REPORT ON A TECHNICAL AND SOCIO-ECONOMIC BASELINE STUDY FOR FISHERIES DEVELOPMENT IN OCEANIA, WITH SPECIAL REFERENCE TO REEF AND LAGOON RESOURCES AND AQUACULTURE

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Japan International Cooperation Agency (JICA)

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Introduction

Development of fishing industry in the Pacific island states has been severly constrained by the small local population, the limited coastal reef fishery resources, a large number of small islands spread over an extensive area and the high cost of transportation and marketing.

However, the tropical Pacific is rich in highly migratory fishery resources, particularly tuna and skipjack, thanks to the favourable oceanic currents. Unfortunately most of the island states lack necessary expertise, technical competence and capital to exploit those species. Only foreign fishing firms, mainly of Japan, U.S.A., U.S.S.R., France, Korea, Taiwan, Australia, were able to develop those resources. Though those foreign venutures provided a limited employment oppotunities to the local population, particularly those living around fishing ports, most of the profit were taken out of the region by those firms.

Toward the end of the 1970s and at the beginning of the 1980s many of the island states became independent. However, they are still far from being able to achieve economic independence. Some of them have nationalized tuna fishing industry by establishing a national fishery corporation with a fishing fleet, canning plant and cold storage with a view to exporting frozen and canned tuna. However, because of the substantial fuel cost increase and the softening of international tuna market, those firms are experiencing serious financial difficulty:JICA so far has extended its assistance mainly, for commercial tuna fishery development, by providing fishing vessels as well ad land-based facilities. On the other hand, the island states have biologically productive reefs, lagoons, and mangrove areas which provide much needed animal protein and cash income to the local inhabitants. Reefs and lagoons provide excellent habitats to sedentary species, such as shellfish and beche-de-mer, and sea, grass beds as nursery grounds for fin fish and others Those resources, however, are limited and prone to over-exploitation.

Environmental degradation, caused by coastal zone development and cutting down of mangrove forest further contributes to depletion of those resources.

Restocking depleted or overexploited resources must be intensified.

However, the island people have no management and mariculture tradition. How to get those people to become management-minded is therefore a big challenge for donors.

Successful restocking and management of depleted resources require thorough biological knowledge of those resources as well as technical skill to rehabilitate and maintain oceanic environment favourable to stock enhancement of those resources.

The baseline study undertaken this time attempted to see how to introduce the restocking and management programme not only from biological and technical point of view but also from socio-economic, cultural and anthropological points of view.

Field studies were conducted during the period from 3 April to 30 April 1989 with visits to Tahiti, Tonga, Fiji, Vanuatu, and the Federated States of Micronesia. The findings are then reviewed and discussed at a workshop held at University of the Ryukyus from 4 to 6 July 1990. As a result, we feel we have been able to develop a strategy for future development of fishery resources of the island states in the tropical Pacific which JICA and other interested donors may wish to consider in extending future technical assistance to those states.

We wish to express our deep appreciation to all those who have collaborated in this effort both in Pacific island states and in Japan.

Signed UTSUKI
Director, Forestry and
Fishery Technical Cooperation
Division,
JICA

Contents

Summary

With respect to economic and technical assistance by the Japanese Government for the island-countries in the Pacific Ocean, many fishery projects have been carried out because of the rich fishery resources in the region. Particularly for tuna resources, the foreign companies (Japan, Taiwan, South Korea, U.S.A., Australia, New Zealand) have operated commercial fishery with little local involvement and participation, due to the shortage of local manpower, lack of local capital and so on.

However what is the most crucial factor is that most of local men seem not to have working habit necessary for commercial tuna fishing.

JICA has tried to demonstrate technical and economic feasibility of a 27 ton pole and line skipjack tuna boat and of bait fishing project during 1978 - 1981 with much difficulty.

Through the project, we learned that there are still many things to be done prior to commencement of a fishery project.

Improvement of infrastructure has been made and an emphasis has been placed on further development of small scale fishery by which people in the island-countries make their living (Subsistence and artisanal fishery).

The people in the island-countries depend upon the coastal fishery resource for their food.

However, many inshore resources seem to have been over-exploited due to the pressure of increasing population.

Therefore, fishing effort should not be increased anymore. Instead more attention should be paid to management of the existing coastal resources including prevocation of enviromental degradation and rehabilitation of seaweed beds and mangrove areas.

In order to make fishermen resources management minded, a thorough study of their socio-economic behabiour and cultural background should be made..

Secondly aquaculture and restocking of sedentary species should be undertaken to increase the availability of these resources.

Consequently a mission was organized in April 1989 to review the actual situation and suggest a future course of actions for fishery development in the region.

The mission's findings were subsequently discussed and reviewed by a workshop held at University of the Ryukyus on July 4 ∿ July 6 and the following strategy emerged as a result of the workshop.

Strategy for fishery development in the tropical Pacific region

1. The objectives are to increase fish and fish products supply for local consumption and foreign exchange earnings.

2. Technology to be transferred should be adaptable to local condition and sustainable by local population. This calls for a careful study of local culture, habits, tradition, custom and social structure fefore deciding on a technology transfer.

3. Most of the local population has seagoing tradition and not farming. Therefore, in principle stocking of depleted living resources should be promoted and not fish farming.

4. Priority should be given to conservation and protection of existing resources from commercial overfishing, poaching, illegal fishing and environmental degradation.

5. Specifically protection/rehabilitation of seagrass beds and mangrove areas should be promoted.

6. Education of local population as to the importance of resource conservation and stock enhancement should be intensified.
   Resource assessment and monitoring of catches should be conducted for commercially important species.

7. Regarding the resources to be stocked priority should be given to sedentary stocks of high values such as giant clams, trochus, green snail and beche-de-mer. This requires a careful study of currents and existence of predators to identify best stocking sites and timing. Enough research is being done on giant clams but more research is needed for trochus, green snail and beche-de-mer.

8. Stocking of larger rivers and reservoirs by grass carp and giant freshwater prawn (Macrobrachium rosenbergii) could be useful if conditions are favorable like in Fiji.
   Semi-intensive/extensive culture of mullet, rabbit fish and milkfish which require little animal protein feeds could be tried in some coastal areas.

9. When establishing a fishery research center in the region, care should be taken not to duplicate activities being conducted in the region.

Instead it should concentrate on development of stocking or culture system suitable for local conditions. A concept of establishing a network of research centers through the SPC in collaboration with JAPAN/FAO Regional Aquaculture Development Project based in Fiji should be pursued.

10. In formulating a resources stocking or management programme, a pilot/demonstration approach should be considered. The demonstration site should be carefully selected where a strong local leadership exists and where the local population is ready to participate in such a programme.

11. The proposed establishment of an international fishery training center in Okinawa should be strongly supported.
Okinawa is the only region in Japan where climatic and oceanic conditions are identical to those of tropical island states where relevant training can be conducted.

12. Regarding the proposed ODA assistance to Tonga, the rehabilitated research center should concentrate on stocking programme for giant clams, trochus, green snail and semi intensive culture of mullet and rabbit fish. It should also deal with fishery resources management of reefs and lagoons.

Study schedule for group I

1989 (Anraku, Yamaguchi, Shokita, Sasaki)

April 3 (Mon.)	Tokyo	
	Honolulu	visit to the University of Hawaii
4 (Tues.)	Papeete	
5 (Wed.)	Papeete	courtesy call to 'Ministre de la mer' and 'Directeur, EVAAM', meeting with the staff
6 (Thurs.)	Papeete	members of EVAAM, IFREMER and ORSTOM collection of data, reef survey and
7 (Fri.)	Raitea	observation of facilities concerned
8 (Sat.)	Rangiroa	
9 (Sun.)	Papeete	
10 (Mon.)	Papeete	report of the site survey, and exchange of views with the staff members of EVAAM and SMA
11 (Tues.)	Papeete	
	Auckland	
12 (Wed.)	Tongatapu	courtesy call to 'Director of Agriculture, fisheries and forests', and meeting
13 (Thurs.)		with the staff members of fisheries division, and reef survey
14 (Fri.)	Vava'u	meeting with the staff members, and site survey at the reef and the lake. Dr. Sudo
15 (Sat.)		joining the Team and making an anthro-pological study
16 (Sun.)		
17 (Mon.)	Tongatapu	
18 (Tues.)		report of the site survey, and exchange of views, collection of data
19 (Wed.)	Tongatapu	report of the baseline study to the Embassy of Japan and JICA Fiji office,
	Suva	meeting with the staff members of fisheries division
20 (Thurs.)		
21 (Fri.)		exchange views with the representatives of UNDP and FAO

April	22 (Sat.)	Suva	meeting with staff members of 'Ministry of Agriculture, Forestry and Fisheries'
		Port vila	site survey and Dr. Akimichi joining the Team and making an anthropological
	23 (Sun.)	Port vila	study at Aneityum
	24 (Mon.)	Aneityum	fisheries resource survey at Aneityum and Santo
		Santo	
	25 (Tues.)	Aneityum	
		Santo	
	26 (Wed.)	Port vila	report of the site survey, and exchange views with the staff members of the
	27 (Thurs.)		fisheries division, visit to a shell factory and other related facilities
	28 (Fri.)		
	29 (Sat.)	Port vila	
		Nadi	
	30 (Sun.)	Tokyo	

Study schedule for group II

1989 (Sudo)

April	3 (Mon.)	Tokyo	
	4 (Tues.)	Nadi	
	5 (Wed.)	Tongatapu	meeting with JOCV office and staff members of the fisheries division
	6 (Thurs.)		staying with a fisherman family at Hoy village and hearing of the fisherman's
	7 (Fri.)		life and observation of their night fishing
	8 (Sat.)		market survey
	9 (Sun.)		
	10 (Mon.)		collection of data and information market survey
	11 (Tues.)		hearing of the activities of JOCV
	12 (Wed.)		joint survey with the group I and meeting with the staff members of fisheries
	13 (Thurs.)		division
	14 (Fri.)	Vava'u	meeting with the staff members, and site survey at the reef and the lake, making
	15 (Sat.)		an anthropological study on the fisher- man's life
	16 (Sun.)		
	17 (Mon.)	Tongatapu	
	18 (Tues.)		report of the site survey, and exchange of views, collection of data
	19 (Wed.)		staying with a fisherman family at Hoy village and hearing of the fisherman's
	20 (Thurs.)		life and observation of night fishing market survey
	21 (Fri.)		and making an anthropological study on the fishery situation
	22 (Sat.)		
	23 (Sun.)		
	24 (Mon.)		
	25 (Tues.)		
	26 (Wed.)		

April	27	(Thurs.)	meeting with the JOCV and report of the site survey and discussion report of the site survey to the staff members of the fisheries division
	28	(Fri.)	
	29	(Sat.)	Tongatapu
			Nadi
	30	(Sun.)	Tokyo

Study schedule for group III

1989 (Akimichi)

April 3 (Mon.)	Tokyo	
4 (Tues.)	Port vila	meeting with JOCV coordinator
5 (Wed.)		meeting with 'Director of fisheries, Ministry of Agriculture, Forestry and Fisheries'
6 (Thurs.)		site survey, collection of data and information at a free market
7 (Fri.)		
8 (Sat.)	Santo	meeting with staff mebers of fisheries division and site survey and anthropological study on fishing right and possibility of aquaculture
9 (Sun.)		
10 (Mon.)		market survey of green snail and trochus at Luganville
11 (Tues.)		collection of data at Port Orly
12 (Wed.)		
13 (Thurs.)	Malakula	hearing of the fishery situation at Malakula from fishery extension officer and the people concerned
14 (Fri.)		site survey in the Uriviv island
15 (Sat.)		
16 (Sun.)		
17 (Mon.)	Santo	report of the survey to the fisheries division, collection of data
18 (Tues.)	Port vila	preparation for the next survey at Aneityum
19 (Wed.)		meeting with the staff member of fisheries division
20 (Thurs.)	Emae	interviewing with a village chief
21 (Fri.)	Port vila	
22 (Sat.)		meeting with the group I and preparation for the trip to Aneityum
23 (Sun.)		
24 (Mon.)	Aneityum	joint survey with the group I and interviewing with the people concerned at Aneityum
25 (Tues.)		

April	26 (Wed.)	Port vila	report of the survey, and exchange views with the staff members of the
	27 (Thurs.)		fisheries division collection of data
	28 (Fri.)		hearing of fishing right and ownership of reef at the court
	29 (Sat.)	Port vila	
		Nadi	
	30 (Sun.)	Tokyo	

Study schedule for group IV

1989 (Asakura)

April 3 (Mon.)	Tokyo	
	Guam	curtesy call to the Agana general counsel of Japan
4 (Tues.)	Ponape	meeting with the staff members of the marine resources division
5 (Wed.)		
6 (Thurs.)		market survey
7 (Fri.)		staying with a fisherman's family and observation of the life and fishing activities
8 (Sat.)		
9 (Sun.)		
10 (Mon.)		making an anthropological study in the way of questionnaire to the Central Senior High School on fish eating habit
11 (Tues.)		
12 (Wed.)		staying with a fisherman's family and observation of the life and fishing activities
13 (Thurs.)		
14 (Fri.)		
15 (Sat.)		
16 (Sun.)		
17 (Mon.)		
18 (Tues.)		collection of the questionnaire and analytical work for it
19 (Wed.)		
20 (Thurs.)		
21 (Fri.)		making an anthropological study in the way of questionnaire to the Vocational High School on 'fish eating habit'
22 (Sat.)		
23 (Sun.)		
24 (Mon.)		collection of the questionnaire and analytical work for it
25 (Tues.)		

April 26 (Wed.)		
27 (Thurs.)		report of the site survey to the staff members and exchange views with them
28 (Fri.)	Ponape	
	Guam	
29 (Sat.)	Guam	
30 (Sun.)	Tokyo	

Study team

1.	Masateru Anraku	Leader	Senior Advisor, Overseas Fishery Cooperation Foundation (OFCF)
2.	Tomoya Akimichi	Ethnologist	Associate Professor, National Museum of Ethnology
3.	Toshio Asakura	Ethnologist	Assistant Professor, National Museum of Ethnology
4.	Naoyoshi Sasaki	Project Planner	Deputy Director, Fisheries Technical Cooperation Division, Japan International Cooperation Agency
5.	Shigemitsu Shokita	Resource Biologist (Crustacean)	Associate Professor, Department of Oceanography, Faculty of Science, University of the Ryukyus
6.	Ken-ichi Sudo	Ethnologist	Associate Professor, National Museum of Ethnology
7.	Masashi Yamaguchi	Resource Biologist (Mollusca)	Professor, Department of Oceanography, University of the Ryukyus

List of persons interviewed

1. TAHITI

(1)	Tsoris Lêontieff	Ministre de la mer de L'Equipment et de L'Energie
(2)	Patrick Galenon	Director, EVAAM
(3)	Adams Gerald	Aquaculturist, EVAAM (Rangiroa)
(4)	A. Stein	Aquaculturist, EVAAM (Raiatea)
(5)	Stephen Yen	Biologiste, Department Pêche, EVAAM
(6)	Simone Grand	Directrice, Service de la mer et L'Aquaculture
(7)	Jacques Calvas	Head of the Aquacop Team, Centre Oceanologique du Pacifique
(8)	Alain Michel	Directeur, Centre Oceanologique du Pacifique IFREMER
(9)	Paul Vernaudon	Présidént Directeur, Général

2. TONGA

(1)	Haniteli Fa'Anunu	Director of Agriculture, Fisheries, and Forests
(2)	'Aleki Sisifa	Deputy Director, Agriculture, Fisheries, and Forests
(3)	Semisi Fakahau	Principal Fisheries Officer, Fisheries Division

(4)	Uluan Faamuvu	Aquaculture Officer
(5)	Sarah Langi	Research Officer, Fisheries Division
(6)	Viliami Langi	Head of Research Officer, Fisheries Division
(7)	Sione Hoeaki	Marine Engineer, Fisheries Division VAVAU
(8)	Lomio Tonga	Electrician, Fisheries Division, VAVAU
(9)	Uanoa Toutai	Fisheries Extension Officer, Fisheries Division, VAVAU
(10)	Tooru Abe	Coordinator, JOCV Tonga Office
(11)	Tadashi Kimura	JOCV

3. FIJI

(1)	Robert Gillett	Fisheries Development Advisor, UNDP
(2)	Abdul Latif	Deputy Resident Representative UNDP
(3)	Keith Meecham	Programme Director, UNDP
(4)	Hideyuki Tanaka	Regional Aquaculturist South Pacific Aquaculture Development Programme FAO
(5)	Surendra Sewak	Principal Fisheries Officer
(6)	Toshio Isogai	Ambassador, Japanese Embassy
(7)	Yoshio Yoshida	Resident Representative, JICA Fiji Office

(8)	Shunichi Mizoochi	Representative Associate, JICA Fiji Office
(9)	Nobuo Itoi	JICA expert

4. VANUATU

(1)	Wycliffe Bakeo	Director of Fisheries, Ministry of Agriculture, Forestry and Fisheries, Government of Vanuatu
(2)	George David	Researcher, ORSTOM Department of Fisheries, Port Vila
(3)	Larry Valence	Fisheries Consultant NATAI Fish Market, Box 883, Port Vila
(4)	John Lee	Manager, Santo Fish, Luganville, Espiritu, Santo
(5)	Neil Crysler	Santo Extension Officer, Luganville, Espiritu, Santo
(6)	Robert Frosty	Fisheries Extension Officer, Lakatoro, Malakula
(7)	Yoshiko Taniguchi	Coordinator, VOCV Vanuatu Office
(8)	Jean-Michel Guerin	Ingenieur Agrorome de l'Ensar

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FOR
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WITH SPECIAL REFERENCE TO
REEF AND LAGOON RESOURCES
AND
AQUACULTURE

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CONTENTS

INTRODUCTION

Tropical islands of Oceania are characteristically fringed with extensive coral reefs and to a certain extent by mangrove forests around the shores. The people of Oceania have traditionally relied on fishery resources from reefs as one of the most important protein sources for subsistence. After establishment of contacts with outside world, some of the marine resources from coral reefs, such as beche-de-mer, pearl shells, trochus etc. became important export commodities for their cash income.

Despite its importance to the people of the tropical Pacific, relatively little attention has been paid to the inshore fisheries until recent upsurge of concern about its grim future outlook. Many fisheries authorities of member countries of the South Pacific Commission (SPC) expressed their concern and requested SPC to assist their needs in research and development in this aspect. In response to these, the Inshore Fisheries Research Project (IFRP) was established in 1987 under the SPC Fisheries Programme. This IFRP assists to support surveys and assessment of various resources in the region and held a major Workshop on Inshore Fishery Resources, in 1988, which brought together fishery specialists and marine biologists from throughout the tropical Pacific (South Pacific Commission, 1988; Yamaguchi, 1988b). This workshop resulted in valuable and comprehensive documentation on the status of the fishery in the tropical Pacific region.

Aquaculture has been considered as one of the possible avenues to developing fishery industry in the Pacific region (e.g. Brewer and Corbin, 1984). However, the past performances in aquaculture development activities have been rated as poor or unsuccessful in the majority of cases. This is mainly due to more or less inevitable constraints in the small scattered nations with poorly-developed infrastructures, small internal and remote outside markets, lack of incentives among the people in subsistence economy and so on. Nevertheless, the interest in aquaculture in its broader sense, including stock enhancement by marine ranching etc., is being revived by establishment of the FAO South Pacific Aquaculture Development Project in 1987.

The majority of nations in the tropical Pacific depend heavily on financial and technical assistance from international, regional, and individual national organizations for their research and development in fisheries. Many of the major aid donors in the region (FFA, SPC, UNDP, FAO, USAID, and BDDP) organized a joint fisheries strategy mission to investigate opportunities

for fisheries development assistance in the South Pacific (excluding French and U.S. territories) in 1988. Unfortunately, none of the Japanese agencies such as JICA and OFCF were represented in this mission.

The present paper is one of the reports on a fact-finding mission by the Japan International Cooperation Agency (JICA) on fishery assistance and cooperation in Oceania in April 1989. The reef and lagoon resources and aquaculture were the main topics of the present mission. Overviews of these for each individual country/territory and accounts of major inshore resources (mainly molluscs) are presented here as references for those who are concerned with fishery development in Oceania. The views expressed here are those of the author and do not necessarily represent those held by JICA.

1 Overview of Countries/Territories

Recognizing that the South Pacific nations are among the highest per capita aid recipients in the world, Cole and Parry (1986) pointed out negative aspects in the effects of aid in a small economy. Development assistance may cause expansion of government employment beyond local capacity, raising wages and salaries and rates of exchange might become overvalued, biasing the economy against exports and in favor of imports. The smallness would be the major constraint in dealing with the development in Oceania if we maintain the traditional ways and means in assisting economic development.

Indeed, the nations and territories under consideration are small in sizes of population and land area, except for Papua New Guinea (Table 1). Nevertheless, population sizes have been increasing rapidly, except for the areas with high emigration. Furthermore, urbanization has been extensive for the most nations and territories. Thus, the subsistence economy of islands has rapidly been disintegrating and the cash economy, which is dependent on aids from outside world, has been established in the urban centers of each nation/territory.

Many island nations and territories share the same constraints such as mentioned the above and they may be grouped according to similaritiies in cultural and/or geographical backgrounds. However, individual nations are unique in their cultural heritage, history, relative size, topography, degree of reef development etc., so that it is impossible to discuss them as groups of nations in this report. The following accounts will discuss

the general overview of each nation/territory with regard to fishery and its development, emphasizing inshore resources and aquaculture.

Table 1. Summary of Island Nations in Oceania (in order of population size)

Country or Territory	Population		Land Area sq. Km	Aid per capita US$ 1983
	1985	1970		
Papua New Guinea	3,328,710	2,460,000	462,840	(k60)
Fiji	696,000	524,457	18,272	49
Solomon Islands	270,600	160,998	29,785	108
French Polynesia	172,500	112,000	4,198	1,170
Western Samoa	163,400	144,600	2,842	172
New Caledonia	153,000	100,579	19,058	1,246
Vanuatu	142,000	86,000	14,763	213
Guam	115,756*	86,926	549	317
Tonga	109,000	87,406	747	173
Federated States of Micronesia	86,950	57,263	721	1,018#
Kiribati	64,000	43,578	868	285
American Samoa	35,400	27,769	197	1,615#
Marshall Islands	33,600*	20,206	205	(531)
Northern Mariana Islands	19,110+	12,256	471	---
Cook Islands	18,200*	21,622	237	517
Palau	15,000*	12,525	487	1,885*
Wallis and Futuna	12,391+	8,372	255	---
Tuvalu	8,050*	5,782	26	525
Nauru	8,000+	6,927	21	0
Niue	3,800+	5,303	263	1,866
Tokelau	1,650*	1,687	12	900
total (rounded)	5,457,000	3,986,000	557,000	

(*: 1984, +: 1983) (#: 1986)

NOTES: (1) PNG per capita aid of k60 is in Kina (1985).
(2) Marshall Islands receives a large sum of revenue from the U.S. military sources.

Because a period of only 4 weeks was available for field trips, only four (French Polynesia, Tonga, Fiji, and Vanuatu) of the many nations/territories were visited by the present author during this mission. Information from the remaining localities (excluding Papua New Guinea, Nauru, Niue, and Wallis and Futuna) has been accumulated by the author during previous trips to some of the islands and through correspondences and literature surveys.

1-1 Countries visited by the study team in April 1989:

French Polynesia

There are around 130 islands, of which 84 are atolls and the most of the remainder are high volcanic islands, in five distinctive archipelagos: Society, Tuamotu, Gambier, Marquesas, and Austral Islands (IUCN/UNEP, 1988). Total lagoon area of about 7,000 sq. Km is greater than total land area of about 4,000 sq. Km. Total population was estimated at 192,000 in 1988. The capital Papeete is located in Tahiti in the Society Islands.

Lagoon and reef fisheries are mainly at subsistence level in the remote islands and rural areas outside the urban centers. However, artisanal fisheries using fish weirs in lagoons and also trolling for pelagic fishes are developing to supply fresh fish for markets in urban centers (Blanchet, 1985; Morize, 1985; Stein, 1988; EVAAM, 1988). Among molluscan reef resources, a small giant clam Tridacna maxima, an octopus, and a turban snail Turbo setosus were noted as important for food (Salvat and Rives, 1986).

Trochus niloticus was introduced to French Polynesia from Vanuatu in 1957 and it became established as an important resource after opening of its exploitation in 1971 (Yen, 1985). Trochus was further transplanted to the islands of other Society Islands and also to those of Tuamotu, Gambier, and Austral Islands from 1963 to 1972 (Yen, 1988). In Raiatea/Tahaa, the present author saw abundant trochus on the reef, awaiting harvest. A total of 1,553 tonnes of trochus shell was harvested in French Polynesia from 1971 to 1985.

Green snail Turbo marmoratus was also introduced to Tahiti from Vanuatu in 1967 and has become established but harvesting has not been allowed, pending resource assessment (EVAAM, 1988). Although exploitation of green snail was banned, large numbers of both polished and unpolished shells of this gastropod are offered for sale at the market in Papeete.

People of French Polynesia extensively use shell necklaces as gifts and ornaments. Shell crafts and decorative shell specimens are also important in the tourist trade. Therefore, large quantities of such shells and their products are found in the local markets. Impressive quantities of a bivalve shell, Fragum fragum were found among them. Glude (1972) noted its abundance in certain atolls in Tuamotu Islands. This bivalve shell has symbiotic

zooxanthellae like tridacnids but inhabits shallow sand-flats in lagoons and reef flats.

Richard (1977 and 1982) studied production of lagoon and reef molluscs in French Polynesia. In his study, the small giant clam Tridacna maxima was abundant and its standing stock was estimated as 530 tonnes representing 14 million individuals in Takapoto lagoon (78 sq. km). Standing stocks of a few other dominant lagoon bivalves such as Arca ventricosa at Takapoto and Cardium (= Fragum) fragum at Anaa Lagoon were also estimated as 340 and 2,200 tonnes, respectively.

Edible local oyster, Crassostrea cucullata, was once promoted to develop its aquaculture in Raiatea and Tahaa but is now forgotten after collapse due to the problem of parasitic polychaetes. Transplanted oyster from New Caledonia (Crassostrea echinata) also failed to be established for replacement. Attention has been given to the green mussel, Perna viridis introduced from the Philippines, in the recent years. A hatchery of IFREMER at Tahiti produce its spat for cultivation around the Society Islands. However, suitable farming grounds having good nutrient supply for the filter-feeder, but without stressful changes in salinities etc., appear to be very limited in French Polynesia.

In 1987, French Polynesia imported a total of 55.6 tonnes of mussels mainly from New Zealand. At present, the IFREMER hatchery has a capacity of spat production for cultivation of green mussel of up to 30 tonnes per annum, but actual productions were 13.4 and 6 tonnes in 1986 and 1987, respectively (Bulletin Statistique du Secteur de la Mer, 1987).

The most important aquaculture in French Polynesia at present is that of the black-lipped pearl oyster Pinctada margaritifera and its black pearl production. Despite efforts by hatcheries of EVAAM in Rangiroa and IFREMER in Tahiti, artificial spat production has not been successful. A large number of fishery cooperatives in many islands of the Tuamotu and Gambier Islands, therefore, depend on natural spatfalls in lagoons of several islands, such as Takapoto, for production of the shell (Cabral et al., 1985). Heavy mortalities of the pearl oysters by unknown causes have been experienced at closed lagoons since 1985 (Sims, 1988b).

A trial culturing of the seaweed Eucheuma sp. was being attempted privately in the lagoon off Uturoa in Raiatea. Although marketing of this seaweed

may be a problem, it grew well at the experimental site. Many islands of the Society Islands are surrounded by wide and deep lagoons, providing well-sheltered and relatively nutrient-rich areas for such cultivation.

Staff of EVAAM expressed their interest in introducing the smooth giant clam Tridacna derasa, possibly from Palau. As there are abundant habitats for this species to grow, and because the only existing species of giant clams (T. maxima) is heavily exploited for food, it would become a good supplement to the local subsistence fishery.

Tonga

The Kingdom of Tonga consists of a total of 171 islands, 37 of which are inhabited. These are mainly elevated coral reefs which cap the peaks of two parallel submarine ridges. Several small volcanic islands are found along the western ridge. These islands are subdivided in three major groups as Vava'u, Ha'apai and Tongatapu (IUCN/UNEP, 1988). The capital Nuku'alofa is located in the southern Tongatapu Island. The total population was estimated at 94,535 in 1988 but there are large numbers of Tongans living outside the country in Canada, New Zealand, and U.S.A.

Extensive and intricate lagoons are surrounded by elevated and flat-topped limestone islands in the Vava'u Group. Numerous small limestone islands and islets along with submerged coral banks are scattered in the Ha'apai Group. Tongatapu is the largest island of the Kingdom (257 sq. Km, the highest elevation 82 m) and there are two chains of islets with well-developed coral reefs off both ends of the north coast. Fanga'uta Lagoon is a shallow enclosed embayment on the northern coast of Tongatapu. Except for a few in volcanic islands, such as 'Eua, there are no rivers in the limestone islands in Tonga.

Several important marine benthic species appear to be missing in Tonga. For example, commercial top shell (Trochus niloticus), and green snail (Turbo marmoratus) are not found along the Tongan reefs. Red-lipped stromb (Strombus luhuanus) is likely to be missing in the extensive shallow lagoon floors and reef flats suitable as habitats for the species. This is probably because the island groups are located outside the rich Indo-Malayan Sub-region of the Indo-West Pacific. Many Indo-West Pacific species are limited in their distribution to Fiji Islands in the east, not extending to Tonga.

Bondurant (1987) reported the most commonly consumed and the most preferred shells as Anadara scapha, Turbo setosus, Atrina vexillum, and Tridacna sp. in Vava'u. I found that the bivalve shell A. scapha, fresh and dried octopi, intestines of sea cucumbers, and giant clam meat were offered for sale at the fish market in Nuku'alofa. Large quantities of the bivalve shells of Gafrarium spp. were found from coastal middens in Tongatapu, indicating their availability for prehistoric consumption (Spennemann, 1987).

Exploitation level of shallow inshore resources was considered to be nearly equal to the maximum sustainable yield, at about 2,000 tonnes per year, estimated by the Fisheries Divison, the Ministry of Agriculture, Fisheries, and Forests (Fifth Five-Year Development Plan, 1986-1990, Kingdom of Tonga, 1987). The total potential yield from all sectors of fisheries, if the pelagic and bottom resources were fully exploited, was estimated to be large enough to provide protein needs of the present population of Tonga.

Considerable efforts have been made to develop commercial and artisanal fisheries in the past decade in Tonga, exploiting underdeveloped offshore and deepwater resources (Koloa, 1987). These and low net population growth, due to emigration, contributed to offset the fishing pressure against inshore resources. However, the relatively more vulnerable sedentary resources such as giant clams are considered to be threatened (McCoy, 1980; Chesher, 1987). A species of indigenous mussel known as "kuku" (Modiolus auriculatus) was once abundant in lagoons of Vava'u and Tongatapu but is now almost non-existent as a resource.

The Ministry of Lands, Surveys and Natural Resources (Ecology Division), in 1986 initiated a program to collect and hold larger giant clams in circles as broodstocks in natural waters, although the Fisheries Division expressed concern about the effectiveness of such attempts (Langi and 'Aloua, 1988). About 100 clams were originally placed in two circles, at about 1.5 meter distance to each other of the next individual, in front and offshore of the central town of Nuku'alofa. During the visit, the present author examined the site of this clam circle and found 85 live clams, 5 of which were Tridacna squamosa and the rest T. derasa, 1.5 to 3 meters in depth on muddy-sand bottom. Colors of their mantles were not as vivid as those found for the animals in clean offshore waters and at least five dead, empty shells were found in rather turbid water there.

The clam circle at Nuku'alofa is questionable in its function and value as a broodstock, because of its location at unnatural habitat where the animals were likely to be under stress from reduced salinities and extensive siltation during the rainy season. However, another clam circle established in Vava'u appeared to be located at an ideal place, if poaching was not a problem.

Aquaculture research and development was initiated in the early 1970s, focusing on mullets and milkfish in lagoons of Tongatapu and oysters and mussels in Vava'u and Tongatapu. Attempts to introduce seedstocks of various oysters from New Zealand, Fiji, Japan and Tasmania as well as those of green mussel Perna viridis from Southeast Asia failed after repeated trials in latter half of the 1970s and early 1980s because of high mortalities and/or poor growth etc. as well as poor prospects for marketing (PIDP, 1984).

Although there were some local pearl oyster species, they were not abundant enough for cultivation of pearls. Tasaki Pearl Company of Japan introduced four species of pearl oysters, Pinctada margaritifera, P. maxima, P. furcata and Pteria penguin, to Vava'u in 1977. Feasibilty of pearl culture was assessed by trial productions and the company proposed to develop such an industry by establishing hatchery production of pearl oysters, on the condition of exclusive rights to cultivate pearl oysters in Tonga. The Government of Tonga denied such rights and instead suggested a joint venture which has not been realized to date.

Cultivation of fishes, such as native milkfish and mullets as well as introduced mollies and tilapia, as food or baitfish all resulted in poor records in the past attempts. Although a mariculture center was donated by JICA in 1978, near the experimental ponds already constructed by U.S. Peace Corps earlier, it did not function well due to a lack of trained personnel and coordinated planning. This facility was severely damaged by a cyclone in 1982 and has not been used as such since. Kafuku and Ikenoue (1987) suggested rehabilitation of this facility to develop aquaculture mainly of mullets in Tonga.

Cultivation of commercial seaweed Eucheuma spp. was the major aquaculture project since a pilot culture was initiated in Vava'u in 1982. A joint venture between the Government and a New Zealand firm was established in 1984, with finacial assistance for the project from a Commonwealth fund while technical assistance was provided by New Zealand.

In 1986, a total of ca. 10 tonnes of dry Eucheuma valued at about T$5,000 were harvested by 20 algal farmers. However, the farming of the seaweed did not continue to develop because of marketing problems. The present author visited one of the experimental farm in Vava'u and found it in a state of near collapse, although a caretaker was still working and a textbook for cultivation of the seaweed in the local language was made by a JOCV for promotion of the farming (Matsunaga, 1988).

According to the development plans for 1986-1990, Eucheuma, mullets and tridacnid clams were listed as target species for aquaculture research. Trochus was listed as a species for introduction and aquaculture, and also local oysters for pilot culture. To date, none of the above were studied thoroughly for development, research on marketing not being considered in advance. It appears that "intensive aquaculture" is premature under the prevailing circumstances in Tonga. Perhaps, more attention should be given to research into conservation of inshore resources under pressure and also introduction of "missing" resources such as trochus and red-lipped stromb to increase potential resources not being realized by their absences in the respective habitats.

FAO/UNDP Regional Fishery Support Programme published a useful fisheries bibliography for the Kingdom of Tonga (Gillett et al., 1988).

Fiji

Fiji comprises about 844 islands and islets (of which about 106 are inhabited), including the two main islands of Viti Levu and Vanua Levu plus several larger islands such as Taveuni, Kadavu and Gau. Geographic as well as oceanographic features of many of the islands and associated reefs are described by IUCN/UNEP (1988). The capital Suva is located at the windward coast of Viti Levu, the largest island of Fiji. The total land area is ca. 18,000 sq. Km (ca. 90 % of this total by the two main islands) and the total population 715,000 (1987 estimate).

Reefs are well-developed, forming complex structures around the majority of islands in Fiji. An extensive barrier reef system is found off along the northern coast of Vanua Levu (Great Sea Reef). Some atolls and atoll-like reefs are scattered in the eastern Lau Group. Although the islands of this group are close to each other, they are often separated by deep water,

down to 1,500 m. There are fringing reefs, sheltered by offshore barrier reefs and having muddy intertidal flats and mangrove forests along the shore, in some areas in Viti Levu and Vanua Levu. Mangrove forests of the main islands are subjected to significant pressure by reclamation for agricultural and other land development (Lal, 1984).

Fiji has been fortunate enough to have industrial fisheries developed with a tuna cannery and a fleet of off-shore fishing boats, as well as commercial fisheries exploiting deep-bottom resources of snappers and groupers. According to the annual report of Fisheries Division for 1988, Fiji exported ca. 850,000 cartons of canned tuna valued at $46.7 million and 244 tonnes of fresh or frozen fish (mainly deep-water snappers) at $1.26 million. Nevertheless, artisanal and subsistence fisheries are still of great importance to the local communities, both urban and rural. The outlets for such fisheries are complicated and difficult to be assessed, but the Fisheries Division collected statistical data on the small scale fishery by license system and estimated that 4,748 tonnes of fresh or frozen fish and 2,119 tonnes of non-fish resources were sold through various outlets in 1988, including direct sales to hotels and restaurants, roadside sales, etc. On the other hand, a reliable estimate for subsistence catch is not available. The Fishery Division uses a rough estimate of 14,000 tonnes as a total catch of subsistence for 1980, based on an interview survey, plus a growth of 200 tonnes per year. Thus, more than half of the total catch (27,000 to 28,000 tonnes per annum for 1982-1988) was derived from the subsistence sector.

Table 2 Exports of non-fish marine resources from Fiji, 1987 and 1988.

export commodity	1987	1988	main destination
beche-de-mer tonnes	640.4	717.4	Hong Kong, Taiwan, Singapore
($1000)	(2,234)	(2,852)	
trochus shells	250.4	398.5	Japan, Hong Kong, Korea
	(987)	(2,010)	
mother-of-pearl shells	23.2	57.5	Japan, Hong Kong, Taiwan
	(147)	(465)	
turtle shells	2.0	0.18	Japan, France, Tahiti
	(113)	(16.5)	
dried seaweed	216.9	60.3	New Zealand
	(137)	(21)	
corals and others	---	---	Japan, USA, Korea, W. Samoa
	(136)	(159)	

Non-fish marine resources such as trochus, mother-of-pearl shells, and beche-de-mer etc. are important export commodities in Fiji. The above table indicates such exports in volume (metric ton) and value ($1000) for 1987 and 1988.

Dried sea-cucumbers (beche-de-mer) markets have been expanding rapidly since the mid-1970s (Conand, 1989). A vast increase in export trade of this commodity recently took place in Fiji, because of the market demands for low-grade species in shallow waters, which were considered to be vulnerable. Therefore, the Fisheries Division is undertaking beche-de-mer resource surveys with financial and technical assistance by SPC (Anon, 1988) and recently imposed minimum size limits for all species, as an interim measure.

A private Japanese firm was established for producing black pearls using black-lipped pearl oysters in 1966. Development of this industry appears to be limited by poor local supplies of the pearl oyster (Adams, pers. comm.).

Four local button-blank factories have been established in Fiji since 1984. Therefore, local demand for the trochus shells has been increasing. The local trochus price doubled in 1988 in response to the increased demand. The Fisheries Division recommends 500 tonnes per year as maximum allowable exploitation for trochus but 1988 harvest (including that for domestic use) exceeded this.

Although green snail (Turbo marmoratus) was reported to be present in Fiji (Cernohorsky, 1972), Dr. T. Adams of the Fisheries Division indicated that he had not seen any specimen of this species. The present author did not find it among large quantities of various specimen and ornamental shells offered for sale to the tourists in several souvenir shops and also in the central market in Suva. Parkinson (1982) listed specimen shell resources of Fiji but did not indicate presence of the green snail.

Licensed export of giant clam meat, mainly of Tridacna derasa, by domestic commercial harvest, started in 1984 (Adams, 1988; Lewis, et al., 1988). This commercial exploitation also supplied the local market and likely added significant impact against the remaining stocks that were inaccessible for the subsistence sector. The following table, cited from Lewis et al. (1988), indicates estimates of non-subsistence harvest for giant clams in Fiji. Giant clam stocks of larger species were also subjected to poaching

by foreign fishing vessels in the early 1980s and earlier. Export of giant clam meat was prohibited in December 1988, for a 10-year period.

Table 3 Production figures for giant clams in Fiji, 1979-1988, by outlet type (meat weights in tonnes, for mantle and muscle).

Year	Municipal markets+	Wholesale and retail outlets*	Exports*	yearly total
1979	6.79	...	...	6.79
1980	13.83	0.23	...	14.06
1981	13.41	4.65	...	18.06
1982	11.96	...	...	11.96
1983	12.70	4.62	...	17.32
1984	8.35	33.85	7.3	49.5
1985	7.14	9.46	20.8	37.4
1986	13.74	5.32	11.42	30.48
1987	4.01	17.65	10.69	32.35
1988	8.96	13.13	37.52	59.61

+ : includes some whole shell figures
* : more than 95% Tridacna derasa

The above table did not include figures by poaching and susbsistence, which are very difficult to assess. Nevertheless, Lewis et al. (1988) remarked that even subsistence consumption could severely deplete tridacnid populations near populated areas. The smaller ubiquitous species such as Tridacna maxima and T. squamosa have been used for subsistence within traditional fishing rights areas. They are now in very low population densities near urban centers, according to the survey results by Lewis et al. (1988). In a case study of socio-ecology at Lakeba Island, Lau Group, Salvat et al. (1977) indicated that giant clams had been overexploited by the local residents even for subsistence.

The largest giant clam species Tridacna gigas appears to have become locally extinct in Fiji in the last two decades, the last known live specimen having been collected in the mid 1970s (Lewis et al., 1988). An inshore species of horse shoe clam Hippopus hippopus is also extinct and its shells are found commonly in coastal middens (Lewis et al., 1988). Overexploitation might be responsible for this prehistoric extinction of very vulnerable resource, although it is difficult to prove.

The Fisheries Division has a field station with a giant clam hatchery at Makogai Island and is rearing juvenile T. gigas introduced from Australia for restocking, as well as spawning trials on local T. derasa and T. squamosa.

During low tides, many women and children are found collecting shells and other edible organisms on many well-developed reef-flats in Fiji, as in most of the islands in the tropical Pacific. These activities are mostly for collecting subsistence food and hence it is hard to evaluate significance of their contribution to the local economy. In fact, such subsistence fishery as shell-collecting has received little attention scientifically. However, Squires et al. (1973) reported on a case study of shellfish collecting at Wailoaloa Beach, Nadi. In this study, standing stocks of dominant shells were assessed by belt-transect survey and meter-grid collection, and fishing activities by local fisherwomen were observed. Because the fishing was limited to the shallower sector of the reef-flat where the fisherwomen could wade, the most dominant shell (Anadara spp.) stock was exploited without danger of overharvesting. If this fishery were developed to a commercial level using advanced methods of collecting, in order to supply local markets in return for cash income, this shell resource would easily become a victim of overexploitation.

Glude (1972) recommended aquaculture development of edible oysters of both indigenous and introduced species at various localities in Fiji. Later, Japanese oyster Crassostrea gigas spat and also those of C. iredale from the Philippines were introduced for aquaculture trials in 1975. JICA supported an oyster aquaculture development project from 1983 to 1985 (Institute for International Cooperation, 1989) but all these attempts failed to establish the cultivation, because of poor survivorship due to disease etc. Green mussel seeds were introduced for development of commercial cultivation but resulted in failure as well, perhaps because site selection was not appropriate.

Cultivation of a commercial seaweed Eucheuma alvarezii var. tambalang (= E. cottonii) has been established in Fiji, although this industry is experiencing a marketing problem. In 1987, 240 farms in Bua area produced 277 tonnes of dried Eucheuma, which were exported to New Zealand. However, this market was closed and alternative ones in Europe had to be sought after. According to Dr. Adams, reorganization of farmers is underway to establish larger-scale farming of this seaweed.

The first commercial exploitation of hermatypic (= reef-building) corals began in 1985, although these corals had been used by the local communities for construction and curio-trades etc. for many years (Viala, 1988). Certain coral species with intricate colony forms appeared to be preferred, judging from the list of species exploited. Thus, it is likely that some species are more heavily exploited than others. Because reef-building corals are fundamental components of the coral reefs and also they are slow-growing, their exploitation has been closely monitored by the Fisheries Division, in order to assess effects of such fishery, and exports have been limited to one licenced company.

If we consider certain reef-building corals as resources for export from the islands such as those in Fiji, life-history and ecology of the species in question should be studied in detail, with emphasis on reproduction and growth, so as to exploit them wisely. Many corals reproduce at very limited time periods in a year, usually within a week after full moon in the months of early summer, at least in the Great Barrier Reef of Australia (e.g., Harrison et al., 1984), and in the Ryukyus (Heyward et al., 1987), so that the larvae of desired species might be collected as seeds for artificial farming of coral colonies.

Vanuatu

The Republic of Vanuatu attained independence in 1980, after dual administration by France and U. K. as a condominium of New Hebrides since 1906. The archipelago consists of more than 40 islands in double chain of islands and the capital Port Vila is located in Efate Island. Total land area is ca. 15,000 sq. Km and the population 144,900 (1986).

The majority of islands are volcanic in origin and are in general surrounded by narrow fringing reefs with steep reef slopes and drop-offs. There are, however, lagoon systems and mangrove areas around islands such as Malakula and Hiou. The total coral reef and mangrove areas are estimated as 10,600 sq. Km and 25 sq. Km, respectively (David, 1985a).

The coral reefs of Vanuatu are diverse in geomorphology. Being tectonically active, uplifted fringing reefs are found around Efate, Santo, and Malakula, more than 300 m high in some places (Guilcher, 1974 and 1988). There are submerged karst formations around Maskelynes Islands south of Malakula. In

the northern district of Banks and Torres, there is a bank reef or a large patch reef (Guilcher, 1988). Atolls and barrier reefs are not found in Vanuatu.

Fisheries Department of the Ministry of Agriculture, Forestry and Fisheries, Government of Vanuatu was originally set up in 1978 in order to develop fisheries by exploiting resources including deep-sea demersal fishes. The first programme for the development of fisheries in Vanuatu was drawn up in 1981 and its main objectives were to develop coastal fisheries to supply local demand for fresh fish and to develop a locally based tuna fishery as well as to build up capabilities of providing assistance to the fisheries sector by trained personnel (Annual Report for 1981-1982, Fisheries Department). The Department has received extensive financial and technical assistance from aid donors of various agencies of France, Australia, U.S., EEC, U.K., Canada, New Zealand, Japan, as well as FFA, SPC, and FAO/UNDP.

Although the people of Vanuatu are considered as agriculture-oriented in their tradition, subsistence fishery is very common among the coastal inhabitants. They use traditional outrigger canoes and their activities are confined around the shallow reef areas close to the shore. A census of local fish consumption and subsistence fishery indicated that, in 1983 and 1984, the total production from coastal fisheries were around 1,000 tonnes of fish and 1,400 tonnes of shellfish and other marine organisms annually and that only about 1/4 of these production entered into the market sales (David, 1985b).

The Fisheries Department has been promoting so-called Village Fisheries Development Programme (VFDP) since 1982. Small fishing boats and related facilities were financed or subsidized by aid organizations, fishermen were trained at a center and a number of volunteers were recruited from overseas to assist in implementation of the programme throughout the country.

According to the reviews conducted by Canadian and EEC consultants in 1987, this programme achieved one of the objectives to establish a large number of small-scale commercial fishing operations, exploiting the deep demersal fish resource. However, the catch did not approach the target level and did not contribute to decreasing the fish import by 1987. This VFDP is now modified under a new plan.

Fish marketing facilities were developed in Port Vila and Luganville as government-owned but commercially-operated outlets for the small scale fisheries. These were originally financed by JICA. There are programmes for further development of commercial fisheries by using fish aggregating devices (FADs) for pelagic fish resources, supported by OFCF, starting in 1985, also assisted with research by ORSTOM in New Caledonia.

Export of marine products is small both in quantity and value as compared with the imports, the majority of which is canned fish. Total exports of fisheries products amounted at ca. 35, 11, and 23 million VT as opposed to the total import of ca. 115, 141, and 81 million VT in 1985, 1986, and 1987, respectively (1987 Annual Report, Fisheries Department). The main export commodities are shells of trochus and green snail, as well as shark fins and dried sea cucumbers (beche-de-mer). There is a small local factory to process the shells for button blanks using trochus.

Grandperrin and Schaan (1987) reviewed possible research areas with regard to fisheries in Vanuatu and pointed out importance of establishing a research center for aquaculture and technical advancement. They suggested stock enhancement by planting cultured spat of trochus and green snail to be pursued with assistance from countries such as Australia, Palau, and New Caledonia.

Aquaculture of freshwater shrimp and oyster mariculture were attempted by private farms in the past but they were unsuccessful (Carlot, 1988). Hatchery production of trochus was examined so as to determine feasibility of restocking depleted populations. A small experimental hatchery was established at the Fisheries Department in Port Vila and attempts to produce juvenile trochus have been made but this was hampered by destruction of facilities by Cyclone Uma in 1987 and also lack of trained personnel (Nash, 1989).

An extensive survey of marine resources such as corals, seagrass beds and giant clams etc. was carried out by a team of scientists from Australia, at many sites of major islands throughout the Vanuatu archipelago in 1988, based on a request from Environment Unit, Ministry of Lands, Minerals and Water Supply of Vanuatu Government (Zann and Ayling, 1988; Done and Navin, 1989).

Vanuatu Fisheries Bibliography published in 1987 by FAO/UNDP Regional Fishery Support Programme is very useful (Gillett and Kenneth, 1987). Also useful is a section on Vanuatu in a recent publication entitled as "Coral Reefs of the World" by IUCN/UNEP (1988).

Federated States of Micronesia

The Federated States of Micronesia (FSM) consist of the majority of islands in the Caroline Islands, excluding the western-most subgroup of Palau. This newly independent nation (but in free association with the U.S.A.) consists of four states: Yap, Truk, Pohnpei, and Kosrae. The capital is in Pohnpei Island. The total population of the nation was estimated at 95,000 in 1988.

The following accounts summarize geomorphological features of each state. based on descriptions given by IUCN/UNEP (1988).

Yap State: So-called 'Yap-Proper' consists of four volcanic/metamorphic islands (Yap, Tomil, Map, and Rumung) close to each other, separated by narrow channels between them but altogether surrounded by fringing reef systems which are cut by several inlets. There are fourteen atolls in Yap State including Ulithi Atoll, the largest in the Caroline Islands, and one raised atoll (Fais).

Truk State: Truk is an almost-atoll with many small islands representing unsubmerged peaks of the central volcanic cone, within a lagoon which is encircled by an extensive barrier reef system. There are twelve large and small atolls and a few low-lying small islands in the State.

Pohnpei State: Pohnpei Island is the largest and tallest island in the FSM, ca. 20 Km in diameter with the highest peak of 791 m. This volcanic island receives an estimated 10,000 mm precipitation per annum in its interior. Thus, there are numerous streams discharging freshwater into the lagoon and the shorelines are fringed with well-developed mangrove forests. Its barrier reef system encircles a deep lagoon where there are several small islands with fringing reefs in addition to the main island. Lagoon water is quite turbid. Eight atolls in the eastern Caroline Islands belong to Pohnpei State.

Kosrae State: Kosrae is a high volcanic island with the highest peak exceeding 600 meters. Its entire coastline is surrounded by fringing reefs which are cut by a few small embayments. Mangrove forests are extensive along some parts of the shorelines.

Reef resources of major islands (Yap, Truk, Pohnpei, and Kosrae) have been surveyed and their inventries have been published as both atlases and documents by U.S. Army Corps of Engineers and others.

Small-scale commercial fisheries have been developing at each state center, exploiting nearshore pelagic and bottom fishes, in order to supply fresh fishes to the urban areas in the nation. However, subsistence fishery is still very important throughout the rural areas and isolated atolls. There is little quantitative information about the subsistence sector but it is probably under pressure due to rapid population growth and also urbanization particularly near state centers. Sedentary resources such as giant clams, spiny lobsters, and mangrove crabs among others are particularly prone to over-exploitation (e.g. Perrin, 1978).

In 1984, ca. 1,000 giant clam (Tridacna derasa) juveniles were introduced from Palau to Yap-Proper for reseeding. The 15 months-old juveniles had been raised at Micronesian Mariculture Demonstration Center in Palau. After being kept within protective cages at nursery areas for 12 months, they were transferred to 31 different sites around Yap-Proper. Their overall survival rate was ca. 60 % by September 1986 at about 4 years age and 21.6 cm in average shell length (Price and Fagolimul, 1988). The clams thus raised to the adult stage are expected to become broodstocks for reseeding local population. Additional shipments of new cohorts of giant clam seedlings were made from MMDC, between 1985 and 1987, for distribution to outer atolls and also to all municipalities which claimed reef-ownership (Price, 1988). The largest giant clam species T. gigas is not found alive but its shells are found at dredging sites at least in Yap and Pohnpei.

There is a small experimental hatchery at Lenger, a lagoon island in Pohnpei. The present author visited this facility briefly in July 1988. Juveniles of T. derasa from MMDC were kept inside protecting cages on the lagoon floor near the hatchery and those of Hippopus hippopus (spawned locally) were reared in raceway tanks. Pohnpei State Marine Resources Division is trying to develop methods for reseeding giant clams and trochus at this hatchery.

The commercial trochus (Trochus niloticus) was originally distributed only in Yap-Proper within the FSM, but has been transplanted from Palau to Truk by Japanese in the 1920s. Thereafter, it was transplanted from Truk to Pohnpei in 1939, from Yap to Ulithi Atoll in 1938, and between many other islands in Micronesia in the 1930s (Asano, 1963; Yamaguchi, 1987).

After WW II, trochus shells were again transplanted further from Pohnpei to Kosrae in 1959 (Gawel, 1982). About 9 tonnes of trochus shells were harvested from Kosrae for the first time in 1984 and 15 tonnes in 1985. A total of ca. 730 tonnes of trochus shells were exported from Pohnpei State between 1981 and 1988. Yap State harvested a total of ca. 108 tonnes of trochus shells for three years from 1985 to 1987.

Traditional fishing rights are maintained in Yap and Truk while they are no longer observed in Pohnpei and Kosrae. These different situations in sea tenure system might have been responsible for different degree of success in conserving trochus resources in each state. Because the state governments could enact sanctuaries by legislative actions, broodstocks have been maintained in Pohnpei and Kosrae. When the author visited the two states, he found trochus populations in high densities within sanctuaries, except for one of the six in Pohnpei which appeared to be most accessible to poachers (Yamaguchi and Kikutani, 1989). Yap State Marine Resources Division has been trying to protect the trochus resource in Yap Proper by annual baseline surveys to estimate standing stocks, so that lengths of harvesting period could be established (Fagolimul, 1988).

The Marine Resources Division of the FSM National Government held a workshop on aquaculture planning at Kosrae in 1986 (Gawel, 1986). The participants concluded that aquaculture of giant clams, seaweeds (Gracilaria and Eucheuma), the black-lipped pearl oyster, milkfish, and bath sponges should receive highest priority in the FSM. An aquaculture center was proposed to be established at Kosrae prior to this workshop.

Cultivation of Eucheuma has been attempted by local residents in Pohnpei and a pilot study was carried out by Marine Resources Division of Kosrae State since 1983, but they have experienced problems with fish predation and also marketing of the dried seaweed. Feasibility study and pilot cultivation of bath sponge is underway in Pohnpei Lagoon (Croft, 1987).

FAO South Paicifc Aquaculture Development Project supported a feasibility study on green snail transplantation to FSM (Yamaguchi and Kikutani, 1989).

Community College of Micronesia located at Kolonia, Pohnpei State, has a marine science curriculum including aquaculture since 1986.

1-2 Literature Survey:

Palau (Belau)

The Republic of Palau is to become an independent nation in free association with the U.S.A. (awaiting for ratification)

This western-most group of the Caroline Islands consists of the main island group around the largest island of Babeldaob and the capital of Koror Island with a small atoll of Kayangel in the north and elevated coral islands of Peleliu and Angaur in the south. There are five small islets or reef islands further to the south. The total land area is ca. 487 sq. km, ca. 70 % of which are by the volcanic Babeldaob Island. The total population was ca. 15,000 in 1984 estimate.

Before WW II, Fisheries Experimental Station of the South Seas Agency, established in 1931, and Palao Tropical Biological Station, established in 1935, engaged in basic and applied research on marine biology and fisheries at Palau and elsewhere in Micronesia. Thus, there are exhaustive and useful literatures on marine biota and fisheries resources of Palau even for the pre-war period. FAO/UNDP Regional Fisheries Support Programme published an extensive marine resources bibliography (Izumi, 1988).

According to 1983 survey, subsistence sector dominated over commercial one as the former was estimated to consist 95 % of GDP in fisheries. This is particularly true since a tuna trans-shipping company, which had exported up to 10,000 tonnes of tuna annually during the period 1964-1981, ceased to operate in 1982.

Johannes (1978 and 1981) documented fishing and marine lore in Palau, which indicated rich heritage in Palauan knowledge in inshore fishery and its conservation.

Trochus shells are harvested during June collecting season, ranging from 100 to 300 tonnes per year. An arbitrary sanctuary system for trochus was established along the barrier reef in 1960. Heslinga et al. (1984) examined the trochus stocks in the original seven sanctuaries and found that trochus were distributed at lower densities in the designated areas than others. Based on the new information, trochus sanctuaries were relocated and consolidated in 1982, in order to manage them more effectively.

All of the seven known species of giant clams occur in Palau. Poaching of larger giant clams, Tridacna gigas and T. derasa and possibly Hippopus hippopus, contributed to declines in their populations in Palau in the mid-1970s. Helen Reef, an isolated atoll in the southern district, was invaded by foreign poachers repeatedly. They removed adductor muscles from the larger clams, leaving dead empty shells agape. In a 1972 survey, ca. 50,000 T. gigas and ca. 33,000 T. derasa were estimated to occur in Helen Reef (Hester and Jones, 1974) but they were more than 95 % dead in 1975 (Bryan and McConnell, 1976) and remained in a similar state in 1976 (Hirschberger, 1980).

The Micronesian Mariculture Demonstration Center, established in 1969, is now well-known for its achievement in developing giant clam mariculture, mainly of Tridacna derasa (Heslinga and Fitt, 1987). It has been able to raise several cohorts of T. derasa to sexual maturity in five years from spawning and thus far produced over one million seed clams to distribute throughout Micronesian islands and some of the Polynesian islands such as the Cook Islands and American Samoa. The Center also contributed to training and extension for many personnels in the Pacific nations by offering courses of clam culture (Heslinga et al., 1988).

The MMDC tried to develop aquaculture of oysters, a freshwater prawn, rabbit fishes, etc. without success in the past. Pearl oysters were cultivated by Japanese in Palau before WW II and again in post-war periods but this industry has not been established. Commercial sponges had been cultivated by the Fisheries Experimental Station but this aquaculture did not advance beyond experimental stage before the War.

The MMDC is currently producing larvae and juveniles of commercial trochus Trochus niloticus for local stock enhancement and for export.

Marshall Islands

The Republic of the Marshall Islands became a freely associated nation with the U.S.A. in 1986. It consists of 29 atolls (20 are inhabited) and five low coral islands (four inhabited) in two chains, Ralik and Ratak Islands. The total land area is ca. 205 sq. km with the total population of 40,000 (1987 estimate). Its rate of population growth is very high and also urbanization is very intensive at two urban centers of Majuro and Ebeye (in Kwajalein Atoll). Although the rural areas may retain subsistence fishery, the country imports large quantities of canned fish to supply fish protein to the urban centers.

There have been private and/or joint-venture projects for developing inshore fisheries exploiting spiny lobsters for export, trochus for button-blank manufacturing and aquaculture of pearl oysters, etc. However, most of such attempts were short-lived or only experimental.

The Marshall Islands Government has a plan to establish a Mariculture Laboratory, targetting trochus and giant clams. Seedstocks of Tridacna derasa were imported from MMDC in Palau in 1985 and 2,000 juveniles were kept in a nursery at Calalin in Majuro Atoll. In 1989, 1,300 individuals survived and became sexually mature at 5 years old (Heslinga, pers. comm.).

There are private giant clam hatcheries at Mili Atoll and Kwajelein Atoll. Seeds of the local population of T. gigas was produced at the former facility in 1986 and 1988. One thousand juvenile T. derasa was shipped from MMDC to the latter in 1989 (Heslinga, pers. comm.).

A project-finding mission was sent to the Marshall Islands in 1985 by Overseas Fishery Cooperation Foundation (OFCF), for fisheries development assistance. Okutani (1987) evaluated feasibility of developing aquaculture of giant clams and trochus etc. based on the technology developed in Palau. He recommended to develop these and also black-lipped pearl oyster aquaculture by securing experts and through long-term basic studies including marketing research.

Guam

Guam is a territory of the U.S.A. and is the southernmost island of the Mariana Islands. Its land area is ca. 541 sq. km and the total population was estimated at ca. 116,000 in 1984. Raised multiple terraces of limestone in the northern part contrast weathered volcanic terrain in the southern part of Guam Island. Narrow fringing reefs fill in many bays along the most coastline. There are two small lagoons encircled by reefs at the west and south ends of the island.

The community of Guam is dominated by consumer society because of military expenditures and well-developed tourism catering for Japanese visitors. Small quantities of fresh fish are supplied by part-time fishermen at the local fish market but the people are more inclined to recreational fishing. Various traditional and contemporary fishing methods and resources utilized were described by Amesbury et al. (1986). Hedlund (1977) and Stojkovich and Smith (1978) surveyed distribution and utilization of inshore resources such as shells, sea urchins, seaweeds, and corals on Guam.

Trochus was introduced to Guam from Saipan (also introduced from Palau previously) in the 1950s. It is consumed as food but has not been utilized as exportable resource from Guam. There are regulations in harvesting it (quota, size limit, closed season, closed areas, license for commercial harvest and fees) even for home consumption. Indigenous gastropods such as Turbo setosus and Turbo argyrostomus are also consumed as subsistence food.

Recreational fishing of several species of bivalve shells is common for home consumption on Guam. Larger and abundant species such as Asaphis violascens, Quidnipagus palatum, Gafrarium pectinatum, and Fragum fragum are collected from reef flats at low tide gleaning. Some gastropods such as Strombus spp. etc. are also collected for home consumption. A small giant clam Tridacna maxima is common in shallow reefs but not utilized heavily probably because it is cumbersome to remove the shells embedded in limestone substrates.

Aquaculture of shrimps and fishes developed very slowly because of several problems: lack of locally-produced fry/post larvae, high feed cost, high labor cost, etc. on Guam. The Government of Guam now has a hatchery laboratory jointly operated by University of Guam and Guam Economic Development Authority (FitzGerald, 1986). This facility is located at

an ideal site with good freshwater and seawater supply. The present author visited the site in July 1988 and found it suitable for development of reef ranching of gastropods etc. because it might be able to produce seedlings of target species such as trochus and green snail in large numbers for distribution throughout Micronesian islands using the established air links between Guam and other islands.

Northern Mariana Islands

The Commonwealth of the Northern Mariana Islands became a self-governing territory of the U.S.A. in 1986. It comprises all the Marianas except for Guam. There are volcanic islands, some of which are active, raised limestone islands and volcanic with limestone terraces in the Marianas. The larger southern islands such as Rota, Tinian and Saipan are permanently inhabited. The 1983 population was estimated as ca. 19,100 and the majority of it is in Saipan, where is developing as a tourist destination for Japanese.

Very little is known about the inshore resources and aquaculture activities in the Commonwealth, but reef biota of most of the islands were surveyed by the scientists from University of Guam and others (Eldredge, 1983). Lagoon fishery on Saipan was described by Amesbury et al. (1979).

Kiribati

The Republic of Kiribati is one of the most wide-scattered island nation in the world. Twelve large and small atolls and four coral islands of the Gilbert Islands are all inhabited and make up the main group. Only one island each is inhabited out of eight respective atolls or coral islands of Phoenix and Line Islands. There is one isolated raised atoll (Banaba or Ocean Island). Total land area is ca. 868 sq. km and the total population ca. 64,000 (1985 estimate).

There is a government-owned commercial fishing company which exploits pelagic resources, mainly skip-jack tunas, and artisanal fishery sector is developing in the urban center of Tarawa Atoll. However, subsistence sector is still prevailing as indicated by 1985 census: about 80% of the population belonged to this. Because the land areas are small and infertile,

the marine resources provide most of the protein needs, with per capita consumption of fishes being among the highest in the world.

Inshore resources are under increasing pressure by rapid growth of atoll populations and their high densities, particularly at the urbanized Tarawa. Sedentary resources such as molluscs have been regarded as emergency food in tradition (Zann, 1985) but recent studies indicated declines in stocks of giant clams (Munro, 1988; Taniera, 1988).

Lagoon bivalve shells such as Anadara maculata, Gafrarium tumidum and Asaphis violascens became important staple food in the recent years at Tarawa (Lewis, 1988) and are likely under pressure. More than 3,000 tonnes of these bivalves were harvested in Kiribati in 1985 and also in 1986. Fisheries Division tried to transplant the most important species of these (Anadara maculata) in order to spread the resource widely among the atolls but the efforts proved unsuccessful and the project was discontinued in 1985.

Milkfish (Chanos chanos) fry were collected from the wild stocks and were kept in natural fresh or brackish pools and also excavated ponds in the past. This traditional small-scale aquaculture declined due to interference by transplanted Tilapia (by FAO in the 1970s) which ate the milkfish fry and competed in the ponds. In order to supply baitfishes for the skip-jack fishing, milkfish has been cultivated in a larger scale by the Kiribati Fisheries Division since 1975. Tilapia again poses problem in this milkfish cultivation because it is difficult to prevent its entrance to the culture ponds (Teraroko, 1986).

Experimental culture of Eucheuma striatum began in Kiribati in 1983. The commercial farming expanded and a total of 24 tonnes of dry seaweed were produced by 50 farmers in Tarawa in 1985. At present, the farming of the seaweed is being carried out on most of the islands in the Gilbert Group (Teraroko, pers. comm.).

There is a plan to initiate hatchery production of giant clams using local species, to be assisted by ACIAR in Australia. Also proposed is a brine shrimp cultivation at Kiritimati where are suitable salt ponds available. A past attempt of extensive brine shrimp culture was a total failure in the 1970s, but it is hoped to be revived as an intensive cultivation (Teraroko, pers. comm.).

Tuvalu

Tuvalu consists of six atolls and three coral islands, with a total land area of only 26 sq. km. More than one quarter of about 8,000 people of this nation live in Funafuti Atoll, the capital island.

Development of small commercial fisheries for nearshore pelagic and bottom fishes were emphasised since mid-1980s, with assistance from aid doners. Subsistence fisheries are most important for the local residents (Zann, 1985).

The South Pacific Commission supported a survey on specimen shell resources and also on assessment of trochus introduction to Tuvalu in 1983 (Parkinson, 1984a and 1984b). In 1985, FAO Regional Fisheries Support Programme provided trochus seedstock to the Fisheries Division. Additional shipments of trochus shells from the Cook Islands were made in 1987 (Gillett, 1988a).

FAO South Pacific Aquaculture Development Project supported a pilot study to assess existing giant clam resources and to identify possible cultivation sites for introduced giant clams in Tuvalu (Braley, 1988). Other pilot projects under consideration by the Fisheries Division are milkfish and commercial seaweed cultivation, and beche-de-mer harvesting.

FAO/UNDP Regional Fishery Support Programme published an Atoll Fisheries Bibliography for Tokelau and Tuvalu (Gillett, 1988c).

Tokelau

Tokelau is a New Zealand territory and consists of three atolls, with ca. 1,600 people. All the three atolls have closed lagoons and there are no passes through the reefs between lagoons andthe ocean.

The inshore fishery resources are important for the subsistence in Tokelau. A study in 1986 indicated that 55% of all animal protein consumed originated from lagoon and shallow reef areas. Exploitation of giant clams Tridacna maxima and T. squamosa was banned in the mid-1980s by the Council of Elders following exportation of large quantities of clam meat to Western Samoa.

FAO Regional Fisheries Development Programme implemented a trochus introduction project from Fiji to Fakaofo Atoll in 1986 (Gillett, 1986). There was a storm in 1987 which was suspected to kill a substantial number out of the 850 transplanted trochus. In 1988, a resurvey was made to assess the results and the second transplantation was carried out in 1988 (Gillett, 1988b).

Tokelau Government is interested in developing giant clam reseeding and also pearl culture on each of atolls.

Cook Islands

Cook Islands is internally self-governing and in free association with New Zealand since 1965. Fifteen islands of the nation are widely scattered in the area 8-23 S, 156-167 W. Its captal Avarua is located in the largest island of Rarotonga. The total population was estimated at 17,185 in 1988. There are greater numbers of Cook Islanders in New Zealand than at the home islands.

The islands are diverse in geomorphology. Rarotonga is a high volcanic (the highest peak 650 m) island with narrow fringing reefs. There are uplifted volcanic islands (Mangaia, Atiu), uplifted atolls (Mauke, Mitaro), an almost atoll (Aitutaki), and atolls (Palmerston, Penrhyn, Manihiki and others). The uplifted volcanic islands and uplifted atolls are surrounded by "makatea", that is a raised coral reef, and also by very narrow fringing reefs outside of makatea. Coral fauna of the Cook Islands is richer in diversity than that of French Polynesia to the east, 35 hermatypic coral genera having been recorded from Rarotonga (Paulay, 1985).

Cook Islanders depends on protein from the reef or lagoon resources as much as 90 % in the isolated islands (IUCN/UNEP, 1988). Estimates of the annual subsistence catches in the southern group and in Aitutaki were between 800-1,100, and 530-780 tonnes, respectively, for the years 1978 and 1979 (2nd Development Plan). Such subsistence fisheries are important but little attention has been paid for conservation and management in these.

A small giant clam Tridacna maxima forms the basis of an important local subsistence fishery, especially on Aitutaki (Paulay, 1987). Sims and Howard (1988) pointed out heavy fishing pressure on this resource and recommended

conservation measures such as establishing permanent reserves and/or artificially aggregated broodstocks.

In 1986, one thousand juvenile Tridacna derasa, a larger species, were introduced to Aitutaki from Palau. They suffered high mortality from predation by a gastropod Cymatium muricinum and also disturbance by a cyclone during their grow-out phase (Sims and Howard, 1988). Another attempt to introduce green mussel Perna viridis from Tahiti for intensive aquaculture was unsuccessful in the Cook Islands.

In the Cook Islands, the export-based fisheries for pearl-shell Pinctada margaritifera on Manihiki and Penrhyn atolls, and for trochus on Aitutaki, are the highest-profile fisheries (Sims, 1988a). The pearl-shell fisheries have a long history since the last century but the trochus fishery was established by the initial introduction to Aitutaki from Fiji in 1957 (Sims, 1985). The first harvest of trochus was made in 1981 and also a program of the secondary introduction to other islands started in the same year, with variable degree of success from island to island (Sims, 1985).

Recently, the government of the Cook Islands allocated a fund to promote pearl-oyster cultivation. A market-survey mission for pearl shell was sent by FFA to Taiwan, South Korea, and Japan in 1988 (Philipson, pers. comm.) Fig 1. illustrates the past production of pearl shells in the Cook Islands.

The 2nd development plan of the Ministry of Marine Resources (1988-1992) focused that pearl shell farming and also possible pearl production, rather than harvesting wild stocks, would be developed and that suitability of culturing giant clams and introducing green snail would be investigated, although aquaculture development had never been given any priority in the past.

An earlier attempt to introduce green snail from Tahiti was unsuccessful (Sims, pers. comm.).

FAO/UNDP Regional Fishery Support Programme published a useful fisheries bibliography for the Cook Islands (Gillett and Tearii, 1989).

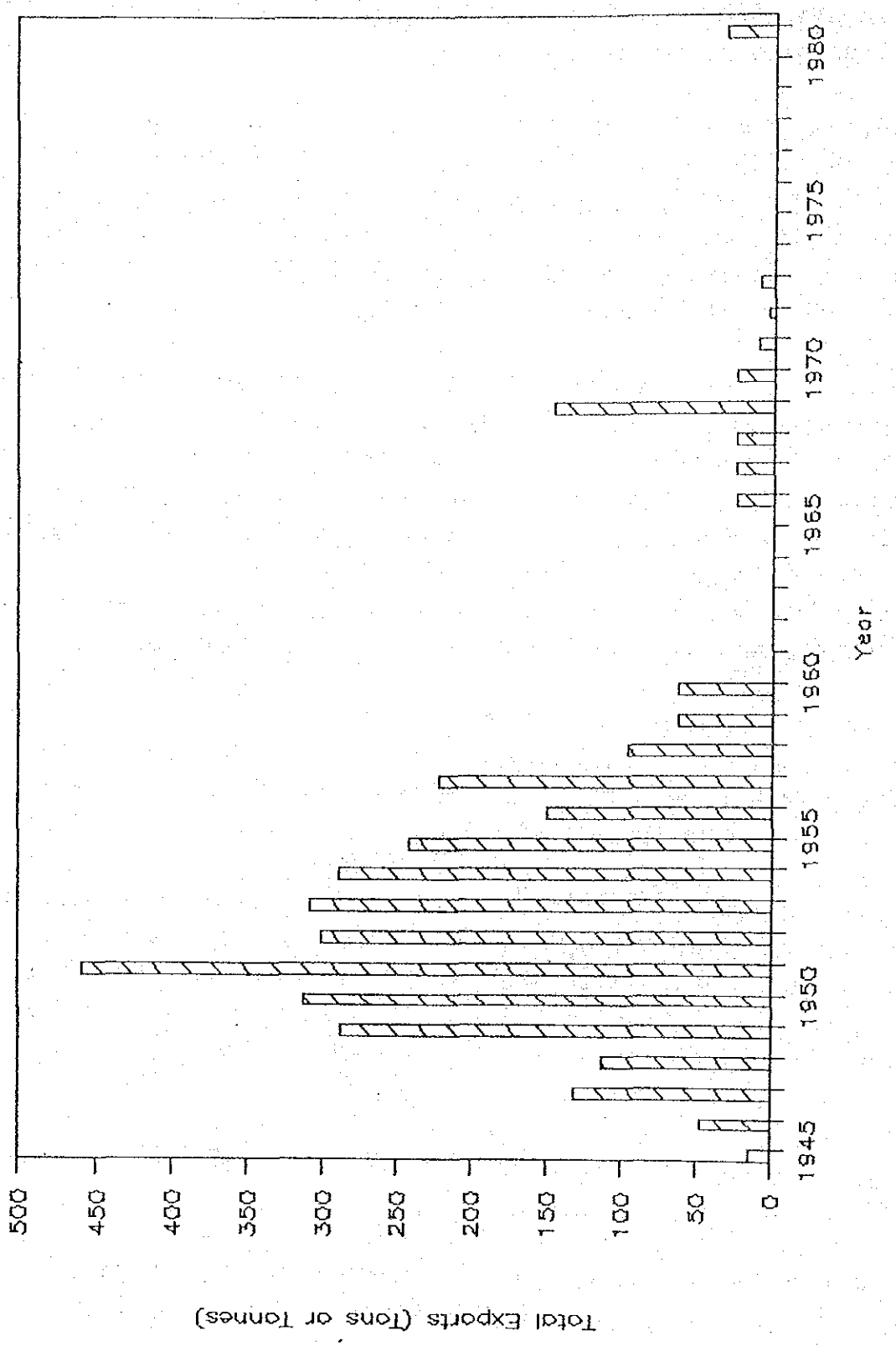

Figure 1 Pearl shell exports from the Cook Islands, 1945-1981. (from Sims, 1988b)

American Samoa

There are five large and small volcanic islands and two atolls in American Samoa, an unincorporated territory of the U.S.A. The mojority of population is concentrated in the largest, Tutuila Island. The total land area is ca. 197 sq. km and the total population was estimated at 35,400 in 1985. The population size remains stable due to emigrations to Hawaii and mainland U.S.A.

American Samoa, with its excellent harbor of Pago Pago, is a center of industrial tuna fishery in the south Pacific, although catches by local fishermen are small. Reef and lagoon fisheries are nevertheless important for the people as subsistence and recreational activities. Wass (1983) described past and present inshore fishery of American Samoa. Artisanal fisheries are developing, exploiting pelagic resources by using FADs and also bottom resources of deep sea snappers and groupers.

A small tridacnid clam nursery has been initiated by a village of Alofau in Tutuila, in cooperation with the Office of Marine and Wildlife Resources, with seedstock of T. derasa from MMDC in Palau (Itano and Buckley, 1988). The first introduction of 1,000 juveniles (mean shell length of ca. 72 mm) was made in November 1986. They suffered a high mortality during shipment from Palau via Hawaii, losing about 13 %. Thenafter, predation by Cymatium muricinum and losses by thefts and unknown causes occurred during the growout period, losing additional 20 % by February 1988. They grew to 149 mm in mean shell length by that time (31 months age). A second shipment of 3,000 juvenile clams was made in November 1987 and they were maintained at two nursery areas.

Glude (1972) noted presence of two bivalve species, harvested locally for subsistence from lagoon flats: Gafrarium tumidum and Lioconcha lorenziana. He recommended basic ecological study on these clams for sustained and/or expanded exploitation including aquaculture.

Environmental conservation and reef enhancement, as well as measures to controlling Acanthaster planci predation of corals were recommended for the Manu'a group (IUCN/UNEP, 1988). There was severe A. planci infestation around Tutuila Island in 1979-1980 (Beurig et al., 1982; Birkeland and Randall, 1979).

Western Samoa

Two main islands, Savai'i and Upolu, with a few associated small islands make up a total land area of 2,842 sq. km of Western Samoa. The islands consist of a high volcanic dome or strings of cones (peaks higher than 1,000 m) with fringing reefs which are partly missing along costlines. The capital Apia is located in Upolu. The total population was estimated at 163,400 in 1985.

A fleet of more than 100 alminium catamarans (called alia), operated by village fishermen, exploit deep water bottom and nearshore pelagic resources to supply a fish market in the urban center of Apia. Apart from this small scale artisanal fishery, the majority of people maintain subsistence fishery where surplus may be sold at Apia market. The commercial catch fluctuated between 1,700 and 3,500 tonnes per year from 1983 to 1986, depending on numbers of FADs deployed and remaining in the fishing grounds (Development Plan VI). On the other hand, large quantities of canned fish were imported, sometimes exceeding the above commercial catch.

A recent market survey indicated around 200 to 300 tonnes of fishes and non-fish inshore resources, sold annualy at the Apia market as surplus or for cash income (Helm, 1988). The total level of subsistence fishery for the nation is hard to assess but the Fisheries Division recognizes it near or in excess of MSY. For instance, giant clam resource has been subjected to heavy harvesting, judged from a field survey by the Division. Johannes (1982) noted the small average sizes of reef/lagoon fishes harvested.

The present author visited Mulivai area of southern Upolu in 1985 and saw a group of men methodically removing every edible organisms along their path on the reef flat while they were snorkelling. Such intensive group harvesting may result in substantial pressure on inshore resource of limited reef areas in Western Samoa.

Green mussel (Perna viridis) has been a target for village aquaculture development project in Western Samoa since 1981. The first trial harvest was well-recieved by the market in Apia (Bell and Albert, 1984). The spat was imported from French Polynesia but availability of spat was disruptive. Spat collecting from locally reproduced larvae failed in Western Samoa.

There may be some good lagoon areas for the mussel culture in both Upolu and Savai'i but its commercial success would depend on availability of spat and good extension service for production and marketing.

FAO/UNDP Regional Fishery Support Programme published a fishery bibliography of Western Samoa (Gillett, 1987a).

Solomon Islands

The Solomon Islands consists of a double chain of elongated islands and the six larger islands have central mountain ridges with peaks rising up to 2,450 meters. There are several atolls and raised atolls outside the chaines. Capital Honiara is located in Guadalcanal which has coastal plaines unlike other major islands. Total land area is ca. 30,000 sq. km and the total population ca. 285,000 in 1986 estimate.

Coral reefs are only poorly developed along the main islands partly because of geological history and numerous streams fed by heavy rainfalls. However, there are some barrier reefs and lagoon systems such as Marovo Lagoon with double barrier reefs in New Georgia Group.

Industrial fishery exploiting skipjack, yellowfin tuna, and other pelagic resources is well-established in the Solomon Islands, exporting substantial quantities of frozen and canned fishes. Village level fisheries are being developed by assistance from aid doner agencies. However, inshore fishery has remained as more or less a subsistence activity.

People of the Solomon Islands are considered as land-oriented but the majority of them are living along the coasts, utilizing inshore resources heavily. Marine shells in particular are important not only for food but also as materials for ornamental and ritual purposes. Shell money is still manufactured in some part of the Solomon Islands. Wood carvings with shell inlays are characteristics of local artifacts.

Shells of trochus, pearl oysters, and green snail make up a good portion of the export commodities. Although they are small in quantities and values if compared with those of finfish exports, shell resources as well as that of beche-de-mer provide significant cash income to the rural people through artisanal fishery with little capital and operation costs.

The following table summarizes exports of non-fish products, excluding crocodile skins, from the Solomon Islands (totals for 1976-87, modified after Govan et al., 1988).

Table 4 Exports of non-fish marine products from the Solomon Islands.

EXPORT COMMODITIES	quantity tonnes	(%)	value SI$	(%)
Trochus	5,120.4	(83.2)	6,117,634	(57.1)
Beche-de-mer	522.4	(8.5)	2,530,737	(23.6)
Other shells	88.1	(1.4)	729,999	(6.8)
Black-lipped pearl oyster	204.6	(3.3)	398,791	(3.7)
Turtle shell	10.9	(0.2)	370,598	(3.5)
Green snail	126.7	(2.1)	241,485	(2.2)
Shark fin	6.1	(0.1)	139,415	(1.3)
Other pearl oysters	36.5	(0.6)	106,188	(1.0)
Giant clam products	36.3	(0.6)	74,486	(0.7)

Detailed account on beche-de-mer fishing and processing activities was described for Ongtong Java Atoll, by Crean (1977): village people used a tool (weighted spearing point) for collecting holothurians from their large lagoon. During an observation period of nine days, a total of 7,122 animals were collected by around 20 fishermen, with an average of 11 per man-hour.

The International Center for Living Aquatic Resources Management (ICLARM) has established the Coastal Aquaculture Center near Honiara in 1987. Several spontaneous spawning activities in a broodstock of the giant clam Tridacna gigas took place starting in November 1987 and large numbers of juvenile clams have been reared in tanks (Usher and Munro, 1988).

Field investigations of giant clam stocks were carried out in the Solomon Islands by the ICLARM and Fisheries Department of the Government in 1986. The largest species T. gigas has been found to be rare near urban areas and it was attributed to local fishing pressure and harvesting by foreign poachers (Govan et al., 1988). There is a tradition of holding giant clams on nearby reefs by coastal villagers.

FAO/UNDP Regional Fishery Support Programme published a fisheries bibliography of the Solomon Islands (Gillett, 1987b).

New Caledonia

New Caledonia is a territory of France and consists of a large island with associated small islands and also the Loyalty Islands, a group of islands running parallel to the main island. The total land area is ca. 19,000 sq. km and the total population 153,000 in 1985 estimate.

A barrier reef system, ca. 1,600 km in length which is the second to the Australian Great Barrier Reef, surrounds the main island (Grande Terre) and encloses lagoons with numerous lagoon reefs and islets. Reefs of the Loyalty Islands are elevated atolls (Mare and Lifou) and a tilted atoll (Ouvea).

Exploitation of reef resources, mainly beche-de-mer and trochus, is a long standing activity by artisanal fishermen in New Caledonia. The French Institute for Scientific Research for Development in Cooperation (ORSTOM) Center in Noumea, the capital of New Caledonia, has been conducting basic studies on resource management of such locally important species.

The fishery for beche-de-mer has been reactivated in New Caledonia in 1983, as in other major producer nations, by increased demands in the world market (Conand, 1986, 1988 and 1989). During the years from 1983 to 1986, a total of 435 tonnes of beche-de-mer were exported from New Caledonia to Hong Kong and Singapore.

Records on exploitation of trochus are available for New Caledonia since 1907. The following Fig. 2 illustrates the fluctuations in catches of the trochus shell for export, after Bour and Hoffschir (1985). It is evident that 1978 harvest recorded at about 2,000 tonnes. This phenomenal increase probably resulted in later decline in catches. The sustainable catch for New Caledonia was estimated as 400 tonnes per annum based on the study on habitat areas by remote-sensing and on growth observations by mark-recapture methods (Bour and Hoffschir, 1985; Bour et al., 1986).

Some deformed and blackened cowries are found in New Caledonia and they are sought after by shell collectors. Those melanesitic and rostrate shells are unique to southern areas and the reasons for their occurrences are unknown (Pierson and Pierson, 1975).

Glude (1972) noted six species of bivalves which were abundant enough for commercial exploitation and development for aquaculture in New Caledonia.

They are lagoon resources such as Gafrarium tumidum, Anadara subcrenata, and Gari (= Asaphis) dichotoma, and oysters such as Crassostrea glomerata, C. echinata, and C. mordax. Trials for developing commercial aquaculture of local and imported oysters were in progress in the early 1970s.

Massive reef corals such as faviids are harvested for manufacturing curios for souvenier trade. Raw corals have been exported to the U.S.A. and Europe (IUCN/UNEP, 1988). Joanott and Bour (1988) examined standing stock of the faviid corals at the only authorized reef for harvesting and found that the present level of exploitation would not support continued harvesting.

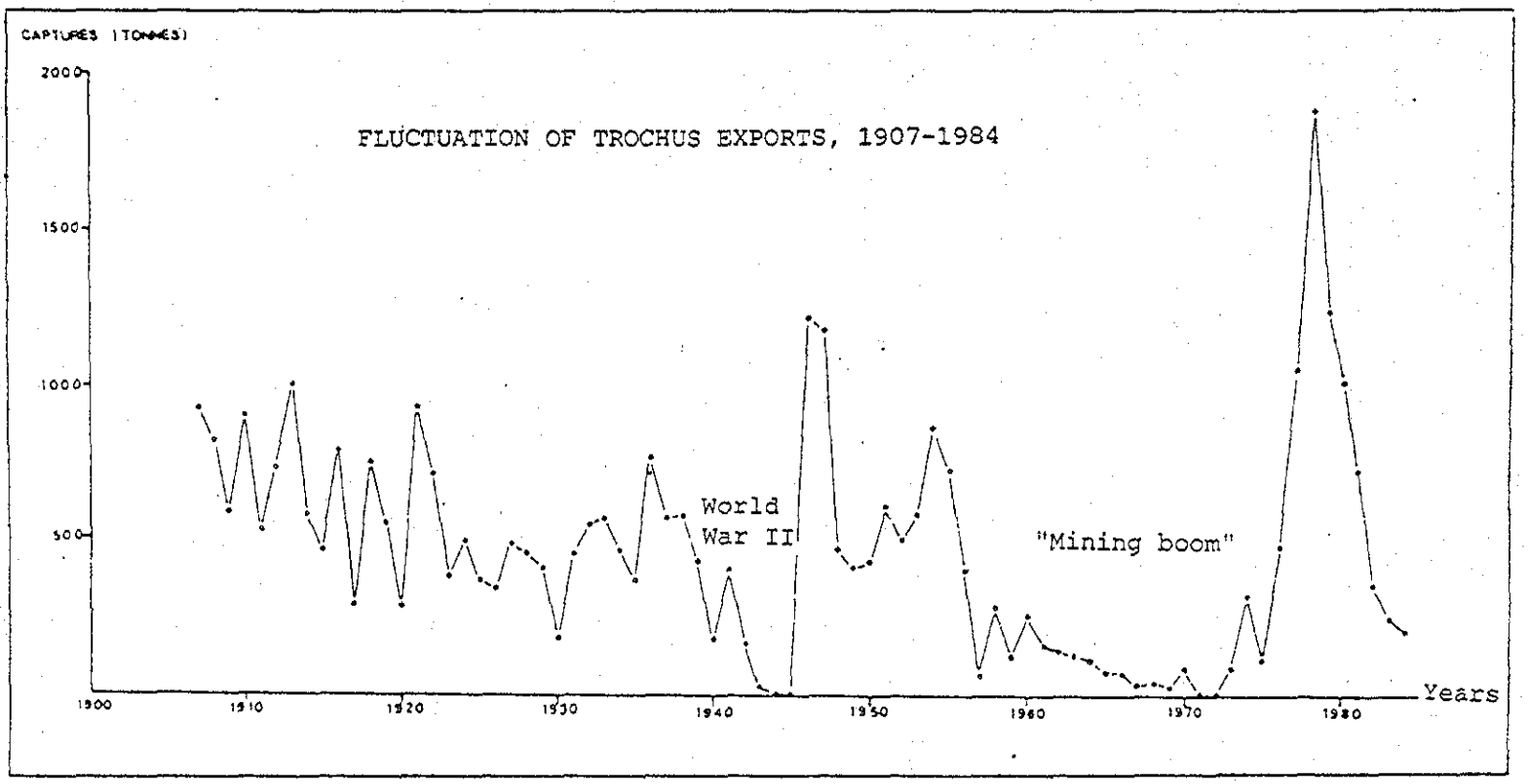

Figure 2. Annual fluctuations in trochus exports from New Caledonia. (from Bour and Hoffschir, 1985)

2. Overview of Reef and Lagoon Resources in Oceania

Very little is known about biology and ecology of the majority of inshore resources which have been exploited by subsistence and artisanal fisheries in Oceania. This is because of the high diversity and complexity in tropical marine biota and because of the limited number of researchers and institutions who have to tackle numerous target species.

In order to exploit the renewable resources wisely, specific information on life history, recruitment, growth, population dynamics, and other ecological aspects must be known for individual species. Furthermore, successful aquaculture, including stock enhancement and transplantation, depends on detailed knowledge of each species as well as innovations in manipulation and management of environmental conditions.

The following account is presented according to the types of exploitation, stating overviews for each species or group of species, from subsistence to commercial level. These dichotomies, however, are arbitrary and should be considered tentative and also variable among different areas and situations.

2-1 Subsistence fishery and locally consumed inshore resources

reef and lagoon fishes

At least 3,700 species in about 180 families of inshore fishes are found in the entire Indo-West Pacific faunal region (Myers, 1989). Many of these are too small in body size or in stock size to be exploited as resources. Some are unpalatable because of toxins or are distasteful as food. However, there are always large numbers of fishes consumed at any locality in the tropical Pacific..

Reef and lagoon fishes are diverse and so are the methods employed for harvesting them. This fact makes it very difficult to collect statistical and biological data as a basis for resource conservation and management.

Information on reproductive ecology is very limited for individual species among the majority of inshore fishes. Johannes (1978) accumulated such data on some coral reef fishes through ethnobiological studies. There are several important points arising from his study as follows.

(1) Spawning aggregation and migration of inshore fishes:
Larger Inshore fishes, which are usually used as food, tend to spawn at specific sites, often away from their usual habitats, forming spawning aggregations which migrate to the area where offshore dispersal of eggs and larvae are likely to occur. Such spawning migration is common among species of mullets, groupers, and rabbit fishes (Table 5). Leis and Miller (1976) also reported that larvae of reef fishes, which spawn pelagic eggs, were most abundant offshore in Hawaii.

(2) Collective peak spawning season for many tropical species:
It is often assumed that tropical species tend to spawn throughout the year because there are little seasonal changes in environmental parameters. However, there appear collective peak spawning months for many species of inshore fishes, although exact timing may differ from place to place (Table 6). Johannes (1978) postulated reproductive strategies in those fishes leading to retention of larvae by such collective spawning during seasons when the prevailing winds or currents are weakest. This may lead to peaks in recruitment of juveniles to the reefs and lagoons.

(3) Lunar periodic inshore juvenile migration:
Cohorts of juvenile fishes may invade the shore in large numbers around specific lunar periods, often full or new moons or both (Table 7). Kami and Ikehara (1976) reported great annual fluctuations in the juvenile migration of rabbit fishes to the reef flats on Guam. The present author witnessed a massive recruitment of juvenile rabbit fishes at Pago Bay Reef, Guam, in 1972. Their abundance was so great that all fleshy algae on the reef flat were grazed down and numerous juvenile fishes were dead after prolonged periods of starvation. It is difficult to expect a stable annual recruitment in fishes which have pelagic larval period of a few weeks or longer (details are not known). Therefore, availability of natural fry may be quite variable for stocking in aquaculture.

The above ethnobiological information is useful in developing aquaculture of inshore fishes such as milkfish, mullets, and rabbit fishes etc., because collection of broodstocks for artificial fry production and also that of natural fry would become predictable if reproductive ecology of local species were known. On the other hand, they are also important in resource management to protect reproductive animals.

Table 5 Spawning migrations in Palau.

Species	Usual habitat	Location of spawning aggregations
Albula vulpes	3	8
Herklotsichthyes sp.	2,3,6	1
Crenimugil crenilabis	3	12
Chelon vaigiensis	3	12
Plectropomus leopardus	many coral areas	seaward portion of, and outer reef slope near 9 and 10
Epinephelus tauvina	5,12	,,
Carangoides fulvoguttatus	6	12
Caranx melampygus	wide ranging	12
Lutjanus argentimaculatus	1	6,12
L. gibbus	6,12	over blue water just seaward of 12
Symphorus spilurus	5,7	12
Plectorhynchus goldmani	5,7,12	12
Lethrinus sp. (Hotch-Palauan name)	1,2	5 (off fringing reef only)
Gerres abbreviatus	3	8
G. oblongus	3	8
Mulloidichthys flavolineatus	shallow sandy areas near edges of 6	12
Choerodon anchorago	4	12
Siganus canaliculatus	2	11
S. lineatus	1,5,7,9,10	sandy bench on 12, near channel mouth
S. punctatus	4	11
Grammatorcynus bicarinatus	6	12

1. Mangrove creeks; 2. Sea grass beds; 3. Sand flats; 4. Coral flats; 5. Lagoonal reef slopes; 6. Lagoon; 7. Lagoon patch reefs; 8. Sand flats close to reef slopes; 9. Channel through fringing reef; 10. Channel through barrier reef; 11. Reef crest; 12. Outer reef slope.

Table 6 Collective peak spawning months for shallow water tropical marine teleosts.

Location	Months	Source
Madagascar	April-May & Oct.-Nov.	Fourmanoir (1963)
Madras, East India	late Dec. through January	Basheeruddin & Nayar (1962)
Mandapam, Southeast India	March & November	Bapat (1955), Prasad (1958)
One Tree Island (Southern Great (Barrier Reef)	Dec.-Feb.	Russell et al. (1974)
Lizard Island (Northern Great Barrier Reef)	Dec.-Feb.	Talbot (pers. comm.)
South China Sea	March-April	Vatanachi (1972)
Micronesia		
Palau	March-May	this paper[1]
Truk	March-May	,, ,,
Ponape	March-May	,, ,,
Nukuoro	March-June	,, ,,
Mortlocks	March-April	,, ,,
Tobi	Feb.-March	,, ,,
Majuro	April-June	,, ,,
Yap	March-June	,, ,,
Hawaii	March-May & October	Watson & Leis (1974)
Curaçao	March-May & Sept.-Nov.	Luckhurst & Luckhurst (1977)
Barbados	March-May & Aug.-Oct.	Powles (1975)
Jamaica	Feb.-April	Munro et al. (1973)

[1] Much of this information was obtained from local fishermen, who, for reasons described in the text, are keenly aware of seasonal spawning rhythms of the fish they seek.

Table 7 Tropical coastal fishes with lunar periodic inshore juvenile migrations.

Species	Location	Migration peak	Reference
Kuhlia sandvicensis	Hawaii	new moon	Tester & Takata (1953)
Acanthurus triostegus	Hawaii	new moon	Randall (1961)
	Gilbert Islands	full moon	,, ,,
Chanos chanos	East India	new and full moon	Krishnamurthy (1957), Rao (1970)
	Palau	,, ,, ,, ,,	A. Purnalis (pers. comm.)
	Philippines	,, ,, ,, ,,	Frey (1947)
Abudefduf abdominalis	Hawaii	new moon	Helfrich (1958)
Siganus spinus	Guam	fourth quarter	Kami & Ikehara (1976)
S. argenteus	Guam	fourth quarter	,, ,, ,, ,,
S. vermiculatus	Fiji	4th to 6th day after new moon	Popper et al. (1976)
S. canaliculatus	Palau	on or slightly before new moon	Hasse et al. (in press)
Megalops cyprinoides	Palau	around new and full moon	Purnalis (pers. comm.)
Gerres argyrus	Gilbert Islands	around new and full moon	Gopalakrishnan (pers. comm.)
Liza macrolepis	,, ,,	,, ,, ,, ,, ,,	,, ,,
L. vaigiensis = fulvus	,, ,,	,, ,, ,, ,, ,,	,, ,,
Valamugil macrolepis	,, ,,	,, ,, ,, ,, ,,	,, ,,

As experienced fishermen are well aware of spawning season, aggregation, and migration of target species, they could easily destroy broodstocks by harvesting such aggregations before reproduction. High market price of particular fish such as groupers might encourage harvesting their spawning aggregations. Thus, commercialized inshore fishery is dangerous for such vulnerable resources, while subsistence fishery is not so self-destructive.

giant clams

There are six exploitable species of giant clams (Tridacnidae) in Oceania. The following Table summarizes present status of each species in each country or territory, compiled from available sources. (as of August 1989)

Table 8 Status of giant clams in Oceania

Country or territory	Tridacna gigas	Tridacna derasa	Tridacna squamosa	Tridacna maxima	Tridacna crocea	Hippopus hippopus
Guam	---	---	VR	Co	---	VR
Palau	Th, Aq	Th, Aq	Co, Aq	Co	Co, Aq	Co, Aq
F.S.Micronesia						
Yap	Ex?	In	P	P	P?	P
Truk	Ex	?	?	?	?	?
Pohnpei	Ex	In	VR	Co	---	P, Aq
Kosrae	Ex	In	?	UC	---	?
Marshall Is.	Th, Aq	In	P	P	---	P
Kiribati	Th	---	Co	Co	---	Co
Tuvalu	Ex	---	VR	Co	---	---
Tokelau	---	---	VR	Co	---	---
Fr. Polynesia	---	---	---	Co	---	---
Cook Is.	---	In	UC	Co	---	---
Tonga	---	Th	Co	Co	---	VR
W. Samoa	---	---	P, Aq	P	---	?
Am. Samoa	---	In	?	P	---	?
Fiji	Ex, In	Th, Aq	UC, Aq	Co	---	Ex
Solomon Is.	Th, Aq	UC	Co	Co	Co	UC
Vanuatu	VR	VR	UC	Co	UC	Co
New Caledonia	---	P	P	P	---	P

Co: common, UC: uncommon, VR: very rare, P: present but status unknown, Ex: extinct, Th: threatened, In: introduced, Aq: hatchery production of juveniles, ---: absent

Meat and shell of giant clams are occasionally exploited for commercial market, sometimes by poachers or licensed foreign fishing boats, as already mentioned in the previous section. However, giant clams are importnat food for subsistence throughout in Oceania (as well as in parts of Southeast Asia). The larger species have been subjected to over-exploitation and poaching and their stocks declined rapidly during the last few decades in most nations and territories. Prehistoric and recent local extinctions of Tridacna gigas and Hippopus hippopus were reported for certain areas.

All giant clam species are listed on Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora).

Substantial progress has been made in aquaculture and biological studies on giant clams during the 1980s (Munro, 1989). Recent monograph on giant clams summarized achievements by MMDC in Palau and ACIAR (Australian Centre for International Agriculture Research) supported research (Copland and Lucas, 1988).

Larger giant clams are ideal for aquaculture because of the following reasons:

(1) They are relatively easy to breed artificially, even by low-tech methods, if broodstock and minimum facilities such as an adequate sea water system and raceway tanks etc. were available.
(2) Giant clams with symbiotic zooxanthellae are autotrophs and they grow well in nutrient-poor waters on the reefs, productitity of clams being comparable to that of mussels in temperate waters (Heslinga et al., 1984).
(3) They do not produce any quantities of feces so that there will be no self-pollution by accumulated excretions which is a common problem in oyster and other bivalve cultivation.
(4) They can be maintained in clean water areas on the reef, so that there will be little problem in health control against bacterial contamination and paralytic shell poisoning etc. which are significant for other cultivated bivalves in general.

Commercial viability of giant clam mariculture has not been properly assessed so far, although a few private giant clam farms have recently been established in Australia. In 1986, Forum Fisheries Agency (FFA) conducted a market survey of giant clams in Hong Kong, Taiwan, and Japan,

but overlooked existing market of Okinawa and ignored shell trade (Dawson, 1986). More recent appraisal by Tisdell and Menz (1988) considered giant clam mariculture as promising economically, although with some reservations such as sea tenure problem and very slow recovery of profit after investing.

Regardless of commercial prospect, farming of giant clams should be promoted for stock enhancement, restocking, and transplantation of these valuable and threatened subsistence food in Oceania (Yamaguchi, 1977).

other bivalves

Studies on coral reef bivalves other than giant clams have been neglected in the past. However, several species of edible bivalves are harvested for subsistence, in large quantities at certain areas in Oceania. For example, blood cockles Anadara spp. are important for local consumption in many areas such as Kiribati, Fiji, Tonga and possibly other nations.

Anadara maculosa in Kiribati (locally called as Te Bun) should receive particular attention because this species has become a staple food for people in urban Tarawa. The large quantity of annual harvest (up to 1,800 tonnes) is difficult to imagine for oceanic atolls where nutrient supply and also suitable habitats may be limited. It is important to find if this species can proliferate in other atolls of the Pacific, in addition to its ecological and fishery studies for efficient management of this resource.

Simple aquaculture of Anadara spp. is common among the nations in Southeast Asia, by redistributing seedlings from natural nurseries to growing areas. Artificial spat production of Japanese blood cockle Anadara broughtonii and its farming has been established in the Inland Sea of Japan since 1976.

There are a large number of miscellaneous edible bivalves on reef and lagoon habitats. They are species of genera such as Gafrarium, Fragum, Codakia, Geloina, Modiolus, Scutarcopagia, Asaphis, Periglypta etc. Although their stocks are usually too small for commercial exploitation, they are good for subsistence and recreational activities.

Fragum fragum is very abundant at certain atolls in French Polynesia. This clam has zooxanthellae as symbiont just like tridacnids, and probably is capable of receiving nutrients from photosynthesis by the algae. This implies that the clam may grow well without rich phytoplankton or detritus

as food for suspension feeding. The reason for this species to be abundant only at certain atolls should be made clear, as it would be a good candidate for lagoon farming.

A large bivalve Codakia orbicularis is exploited as food in the Caribbean. Recent studies indicated that this clam might obtain nutrients from endosymbiotic chemoautolithotrophic bacteria (Berg, Jr. and Alatalo, 1984; Schweimanns and Felbeck, 1985). If this is also true for the related species in Oceania, mariculture of such species would become possible in areas where phytoplankton biomass is poor but sediments are rich in reduced sulfide. Basic research to examine this topic should be undertaken by qualified researchers.

gastropods

There are a few thousand gastropod species in the tropical Indo-West Pacific but only a limited number of them may be exploitable for commercial and subsistence uses as resources. Those harvested for shell trade are discussed separately and edible species for subsistence are considered here.

Strombs are in general favored as food in the tropics. The largest species of the family Strombus gigas is one of the most important inshore resources as both food and shell in the Caribbean (Berg, Jr. and Olson, 1989). Aquaculture of this queen conch has been developed by private farms which produce spat in hatcheries and grow them in holding pens with cultured algal food.

The red-lipped stromb Strombus luhuanus is one of the most widely used gastropod species of coral reefs in Oceania. Its distribution is somewhat limited to the Western Pacific: not found in the eastern nations (Tonga, Samoa, Cook Is. and French Polynesia), while a smaller species Strombus gibberulus is found in all nations and territories considered here (Abbott, 1960).

Strombus luhuanus is a herbivore, inhabiting shallow reef or lagoon flats. It would become a good addition to subsistence food if transplanted to those nations which at present lack this resource on their suitable habitats.

There is a need to undertake a feasibility study to find sufficient sizes of broodstocks for establishing new populations by transplantation, as well as study on larval development. There are a number of reports on ecological aspects such as spawning aggregation, seasonal migration, and growth as well as effect of human gathering on the populations in S. luhuanus (Frank, 1969; Catterall and Poiner, 1983; Wada et al., 1983; Kuwamura et al., 1983; Ritchie, 1986).

If larger strombs such as Lambis lambis, L. truncata, and L. chiragra were cultivated successfully, they would be valuable as food and specimen shells. Length of larval period was ca. 3 weeks in L. lambis and juveniles grew fairly fast on small algae in a preliminary culture (Yamaguchi, personal observation).

Larger turban snails such as Turbo setosus and T. argyrostomus are favored food in many localities in Oceania. Other important species of gastropods as food are a trochid Tectus pyramis, species of haliotids, neritids, and cerithiids etc. Reef ranching of larger archaeogastropods such as trochids and turban snails are promising because they all develop as lecithotrophic larvae which are easy to raise during brief larval periods without supplementary food.

sea urchin

Only one species Tripneustes gratilla among many species of coral reef echinoid is discussed here because of its abundance and palatability. In the Caribbean, a congener T. ventricosus is also important for its roe as food. The abundance of this sea urchin stock has declined drastically by overfishing in recent years, resulting in a collapse of this fishery in Barbados (Scheibling and Mladenov, 1987). Artificial enhancement of recruitment, by seeding natural habitats with hatchery cultured juveniles, is suggested as a means of rehabilitating the sea urchin fishery.

A very similar situation prevails with T. gratilla stocks in the Ryukyus where the annual catches declined one order of magnitude (from as much as two thousand to a few hundred tonnes) in the mid-1970s. Ranching programmes to release juveniles have been endeavored by government hatcheries in the present decade without significant results to date.

seaweeds

Sea grapes (Caulerpa spp.) are eaten raw as marine salad at many tropical localities. These green algae are cultivated intensively in the Philippines and Okinawa.

2-2 Inshore resources for export as non-perishable raw materials

pearl oysters

There are three commercial species of pearl oysters in Oceania: Pinctada margaritifera, P. maxima and Pteria penguin. The black-lipped pearl oyster P. margaritifera is widely distributed while the other two are more limited to the western Pacific nations, Australia, and Southeast Asia. Sims (1988b) reviewed aspects of biology of the two species of Pinctada and the history and current status of pearl shell fisheries and pearl culture industries in Oceania.

In French Polynesia, production (export) of the black-lipped pearl oysters exceeded 1,000 tonnes per annum in some years during the 1920s, fluctuated around 600 tonnes per annum during the 1940s and 1950s, and rapidly declined in the 1960s to less than 100 tonnes per annum in the 1970s and 1980s. The total export figures were 18, 97, and 92 tonnes for years 1985, 1986, and 1987, respectively (S.M.A., 1988). A similar fluctuation and decline in export of pearl oyster shells is found for the Cook Islands (Fig. 1).

Cultured black pearls have become the most important export commodity among marine products in French Polynesia in the recent years. This industry depends on black-lipped pearl oysters, spat of which were collected on collectors in certain atoll lagoons, because artificial production of spat has been unsuccessful. Fisheries Division of the Cook Islands is trying to develop pearl culture in their northern atolls and shells are also grown from the natural spatfalls in the lagoons.

Artificial spat production of pearl oysters has already been established by private farms in the Ryukyus, for all the three species considered here. One of the farms, Tasaki Pearl Co., tried to extend their expertise in Tonga but a joint venture project with Tonga Government did not come to reality after feasibility studies and successful trial cultivations of

imported spat of all three species by the company in Vava'u for several years.

Although assisting in development of pearl and pearl shell production in Oceania would bring up conflict of interest for the Japanese industry, there are great opportunities for this international cooperation.

trochus

The commercial trochus Trochus niloticus is an important material for button blanks and its shell has been harvested at many localities in Oceania, as well as in Southeast Asia. Transplantation of trochus was a major activity by Fisheries Experimental Station, South Seas Agency, from Palau to other islands in Micronesia, before World War II (Asano, 1963).

Efforts in its transplantation continued in the 1950s, and again in the recent years in Oceania, including those from New Caledonia to French Polynesia, Fiji to Cook Islands, and many secondary transplantation within island groups (Gillett, 1988a; Yamaguchi, 1987). Kiribati and Tonga are without this resource and have not attempted its transplantation, but both are considering now.

Table 9 Import of trochus shell by Japan, 1979-1988.

Country	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Indonesia	462	311	577	561	662	677	1151	732	445	386
Philippines	177	170	67	81	149	115	84	68	50	109
Papua New Guinea	92	249	271	343	455	486	426	277	236	235
Solomon Islands	161	284	265	376	403	428	535	533	418	432
Vanuatu	52	81	21	28	0	0	0	1	0	0
New Caledonia	243	539	323	108	182	52	47	58	17	0
Fiji	107	149	166	221	303	335	133	120	121	182
Micronesia*	474	244	251	223	119	132	136	318	40	147
Others	125	188	147	126	92	51	148	139	113	128
Total (tonnes)	1893	2214	2088	2067	2365	2276	2660	2246	1440	1619
Total value (million yen)	543	777	750	830	970	967	1218	918	667	826
Mean value (,000 yen/ton)	287	351	359	401	410	425	458	409	463	510

* Micronesia: Marianas, Marshalls, and Carolines combined

Japan imported more than 2,000 tonnes (per annum) of trochus shells in the recent years. Carleton (1984) postulated that total world production was around 3,000 to 3,500 tonnes per year for 1976-78 when Japan was importing from 1,600 to 2,500 tonnes. The above Table 9 indicates quantities and values of trochus shell imports by Japan for the period of 10 years, 1979-1988.

It is apparent that the mean import value has increased rapidly in the past ten years. This must have encouraged most of producing nations to exploit more intensively, perhaps resulting in overexploitation. Usher (1984) noted that increase in price of trochus did not correspond to that in harvest in Indonesia, and he suspected depletion of stocks.

Trochus is near commercial extinction due to overexploitation in Okinawa. According to a recent survey, harvest of trochus shells declined sharply after peaks in 1983/1984 at major production areas in Okinawa (Okinawa Prefectural Fisheries Experimental Station, 1989). In 1988, the Station together with Okinawa Sea Farming Center initiated a trochus restocking programme, supported by a grant from National Government. In April 1989, the first major field experiment, to release 100,000 juveniles, raised in the hatchery, was initiated. In their preliminary experiments, main causes in early mortality of juveniles were identified.

Similar programmes in trochus restocking are planned or in progress in New Caledonia, Pohnpei in the Federated States of Micronesia, and Palau, and proposed for Vanuatu by FAO/SPADP.

green snail

The green snail Turbo marmoratus is the largest species of Turbinidae and shells more than 20 cm in diameter are 2 to 3 kg in weight. Its nacreous shell is prized as materials for ornaments and inlay furnitures etc. Its geographical distribution is rather limited to continental islands, such as Papua New Guinea, the Solomon Islands and Vanuatu in Oceania. Early life history and other biological aspects of the green snail were described by Yamaguchi (1988a).

It is likely that the main producers of green snail shells, such as the Philippines, Indonesia, and Papua New Guinea, have overexploited their resources (Usher, 1984; Glucksman and Lindholm, 1982; Wells, 1989). The

recent price hike of the shell has been phenomenal, as it more than tripled during the past four years in the Ryukyus. It is apparent that the market demand is very strong but supply of green snail is limited.

Devambez (1961) investigated the green snail stock at Aneityum, a small isolated island located at the southern end of Vanuatu, in 1959 and 1961. The shelling of green snail and trochus had been prohibited in 1958 when these stocks were found exhausted. Devambez's six divers collected 11 green snails in 45 min. diving at Aneityum in 1959, while 13 shells were found in 10 min. by two divers in 1961. He concluded that the green snail stock had recovered at Aneityum to the level that allowed reopening of harvesting.

During the present survey, the author hoped to examine undisturbed stock of green snail at Aneityum. However, guided by a local expert diver fisherman, Mr. William Nejom, only three green snails were found during ca. 3 hour search at three different areas by two free divers (Mr. Nejom and myself). This population density of green snail was likely to be orders of magnitude lower than that reported in 1961. Overfishing was probably the cause of the reduction in the green snail stock but effect of poaching by foreign fishing vessels was also pointed out by the local residents including Mr. Nejom.

In the Ryukyus, when the snail was first exploited commercially in the 1880s, more than 200 tonnes of green snail shells were exported to European market each year for about a decade. The fishery practically collapsed early in this century (Yamaguchi, 1988c). This history clearly indicated vulnerability of green snail stock under commercial exploitation even by free diving. At present, the green snail is in the state of commercial extinction at most areas in the Ryukyus.

There is no choice but to develop coral reef ranching of green snail, in order to restock the reefs of the Ryukyus with this very important resource. If such attempt would be feasible technically and economically, it will be applied to transplantation of the snail to the areas without this resource in Oceania, if suitable habiatats for growth of juveniles and adults were found (Yamaguchi and Kikutani, 1989).

specimen and ornamental shells

There are large numbers of shell species utilized or collected for sale from coral reefs as specimen and ornamental shells, including those used for materials of shellcrafts. It is a common sight that tourists are offered various attractive shells and shellcrafts at local markets in Oceania.

Because of its fishery is small-scale and artisanal in nature, statistical data are lacking to evaluate importance of ornamental shell trade. It appears to be quite important for many people to generate cash income from the shell trade in Oceania. An assessment of specimen shell resources was carried out in Fiji (Parkinson, 1982). Although Fiji lies outside the faunal center of Indo-Malayan subregion, it supports an extensive range of popular shells exploitable for a small industry.

Very little is known about reproductive biology of most ornamental shells. It is often remarked that large atractive shells such as triton trumpet (Charonia tritonis) and helmet shell (Cassis cornuta) are overfished, but populations of many of such shells are maintained by teleplanic (long drifting) larvae, drifting across the ocean. Therefore, local pressure may not necessarily contribute to decline of population at the specific site of collection.

The majority of shell species would belong to those who produce pelagic larvae, that might spend several weeks to months as plankton, in Oceania. If this is true, larval rearing of ornamental shells may not be easy even for those hatcheries which have good facilities and people with experience. For example, mass cultivation of larval triton trumpet has been unsuccessful at Tarumizu Sea Farming Center of Kagoshima Prefecture, Japan. They have obtained large numbers of veligers hatched from egg capsules laid in tanks but have not reared any to settlement stage, which appeared to be reached after more than 3 months of pelagic life. The larval rearing was attempted repeatedly in the past eight years without success.

Stock enhancement of shell resources might be possible for some species by preserving and deploying good habitats for growout of juveniles. Spat collection of dominant species such as money cowries might be feasible as it was cultivated on palm fronds submerged in atoll lagoons in the Maldives (for production of large quantities of shell money!), according to Heyerdahl (1986).

reef-building corals

Small-scale exploitation of reef-building corals for export or souvenir trade is common among the nations in Oceania. Such activities are under supervision by fisheries authorities in Fiji and are monitored in New Caledonia, as already mentioned in the previous section. Most reef corals are now listed in Appendix II of CITES.

Reef-building corals often suffer from heavy infestation by crown-of-thorns starfish Acanthaster planci in Oceania. Chesher (1969) reported outbreaks of the starfish in Guam and other Micronesian islands in the 1960s. There have been numerous reports on the phenomenon for Fiji, Tonga, Cook Islands, American Samoa, French Polynesia, New Caledonia, and Vanuatu in the South Pacific (Conand, 1983; Moran, 1986; Zann et al., 1987).

In order to facilitate recovery of coral communities after devastation by Acanthaster infestation, coral planulae might be collected for planting on barren areas when corals reproduce anuually in mass-spawning events. Coral nursery might also be established for artificial growout of species useful in export trade, so that natural populations would be conserved. Basic research on this topic should be carried out to find out feasibility of collecting and holding large quantities of coral planulae as seedstocks.

2-3 Export commodities as dried and processed products

beche-de-mer

There are about 80 species of sea cucumbers or holothurians in shallow waters in the South Pacific (Clark and Rowe, 1971). About a dozen larger and more abundant species are harvested for processing into beche-de-mer products by a complex procedure (Conand, 1988 and 1989).

Extent of commercial exploitation of beche-de-mer is very variable among nations in Oceania. Fiji, New Caledonia, the Solomon Islands, and Papua New Guinea harvest and export significant quantities of beche-de-mer, while most others consume raw animals for subsistence food.

Recent increase in its demand by the Chinese market is likely to be related to economic development of the big population. Overexploitation of high quality species and shift of target species to low grade species were mentioned during the SPC Workshop on Inshore Fishery Resources Management at Noumea in March 1988. Stock enhancement using hatchery produced juveniles would be desirable for high grade species but basic study on reproduction and early development of some species has only began recently for tropical holothurians.

sponges

As they can regenerate from fragments, sponges can be cultivated from seeds prepared from mother sponges by cutting into small blocks, which regrow to harvestable sizes in certain periods. Thus, there is no difficulty as far as techniques are concerned in sponge culture. In order to make this aquaculture a viable business in Oceania, careful studies in selecting good sites, good species for cultivation and marketing research to identify dependable outlets should be conducted before implementation.

Storr (1964) pointed out some advantages and disadvantages in sponge culture in the Caribbean. The following factors would affect any sponge culture attempts in Oceania as well.

(1) Because of the slow growth rate of sponges it would not be until several years after starting that any returns could be expected.
(2) The possibility of total loss of several years of work by storm is always present.
(3) High density population of sponges might suffer heavy losses by diseases which might spread very rapidly among the cultured sponges.

2-4 Introduced species for aquaculture: case studies and lessons

commercial seaweeds

Cultivation of the commercial seaweeds (Eucheuma spp.) is most developed in the Philippines, producing 25,000 out of 43,500 tonnes of the total annual world production in 1984 (Stanley, 1987). These algae are processed to extract carrageenan (water-soluble gums) which is used mainly in the dairy industries such as ice cream, filled milk, infant food, custards,

shakes and yogurt as a gelling agent or emulsion stabilizer. Application of semi-refined carrageenan from Eucheuma cottoni expanded for pet food industry in the early 1980s.

Two species of Eucheuma (E. cottoni and E. spinosum) have been introduced from the Philippines to Oceania. Supported by grants from the Commonwealth aid agencies, cultivation of these algae has been promoted in Fiji, Tonga, and Kiribati in the 1980s. There are plans to develop cultivation of the seaweeds in some other nations such as Federated States of Micronesia (Nelson, 1988), the Solomon Islands and French Polynesia.

Methods of Eucheuma cultivation is simple, as the alga grows from fragmented thalii which may be fixed on nylon monofilament strings held in the sea. There are problems in this cultivation such as predation by herbivore fishes and epiphytic growth etc. but the greatest one is the marketing for the farmers in Oceania.

Because a carrageenan extraction plant must process at least a few thousand tonnes of dried seaweeds annually in order to be economical, it would be out of question for any small island nations to operate their own plants, not to mention the present state of this matured industry (Stanley, 1987). Large capacity of fresh water supply necessary for processing would be a limiting factor even in crude refinery. Therefore, the seaweed farming is at the mercy of the market outside the area. It would be very difficult for small nations to penetrate the existing market by producing relatively small quantities.

A New Zealand farm was originally supporting the plans to develop the seaweed farming in Fiji and Tonga, offering expertise in farming and prospect in purchasing the products. In Fiji, 173 tonnes of the dried seaweed were exported in 1986 for the first time. It increased to 217 tonnes in 1987 but fell to 60 tonnes in 1988, due to a trade ban by New Zealand. Tonga exported ca. 10 tonnes of the dried seaweed in 1986 but none thenafter. In Kiribati, 24 tonnes of the dried seaweed were purchased from the farmers by the Government in 1985, and market trials were made (present status unknown).

The commercial seaweeds are in theory good for aquaculture in Oceania but are in fact facing serious marketing problems which are difficult to overcome by local efforts.

green mussel

The green mussel (Perna viridis) is distributed along the South China Sea in China (Zhang, 1984), the Philippines and other nations in Southeast Asia. Much attention has been paid to this species for development of aquaculture in Southeast Asia and Oceania. The channel mussel (Perna canaliculus), also called as green mussel by locals, is cultivated in New Zealand.

Aquaculture of mussels (Mytilus edulis) are most developed in France, producing more than 40,000 tonnes per annum which surpassed the total harvest from natural stocks in the recent decades (Bonnet and Troadec, 1987).

French institution IFREMER has developed methods in spat production of Perna viridis in the hatchery at Vairao, Tahiti (Coeroli et al., 1984). In Tahiti, there is no native population of this mussel and the lagoon water is not rich enough in phytoplankton to support naturally-breeding population for spat collection in the field. Therefore, the hatchery must be self-contained to feed artificially its broodstock with cultured phytoplankton in raceway tanks.

Farming grounds suitable for the green mussel are limited to enclosed ponds or lagoons with extremely rich food supply for the filter-feeding mussels. In Tahiti and also Raiatea, shallow inlets enclosed by dikes are used for growing mussels. Although the mussel withstands rather large fluctuations in salinity and water temperature, unstable environment associated with the culture sites may cause high mortalities.

Cultivation of the green mussel, using spat from Tahiti, has been tried at several areas in Oceania. In the Cook Islands, an area in Rarotonga considered to be suitable for growing mussels was in fact a poor growing site because of deficiency in food conditions (Sims, pers. comm.). The mussel did not grow well in Tonga, also. Results of culture trials in Fiji was inconclusive. However, it was successful at least in certain lagoon areas in Western Samoa, as far as the growing of mussels was concerned.

Production of cultured green mussel has not replaced imported mussels in French Polynesia to date. Because suitable farming area is limited for the mussel, prospect in expansion of its cultivation may not be great in Oceania as a whole.

introduced oysters

The South Pacific Islands Fishery Development Agency (SPIFDA) was organized jointly by UNDP/FAO and SPC in the early 1970s. One of the two aquaculture consultants sponsored by SPIFDA, Glude (1972) recommended mollusc culture development using introduced oysters. Although some of the recommendations were followed, no viable projects resulted at any of the Pacific islands (Uwate and Kunatuba, 1983).

Glude (1884), in retrospect, admitted problems in developing mollusc aquaculture in Oceania, such as inadequate nutrient levels in supporting phytoplankton and poor adaptability of the temperate species of oysters to the tropical environment.

Bayne et al. (1973) demonstrated that a cold-water species of mussel Mytilus edulis failed to grow at 25 C, even under high ration of food because the energy balance was negative (see Figure 3). The high water temperatures in the tropics naturally drives the basic metabolism of poikilothermic species upwards if acclimation was not sufficient. Even if the summer temperatures were similar to the tropical conditions for a temperate oyster such as Japanese oyster Crassostrea gigas, it may not grow well under constant high temperature which is likely to be stressful (Mann, 1979).

Under normal circumstances, it is not wise to introduce temperate species t the tropical environment, particularly oysters. There are tropical oysters such as mangrove oyster Crassostrea glomerata and rock oyster C. echinata which should receive more attention if oyster culture was indeed desired. It should be remembered that even the cultivation of the local species C. glomerata did not last long in French Polynesia because of parasite problem.

Similarly to the case with the green mussel, cultivation of oysters require high concentration of phytoplankton in environmental waters. There has been little study to evaluate the energy budgets of those bivalves in relation to the local conditions in suspended food particles in Oceania. It is important to carry out a basic study in this aspect (energy budgets in mussels and oysters etc. in relation to concentrations of food) in order to evaluate suitable farming sites before implementation of culture projects.

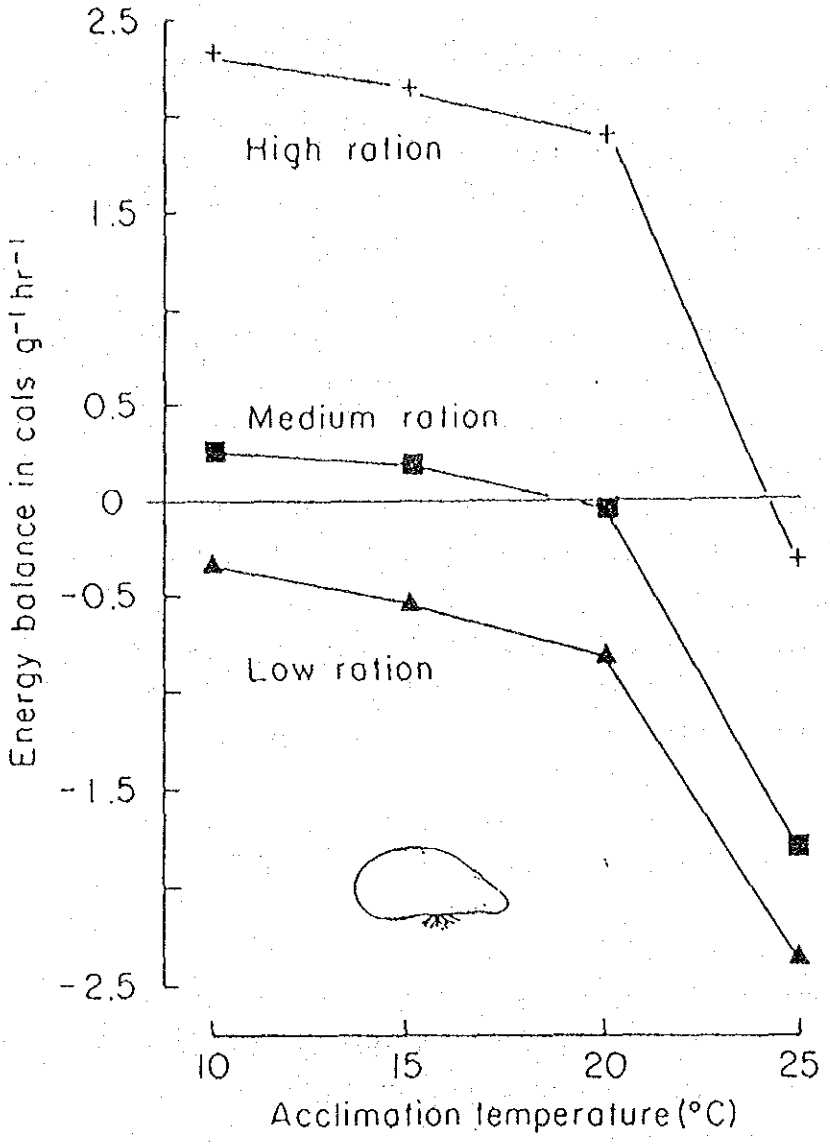

Figure 3 Scope for growth of the mussel, Mytilus edulis, at different temperature and rations. (from Bayne et al., 1973)

3. Some Characteristics of Reef Mollusc Resources

Coral reef resources are quite different from temperate ones in many ways, so that direct application of technologies and concepts developed in the colder waters would often fail to work in the tropics.

The following discussion will focus on some points which are important in resource enhancement, transplantation, and aquaculture of reef molluscs.

3-1 Geographical distribution and larval dispersal

The great majority of marine benthic molluscs produce pelagic larvae for dispersal in the tropics. The length of planktonic life may vary greatly among different groups or species. For example, species of cymatiid gastropods such as the triton trumpet, Charonia tritonis and the short-neck triton, Cymatium muricinum are likely to have long-lived larvae which may disperse widely in the ocean. Scheltema (1986) described 'teleplanic' (long distance) larvae of cymatiid and other gastropods from all the tropical seas. On the other hand, trochids and turban snails have short-lived larvae remaining for less than a week as plankton.

The range of geographical distribution is not necessarily related to the length of larval life in many molluscs. All the giant clam species so far studied produced very similar larvae which spent pelagic lives of around 9 days, but they differ greatly in ranges of distribution (Lucas, 1988). The green snail is found within the Indo-Malayan subregion in addition to the western Indian Ocean localities, but a congener Turbo argyrostomus is widely distributed in the Indo-West Pacific. Nevertheless, they produce larvae of very similar morphology, size, and pelagic larval life span.

Some mollusc species are more confined in their geographic distribution, probably because of their limited ability for pelagic dispersal. I noted absences of certain resource species in Tonga and other eastward nations in Oceania. It is often argued or questioned that introduction of certain species might be detrimental to existing species because of competition. However, those species which are sympatric in other areas should be considered favorably because they are likely to be accommodated ecologically in the 'new' area. For example, trochus, the green snail and some of the giant clams have been subjected to transplantation without any conspicuous ill-effects, at least with regards to competition, to date.

Most reef organisms found in Okinawa are distributed widely in Oceania. Islands of the Ryukyus are located along the warm Kuroshio Current which may transport pelagic larvae of many reef animals from the upcurrent areas such as the Philippines. In fact, almost all mollusc resources of the Ryukyus are also found in the Indo-Malayan subregion of the Indo-West Pacific. Thus, studies on aquaculture and reef-ranching of resources in Okinawa is useful in many nations in Oceania.

3-2 Life-history strategies

Populations of larger benthic organisms on the reefs are maintained by low or episodic recruitment as indicated by adult-predominant population structures. Long life spans of adults and iteroparity (repeated spawning by the same individual over number of years or seasons) would compensate for such recruitment, in order to maintain the population level.

Overharvesting broodstock population would then be very likely to result in destruction of the resource. Relatively long (at least two and often 4 to 5 years) life span before sexual maturation might superficially keep harvestable stock for a number of years before a sudden total crash.

The above population strategies of larger and important mollusc resources tend to make intensive cultivation uneconomical in the short term. It is probably ideal to maintain large enough broodstocks at strategic areas so that the population would be maintained by natural reproduction and recruitment, although natural recruitment levels may be normally low or uncertain. It is of course useful to implement stock enhancement by releasing juveniles which were reared in hatcheries, if such action is feasible and cost effective.

In order to restock or introduce mollusc resources, there is no alternative but to try to produce juveniles for releasing. Because of the life histroy strategy of the animals mentioned the above, it will be a long term project to implement and is unprofitable for private undertaking. Therefore, a reef ranching project with stock enhancement and introduction of green snail and other reef molluscs should be carried out by government/aid subsidized hatcheries until establishment of self-sustaining populations. Such investment would be repaid in the long term as exemplified by the many attempts of trochus transplantation in the past.

3-3 Compensation against poor background nutrition level

The coral reef environment is nearly devoid of phytoplankton for filter-feeding bivalves. Those bivalve molluscs which are successfully maintaining large populations, as harvestable stocks for humans, are found living with symbionts such as zooxanthellae or chemo-autotrophic bacteria as in the case of giant clams and lucinid clams.

In relation to the above, it is important to understand why some other bivalves such as the black-lipped pearl oyster and blood cockles are locally very abundant at certain reefs. If they were dependent on some factors which were reproducible or manageable, then it might become possible to manipulate them to enhance the stocks in other areas.

It is striking to see great abundance of trochus at some reef areas, before or without harvesting efforts, in contrast to the paucity of visible food organisms for them. There has been little study on nutritional value and productivity of encrusting micro-flora over the limestone substrates. Therefore, a basic study should be carried out on the energy sources for the substrate grazers on the reef, in order to evaluate carrying capacities of the habitats.

If the population density would be too high for the resource animal to gain enough nutrient for reproduction, it should be kept lower than such level by redistribution or thining. Gonad conditions of animals from various population density levels should be compared in order to verify this point.

3-4 Physiological constraints

It has been found that many coral reef animals live in environmental temperatures close to their lethal levels. For example, most reef-corals may not survive if temperatures were raised about 4 degrees above the ambient level. Although data on individual species are lacking, it would be wise to be cautious in handling broodstocks, larvae and juveniles of resource animals with regards to the environmental temperature.

4. Socio-Economic and Other Aspects in Fishery Development

4-1 Relative importance of subsistence fishery in the local economy

It is evident that the majority of island nations in Oceania still retain subsistence fishery as a dominant sector (Callaghan, 1988), although exact levels of its contribution are largely speculative. It is also clear that the artisanal fishery sector is developing along with urbanization at population centers.

The so-called 'subsistence affluence' at rural areas is more or less kept intact by emigration of part of the increasing population to urban centers or, in some countries, outside the region. However, it is only matter of time before there will be no more space to absorb the rapid population increase in Oceania at large.

Certain mollusc resources are targets for cash income as well as protein source by many rural people at subsistence level. Because sedentary resources such as molluscs and holothurians are prone to overharvesting, attention should be focused on developing technologies of their stock enhancement and ranching (Yamaguchi, 1989).

There might arise some conflicts in distribution of assistance efforts between rural subsistence and urban commercial fisheries development. Urban development would be more attractive politically and also contribute to the cash economy, but reinforcing rural 'subsistence affluence' would be beneficial to overall balanced development in small islands.

4-2 Sea tenure and commons system in Oceania

Sea tenure and commons system is very variable and has been changing among the island nations in Oceania (Johannes, 1988). As already mentioned for the Federated Statesof Micronesia, it is different from state to state or even among different islands. This fact must be considered whenever any fishery development plans, involving exclusive use of sea areas, are implemented.

There are many attempts at keeping giant clam circles or broodstock holdings in Yap of the Federated States of Micronesia and in Kingdom of Tonga, etc. The traditional sea tenure system is very much alive in Yap so that the

Marine Resources Division of the State was able to distribute the clams among the municipalities throughout the island. On the other hand, the Ministry in charge of the giant clam circle in Tonga had to keep a close eye on the circle, and as such they had to resort to placing the clams under unfavorable environmental conditions. All Tongans share the fishing grounds as marine commons with free access.

The range of stock distribution is related to larval dispersal and therefore a broodstock of one resource may contribute to recruitment to areas other than the originating one. Larvae of the archaeogastropods (trochus, the green snail and others) and giant clams are relatively short-lived, so that unit stock of a resource may be managed within one small island or part of larger islands, depending on the area sizes. However, this size may not necessarily correspond to mangagement units under sea tenure, where exist.

In order to implement reef ranching and stock enhancement of sedentary resources, fisheries or marine resources authorities would need to seek strong support from local residents through public education and other means, because enforcement of conservation measures is very difficult without self-control. They should explore this by careful appraisal of the situation at each locality to avoid the 'tragedy of the commons' problem.

4-3 Destructive fisheries and environmental degradation

There are widespread problems of destructive fisheries using explosives and toxic materials etc. in Oceania (e.g. Chesher, 1985). Destruction and degradation of various habitats, including nurseries for juvenile grow-out, by reclamation and pollution are also prevalent in shallow areas near urban centers (e.g. Pastorok and Bilyard, 1985).

Johannes (1975) reviewed this problem in the tropics and pointed out research needs in many aspects, by pointing out diffrences in responses of ecological communities to environmental pollution between tropics and colder waters.

The South Pacific Regional Environmental Programme (SPREP), established jointly by SPC, SPEC, ESCAP and UNEP in 1980, has formulated an action plan (UNEP, 1983) for managing the natural resources and environment of the South Pacific Region. Many activities and projects are in progress under this action plan, including dynamite fishing problem (SPREP, 1988).

The reef resources are sedentary and dependent on healthy state of habitats for their growth and reproduction. Particular attention should be paid for protection and management of nursery grounds, such as intertidal seagrass meadows and rubble/boulder zones, in order to maintain grow-out habitats for seedlings in reef ranching and restocking projects.

4-4 International cooperation

There are a number of regional, multilateral, bilateral and individual activities in managing reef resources and developing reef ranching and aquaculture. Some projects such as those supported by FAO South Pacific Aquaculture Development Project and SPC Inshore Fisheries Research Project are described in earlier sections.

Activities involving giant clams have been most conspicuous and wide-ranging among such projects. The giant clam culture at the MMDC of Palau has been supported by Pacific Fisheries Development Foundation (PFDF) of the U.S.A. and other agencies. The Australian Centre for International Agricultural Research (ACIAR) supports a multilateral giant clam project, involving many nations of not only Pacific but also Southeast Asia. Furthermore, the International Centre for Living Aquatic Resources Management (ICLARM) has established its giant clam hatchery in the Solomon Islands. In addition to the above, both Okinawa Prefectural Fisheries Experimental Station and Sea Farming Center are working on restocking of small boring giant clam Tridacna crocea.

It will be good to promote similar efforts of international and regional cooperation in developing other resources. SPC Inshore Fishery Resources Project proposed to organize groups of specific interest for dissemination of information among the researchers in the region (SPC, 1988). In this connection, fisheries researchers of Okinawa should actively exchange ideas and information with those working on the same resources in Oceania.

The traditional method of bilateral assistance may limit such activities as international and regional cooperation of fishery development in Oceania. It is essential to upgrade capabilities of fishery workers through close collaboration in the whole region so as to be able to tackle many problems, related to the same resources, by as many researchers as possible within the limited man-power resources.

CONCLUSIONS

Coral Reef Ranching and Lagoon Farming of Inshore Sedentary Resources

Reef ranching and farming of some molluscs and other sedentary organisms would contribute significantly to fishery development in Oceania. Although their commodity values may fluctuate according to market demands, shells and dried products can be stowed at minimal costs, unlike fresh products, so that large enough quantities for export would be accumulated and that their marketing would be managed. Furthermore, shells would become important sources and materials for small-scale industry, manufacturing value-added shellcrafts and ornaments in addition to button blanks (Smith, 1988).

Because of the ease with harvesting and increasing demands in the markets, mollusc resources, such as trochus, green snail and pearl oysters, have been subjected to overharvesting at many localities. Larger giant clams also have been over-exploited for food. There is a pressing need to help alleviate this problem through resource enhancement by ranching/farming of hatchery-produced juveniles (Kafuku, 1986; Yamaguchi, 1989).

Introductions of resource species, which are locally absent but are found elsewhere in the Indo-West Pacific faunal region, into vacant ecological niches at certain localities would be beneficial to fishery development. Reef molluscs as resouce animals are mainly low in the trophic level and are unlikely to cause problems of ecological disturbances associated with their introductions. The past efforts in trochus transplantation resulted in providing cash income for many rural communities throughout Oceania.

Hatchery production of juvenile molluscs would minimize the problem in introduction of the target species associated with pests and other undesirable organisms, because these organisms would be checked by quarantine facilities of the hatchery.

Domestication of resource species should be carried out through hatchery production of juveniles and selective grow-out of those having suitable traits and qualities. On the other hand, information on population genetics of the wild stocks should be carefully studied before disturbing natural systems by transplantation.

In order to develop the reef ranching and lagoon farming of various species of molluscs, greater efforts in basic research are required. Most workers in the small island nations are usually overwhelmed by many problems of day-to-day operations and are often unable to concentrate in research and development of new topics. There are only a few research institutions which may be able to tackle basic problems in reef ranching and lagoon farming in Oceania.

Network of Researchers working on Reef Ranching in Oceania

There is no regular forum for researchers working on the inshore resources in Oceania, other than the Special Interest Groups to be supported by the SPC Inshore Fishery Resources Project. It is vitally important for the researchers to exchange information and ideas on specific topics by assembling at regular seminars and workshops and also by site visits at institutions of other workers.

The cost to support such activities as the above would be significant because of the great distances involved for the researchers to travel by air. There are some opportunities provided for junior workers to be trained at certain institutions such as MMDC at Palau. While it is very important to have such training courses, independent researchers should also be working on original research and development projects. In order for them to be able to pursue such projects, financial assistance is required not only for project itself but also information exchange.

In the case of reef ranching and lagoon farming of molluscs and other sedentary resources, a network of researchers may be established for exchange of information by newsletters, regular meetings and occasional site visits. Expert meetings may be held alternately at different institutions with financial assistance by appropriate aid agencies. I hope that JICA would be willing to support such activities.

Establishing and Expanding Core Institutions in Okinawa and Elsewhere

It is evident that researchers of Okinawa lead the area of reef ranching of gastropods and seed-production of various species of molluscs and other resources in the hatcheries (Shokita, 1988). University of Guam Marine

Laboratory is at present pioneering ranching and farming of holothurians or sea cucumbers. MMDC at Palau, James Cook University of Australia, and many other hatcheries in Oceania concentrate on giant clam farming.

Because the basic needs are almost the same for ranching and farming of various reef resources, research and development involving new targets would be carried out at strategic institutions while field application of established species would be executed at field stations or local facilities. Such segregation of efforts might be possible if development projects would be organized and supported in an integrated manner and participated by a network of researchers having good communication among them.

Fishery institutions of Okinawa in the past have paid little attention to the development elsewhere in Oceania, but they are much more concerned and interested in international cooperation. Not only reef ranching and lagoon farming but also other areas such as Fish Aggregation Devices (FADs) and resources of deep water snappers and groupers are very relevant to the cooperation and assistance. However, they have their own committments in hatchery production quotas and other development, so that additional efforts to accommodate international programmes might become an excessive burdon.

It will be ideal that JICA or other appropriate agencies such as OFCF would establish a fishery institution specifically designed to carry out research and development in addition to training of personnels for the developing nations in the tropics, with emphasis on resources in the Indo-West Pacific. A core institution should be established in Okinawa, where are relevant resources are available for research, in association with the existing laboratories of Okinawa Prefecture, Japan Sea Farming Association hatchery, and the Univeristy of the Ryukyus.

The facilities of MMDC at Palau would be expanded by JICA assistance, so that this institution would be acting as a research center of Micronesia (see Anraku, 1989a and 1989b). Of course, this will depend on the decision to be made by Palauan Government but they should be informed of the needs of such international and regional institution which is beneficial to Palau and the neighboring nations in Micronesia. Likewise, other core institutions may also be considered for Polynesia and Melanesia.