
- Ensures that sufficient suitable food (e.g., microalgae) is produced to undertake large-scale rearing of larvae and juveniles of selected species.
- Presents the results of research at regional conferences.
- Publishes the results of research in reputable scientific journals.
- Prepares reports for ICLARM and SPC.
- Liaises with the Aquaculture Development Advisor at SPC to transfer viable technology for aquaculture to the region.
- Prepares research proposals.
- Performs other duties as directed by the Senior Scientist at the ICLARM Coastal Aquaculture Centre.

Appendix 4. Proposed Duty Statement for the Aquaculture Development Adviser

- Acts as a technical adviser to the Manager of the SPC Fisheries Programme, on aquaculture development concerns.
- Provides technical advice, training, and specialist services through the use of consultants to members of SPC.
- Advises members of SPC on the technical and economic viability of proposed new aquaculture projects.
- Ensures that all members of SPC are kept abreast of developments in aquaculture of relevance to the SPC region.
- Organises, and as appropriate, implements seminars, training courses and technical meetings within the scope of SPC's Work Programme.
- Organises an annual coordination meeting of members of SPC and regional institutions involved in aquaculture development.
- Liaises with regional and international agencies working in the field of aquaculture.
- Fosters the exchange of experts among members of SPC through the development of a technical programme.
- Prepares an integrated Annual Work Programme for the information of members and SPC's Executive.
- Publishes articles and technical papers within the scope of SPC's Work Programme.
- With assistance from the Fisheries Information Section, provides information on aquaculture to members of SPC.
- Performs other duties as the Manager of the SPC's Fisheries Programme may require from time to time.