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SOUTH PACIFIC ISLANDS - ROCK LOBSTER RESOURCES

A REPORT PREPARED FOR THE

SOUTH PACIFIC ISLANDS FISHERIES DEVELOPMENT AGENCY

by

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1. INTRODUCTION

1.1 TERMS OF REFERENCE

The Governments of the South Pacific Islands (Australia, France, New Zealand, United Kingdom, United States of America and Western Samoa), assisted by the United Nations Development Programme and the Food and Agriculture Organization of the United Nations, are engaged in a project whose main purpose was to assist in the establishment and operation of a South Pacific Islands Fisheries Development Agency to determine feasibility areas of fishery development in the region and to assist in formulation and implementation of specific action programmes in the various island territories. The project became operational on 22 July 1970 and as part of the project operation, FAO assigned a Marine Biologist (Crayfish) Consultant, with the following terms of reference:

"To prepare a review of the existing fisheries for rock or spiny lobster (crayfish) in selected territories of the south and southwest Pacific, including identification of the species concerned and compilation of available knowledge of the behaviour of and methods of fishing for these organisms; to indicate areas where further study and research is desirable and to prepare programmes for such investigation and preliminary proposals for the rational management of the available stocks."

The following report is based on interviews with fishermen, private industry and Government officers, supplemented by visits to actual or potential rock lobster areas and an assessment of habitat by diving and by aerial survey.

In 1969, the South Pacific Commission (SPC) and South Pacific Islands Fisheries Development Agency (SPIFDA) circulated a Spiny Lobster Resource Survey questionnaire to assist in the assessment of the identity and the abundance of rock lobster in each Territory.

Additional observations relative to other fishery developments in the Pacific have also been included in this report. In accordance with specific requests for surveys by Territories, the total survey was divided into four tours and each tour carried out by the Consultant commenced and terminated at Noumea, headquarters of the SPIFDA.

The programme was arranged as follows:

Tour 1 - Fiji, Western Samoa, American Samoa and Tonga
Tour 2 - New Guinea, Solomon Islands and New Hebrides
Tour 3 - French Polynesia and the Cook Islands
Tour 4 - New Caledonia

In addition, arrangements were made for Mr. Craig McDonald, a Peace Corps Volunteer, studying rock lobsters in the United States Trust Territory, to report to the consultant in New Guinea.

2. FIJI

2.1 SYNOPSIS OF ACTIVITIES

The Consultant landed at Nadi, visited Suva, Lautoka, Western Yasawa, Lau Group (Komo, Ongea, Fulanga Islands) and carried out an aerial survey of Viti Levu and Yasawa Group as well as visiting the major islets to east of Viti Levu.

2.2 GENERAL TOPOGRAPHY AND CLIMATE

There are two major islands, Viti Levu, 10 471 km^2 and Vanua Levu, 5 535 km^2 between which is an extensive deep sedimentary area known as Bligh Water. Situated around these main islands are several small ones (e.g. Kadavu 407 km^2, Taveuni 435 km^2, Lomaivitu Group 409 km^2) and many small islands some as distant as over 300 km, e.g. those in the Lau Group southeast of Suva (57 islands totalling 461 km^2).

The two main islands and those smaller islands in the immediate vicinity receive much rain - over 5 080 mm in the central and southern parts. Only about 1 800 - 2 500 mm fall in the northern and western parts (including the Yasawa Group). The further offshore islands of the Lau Group also experience low rainfall, and droughts are not uncommon at Komo, Ongea and the Fulanga Islands.

Most of the islands are of volcanic formation and consist of very high peaks, the highest being Mt. Victoria (1 323 m). Cloud hangs almost permanently over these regions and rainfall is regular, resulting in many rivers draining off to the coast forming river deltas of an estuarine nature which are subject to the rise and fall of tide - about 1.5 m (1.8 m during the spring season).

The non-volcanic atolls and calcareous islands are mainly in the Lau Group which are usually low, about 79 m, and receive little rain, villages often suffer water shortages in these areas.

2.3 COASTAL FEATURES AND ZONES

The high rainfall, volcanic islands have mangroves at the water's edge. Due to fresh-water run off and silt content in these areas, coral growth is limited and there are lagoons inside the hard coralline barrier reefs some distance offshore. The low rainfall atolls, cays and limestone islands have coral growth much closer to the island. There is generally a coral reef platform close to the shore and a coralline algae hard outer reef on the side exposed to the major swell (generally southerly (SE)). Where seepage through the limestone is regular, e.g. off Fulanga beach, shallow sea grass beds are maintained behind the barrier reef. In other places seepage near river mouths (e.g. Komo) forms beach rock by cementation of beach sands.

2.4 FINDINGS

2.4.1 Rock Lobster

Reports, discussions and personal observation support the contention that in Fiji four species of Panulirus are present.

P. penicillatus. These were caught mainly on the south east sides of islands on the exposed coralline algal reef edge, living amongst the surf and in the surge channels. Two hundred and twelve specimens were taken on 17 November 1970 in about two hours by 20 villagers from Ongea on the 3 200 - 4 800 km outer reef of Nukosoge Reef. About seven men actually caught the lobster by jumping into the surge channels and pulling out P. penicillatus (and the Butterfly lobster, Scyllarides caledonicus) by gloved hand. The surf in the channels, and the dark coralline algae on the walls made the surge channels quite dark.

P. versicolor. These occur very sparsely well inside the lagoons, on the northwest sides of big islands and in moderately protected water in large eroded coral heads of 1.8 - 3.7 m in depth. It is possible that there is a correlation with some silt and freshwater run off (near stream mouth, e.g. Komo and off Suva or seepage from the island, e.g. near Tavarua Island). This was observed on the islands of Tomberua, Komo, Fulanga and Tavarua; according to Mr. Costello (of Beachcomber Cruises, Lautoka) this species is the most common one inside the Yasawa Group.

P. longipes femoristrige is a very rare species. In 1960 or thereabouts two specimens were collected for the Western Australian Museum and one was reported by Mr. Adams, the Senior Fisheries Officer at Suva, from immediately inside the barrier reef in the Suva harbour passage.

P. ornatus. Large specimens are occasionally taken (mostly together with P. versicolor) from Navua, Lauthala Bay, Tomberua Island, as reported by Mr. Stone, a Fisheries Officer and from north coast Kadavu Island, according to Captain Frazer, a Master Pilot in Suva.

The entire catch of P. penicillatus (212) from Nukosoge Reef was sexed, measured (carapace length (C.L.) in mid-line from ridge between the horns to the back of carapace), and the condition of eggs, spermatophore and swimmerets noted for females. Males are much larger than females and the sexes are about equally represented (Table 1). A little more than half the females carried eggs and all females except one (64 mm C.L.) had long fibrils on swimmerets suitable for carrying eggs. Although the two small females did not carry eggs, they were probably mature at that size (51 - 62 mm C.L.).

The fact that new spermatophores are present on females which are carrying eggs in all stages from newly extruded (red) through to final-eyed embryonic stage (brown) suggests that the females do not necessarily moult immediately before mating (Table 2). There were also some berried females that carried a new spermatophore which had been deposited over the remnants of the old one which in turn had been used to fertilize the berry. These data suggest that frequent spawning (probably without moulting between spawning) would continue over an extended period of time. Reports from the fishermen support this view as females with eggs are found all through the year.

2.4.2 Fishery Development

Past: The Fiji Government supported a venture in 1961 at Kadavu Island to collect and process rock lobster caught by Fiji fishermen. They also tried to improve fishing methods by use of New Zealand pots but caught nothing. The water is very clear and pots set in 15 - 17 m on the south side were easily visible. The Fiji fishermen used to wade over the southern reefs at night using lights. Catches by this method yielded about 20 - 30 rock lobster per night by a team of 20 men (about seven or so did the actual catching).

In about 1963, a New Zealand firm set pots of many designs in the northern waters of Viti Levu and around Yasawa Group, but without success and after considerable expense according to Mr. Costello from Lautoka. P. penicillatus is not abundant there and P. versicolor which is known in that area does not enter pots.

In recent years sport fishermen and tourists have caught rock lobster near Suva on the outer barrier reef (mainly P. penicillatus from reports) and around the tourist centres, particularly at Yasawa (apparently mainly P. versicolor).

Present: The sport and tourist activities continue but the only commercial activity is that supported by the Fisheries Division which provides transport for the Ongea fishermen to exploit the Nukosoge Reef on three to six days during a year. Even at this low level of activity and because of the ruling prices on the Suva market, the Ongea fishermen earn about one tenth of their total annual income on these occasions. They are paid Fiji $ 0.60 per lb for cooked whole rock lobster which have not been speared. A substantial part of the Suva demand for rock lobster tails is satisfied by importation from Tonga.

2.5 RECOMMENDATIONS

(1) Since P. penicillatus appears to be the most common species and can be taken by trap, then the Lau Group should be concentrated on for future development. These are the areas of hard coralline algal outer reefs, good surf action and low rainfall (good oceanic conditions).

(2) Fishermen should be encouraged to expand exploitation. For instance more frequent visits to Nukosoge Reef, by the Onga fishermen is warranted. This can be done by the Fisheries Vessel or a larger vessel for the islanders. In addition night fishing on the reef flats should be profitable. Such encouragement should extend to other islanders of the Lau Group.

(3) Traps or any other means to catch lobster alive should be developed to ensure a top quality product. The need to maintain a good quality product cannot be over-emphasized.

(4) It is necessary to record catch and effort data (e.g. weight and numbers of rock lobster, number of men, hours worked and catching method) and also record the historic development of the fishery so that future management procedures can be instituted if necessary.

(5) Strong limitations to the fishery development should not be enforced at this stage. Development must be encouraged and a watch maintained on changes in techniques and efficiency of the development.

(6) The local market and the large tourist trade should be satisfied first before aiming for substantial exports to other countries. The resource should stand considerable additional exploitation without harm to the stock until much more efficient methods of catching P. penicillatus are devised.

/Note added 12 April 1971: The analysis of the entire catch of subsequent fishing operations at Nukosoge Reef in mid-January 1971 shows no significant change in stock size frequency (Table 5) or reproductive activity (Table 3). As the 4 - 5 km reef is worked only three to six times each year, the stock is not fished heavily at present./

2.6 OTHER OBSERVATIONS AND ACTIVITIES

The University of the South Pacific was visited. It is based on the "school" system and has among its schools, the School of Natural Resources. The position of Head of this school is vacant at the moment. Financial support for marine studies has been offered by the Canadian Government and a marine expert is being called in to advise on marine studies.

Advice was given to the Fisheries Division on a programme of bait fish investigation which they will conduct independent of, but in consultation with, the UNDP local tuna fishery project.

The natural resources of the freshwater and estuary waters of Fiji are very important. Mr. J. Glude (SPIFDA) is already concentrating on oyster investigations. The freshwater prawns (Macrobrachium) and crabs, as well as the shallow water prawns around the north, south and east coasts of the larger islands are potential resources.

Deep water prawns probably exist in the level muddy bottom of Bligh Water and mid-water trawling at night or bottom trawling experiments might be worth conducting.

Initial studies may also be justified (probably in conjunction with the University of the South Pacific, the UNDP, and other agencies) on:

(a) the water circulation around Fiji (using drift cards or bottles),

(b) distribution and ecology of coral species and coralline algae,

(c) production of vegetation map for the estuaries and coasts, particularly the mangroves, to give detail to the coastal zonation and its potential,

(d) river crabs - these are on sale in the markets and warrant some study,

(e) Mantis shrimps. Large burrows were observed in the shallow water near Tomberua Island (off the river Rewa tributary). These are probably the burrows of a large edible mantis shrimp Lysiosquilla maculata which may be locally acceptable at the market.

(f) the butterfly lobster, Parribacus caledonicus,[1/] which lives near the rock lobster (P. penicillatus) of the outer barrier reef, is also commercially acceptable.

(g) the Kona crab (Ranina ranina) has been reported in Nadi waters.

None of these resources are likely to be vast but a diversified fishery for local consumption is usually well received by both tourists and locals.

Advice was given to the Fisheries Division on controls relating to management of the coral reef resources in Fiji waters.

Water is a severe problem for most of the "dry" islands. Perhaps aid to investigate underground and solar still resources should be sought.

Three Crown of Thorns Starfish were observed on the inside (western) side of the lagoon on Nukosoge Reef. These were the only specimens seen during the survey.

Table 1

CARAPACE LENGTH DISTRIBUTION OF PANULIRUS PENICILLATUS,
NUKOSOGE REEF (LAU GROUP, FIJI)
17 November 1970

Length Carapace (cm)	Males	Females	
3.8 - 4.9 (1.5 - 1.9 in)	1	-	
5.0 - 6.2	3	2	(without eggs)
6.3 - 7.4	3	14	(6 with eggs)
7.5 - 8.7	7	39	(26 with eggs)
8.8 - 10.0	14	43	(27 with eggs)
10.1 - 11.2	16	16	(8 with eggs)
11.3 - 12.5	17	1	(without eggs)
12.6 - 13.8	24	-	
13.9 - 15.1	8	-	
15.2 - 16.3 (6.0 - 6.4 in)	4	-	
Total	97	115	(67 with eggs)

1/ Holthius, 1960. Proc: Biol. Soc. Wash. 73:147

Table 2

RELATION OF SPAWNING CONDITION AND SPERMATOPHORE CONDITION OF FEMALE *PANULIRUS PENICILLATUS*, NUKOSOGE REEF (LAU GROUP, FIJI)
17 November 1970

Egg Condition	Condition of Spermatophore			Total
	Nil	New	Old	
Nil	15	12	23	50
Red	1	8	20	29
Orange	1	6	20	27
Brown	1	3	5	9
Total	18	29	68	115

Table 3

RELATION OF SPERMATOPHORE CONDITION AND EGG CARRIAGE OF FEMALE *PANULIRUS PENICILLATUS* NUKOSOGE REEF (LAU GROUP, FIJI)
Mid-January 1971

Note: colour and condition of egg could not be scored since many of the specimens had had the swimmerets cut off

Eggs	Condition of Spermatophore			Total
	Nil	New	Old	
Absent	3	19	51	73
Present	-	11	26	37
Total	3	30	77	110

Table 4

CARAPACE LENGTH DISTRIBUTION OF *PANULIRUS PENICILLATUS*
NUKOSOGE REEF (LAU GROUP, FIJI)
January 1971

Length Carapace (cm)	Males	Females
7.5 (3 in)	-	6
8.5	2	19
9.5	19	35
10.5	16	35
11.5	17	11
12.5	18	2
13.5	17	2
14.5	12	-
15.5	5	-
16.5 (6.5 in)	2	-
Total	108	110

Table 5

CARAPACE LENGTH FREQUENCY OF MALE AND FEMALE PANULIRUS PENICILLATUS
NUKOSOGE REEF (LAU GROUP, FIJI)
November 1970 (212) and January 1971 (218)

November 1970

Carapace length Interval mid point (cm)	Males	Females
1.75 (0.7 in)	1	-
2.25	3	2
2.75	3	14
3.25	7	39
3.75	14	43
4.25	16	16
4.75	17	1
5.25	24	-
5.75	8	-
6.25 (2.5 in)	4	-

January 1971

Carapace length Interval mid point (cm)	Males	Females
7.5 (3 in)	-	6
8.5	2	19
9.5	19	35
10.5	16	35
11.5	17	11
12.5	18	2
13.5	17	2
14.5	12	-
15.5	5	-
16.5 (6.5 in)	2	-

3. WESTERN SAMOA

3.1 SYNOPSIS OF ACTIVITIES

On Upolu Island, the north coast from Apia to Falulo was surveyed and a dive to 30 m at a point situated 5.6 km from Apia was made; in addition, the reef edge and nearby lagoon on the south coast at Salamumu was investigated.

Savaii Island was circumnavigated by road and selected reefs were dived on. Local fishermen on the south coast at Vaiola, Papa (SE), Vaipua, Falelima, Failailoa and on the north coast at Papa (NW), Asau, Lefangaoalii Safotu, Tagomalo were interviewed. Aerial surveys of each island were made on two separate occasions.

3.2 GENERAL TOPOGRAPHY AND CLIMATE

The two main islands are Savaii (1 891 km^2) and Upolu (1 114 km^2). Between these are a volcanic cone island (Apolima) and a sunken crater island (Manona Island). Strong currents flow between the main islands. Upwelling is suspected off the west part of Savaii. Lee et. al. (1970) in their report on Western Samoa state "Apparently there is an area of enrichment off Falealupo, since fishermen in this village claim that skipjack tend to congregate in large numbers in this area, a phenomenon which attracts fishermen from villages along the coast as far away as Asau." Eddy systems probably also occur around the mid north coasts of Savaii and Upolu. Both islands are basically volcanic islands (Savaii has very recent lava fields) rising to 1 829 m (Mt. Maugamu, Savaii) and 945 m (Mt. Fau, Upolu).

Rainfall is generally heavy, up to 6 350 mm in the high central region and less than 2 540 mm in some of the coastal regions. Droughts are more likely in the northcoast regions of both Islands (Curry, 1955 p. 38). The run off is mainly by direct percolation through the porous lava rock so that fresh water abounds at the water's edge where drinking and bathing pools have been built by the villagers. The tidal range is a little under one metre.

3.3 COASTAL FEATURES AND ZONES

Estuarine conditions are generally lacking. Fagaloa Bay appears to be the nearest to an estuarine situation. Major swells are from the south where lava cliffs 3 - 15 m in height and water spouts are common. The northern coasts are calmer although summer north-east variables help to "lump up" the deflected waves along the north coast. Offshore reefs have developed beyond the influence of the fresh water seepage in the older areas at eastern Savaii and around Upolu. Curry, (1955) states: "The extent of the reef can be seen in Fig. 7. It lies off coasts which are not formed of recent lavas, the width of the reef in general increasing with the age of the land behind it". Several reef flats have formed fairly close to the lava cliffs in some places (e.g. at Vaipua) and these flat reefs are fairly smooth and appear to be covered by hard encrusting coralline algae rather than by coral heads. Wave action is generally high and constant, and cool deep water is suspected to reach the surface in these areas.

3.4 FINDINGS

3.4.1 Rock Lobster

All reports and discussions with fishermen indicate that only one species is present in Western Samoa. Two specimens were observed at Papa (NW) and two more were examined before being eaten, by a passenger on the boat travelling between Savaii and Upolu. All were Panulirus penicillatus. The butterfly lobster (Parribacus caledonicus) is occasionally found at the Apia market but is not in demand by the hotel trade.

3.4.2 Fishery Development

Past: In about 1968, Nelson's Store conducted a survey from the vessel PALMAR using traps. Reports suggest that catches were fair but there is no trap fishery today. Local fishermen used to use small (46 cm) banana shaped wicker baskets to trap rock lobster. These were wedged into the cracks in the volcanic lava and recovered the following day. They are not used today.

Present: Rock lobster are taken by spear or hand spasmodically by groups of two to three village fishermen who dive along the coralline reef edge on dark nights while one on the reef holds a pressure lamp. About 5 - 10 are taken in about two hours (Vaipua fishermen). They are not often seen during the day time. Mr. Travis, a Fisheries Officer at Apia, has recently initiated a village project at Vaipua to catch rock lobsters by hand at night and take them alive to Asau (direct sale) or Saleloga (for transport to Apia). If successful at Vaipua, other villages will be incorporated into this development.

3.5 RECOMMENDATIONS

(1) The local demand by Europeans and tourists for a high priced, fresh or properly cooked or processed product should be satisfied. Stocks probably will not support attempts at large scale overseas exports.

(2) Villagers should be encouraged to catch rock lobster by hand or trap, without damaging them.

(3) The quality of lobster at the market must be carefully controlled so that high prices can be maintained for the expected small but constant high quality product. ($ 1 per 0.45 kg whole live weight, to the consumer should be reasonably expected if freshness and quality are assured.)

(4) Fishing techniques should be improved initially by resurrecting the traditional wicker basket trap, then testing buoyed and baited traps that can be operated from the fishermen's vessels. Traps that provide some sort of dark shelter will probably be more successful than ones that allow full light penetration. Dark water such as exists near lava rock flows will probably be preferred rather than coral reefs and lagoons and white sand bottom.

(5) Until fishing techniques are improved and it is not yet known if a worthwhile resource exists and can be utilized, full exploitation must be encouraged, recording in general terms only, the catch and effort as the fishing develops. A general statement for a year or two should suffice as the introduction of a detailed data collecting programme could inhibit such development in Western Samoa. Only by such records can future resource management programmes be instituted.

3.6 OTHER OBSERVATIONS AND ACTIVITIES

Prawns. Freshwater prawns in the rivers and marine prawns in Fagoloa Bay are reported by Mr. Travis. The potential for natural exploitation or cultivation should be examined in the future.

Tuna. Tuna are taken by "bonito" canoe fishermen fairly close to shore at places like Papa and Safotu on the north coast of Savaii where eddying is suspected and where rock lobster will probably be abundant.

Turtles. During the aerial survey 21 November 1970, many turtles (about 40) were observed in the main channel between Savaii and Upolu. Two pairs (copulating) were also seen here. On 23 November during the aerial survey around Upolu, fewer turtles (about 30) mostly around the east end of Upolu, were seen.

4. AMERICAN SAMOA

4.1 SYNOPSIS OF ACTIVITIES

The Consultant visited likely rock lobster places by road, as far west as Palea and east to Oneona and across the central ridge to Fagasa on north coast, diving at Faganeanea at night and at Fagaitua in the daytime. He also used "lobster rafts", pulled along by fishermen in two to three feet of water.

4.2 GENERAL TOPOGRAPHY AND CLIMATE

Tutuila (111 km^2) and Manua Island (49 km^2) are high (Mt. Matafao 653 m and Mt. Lata 931 m respectively) volcanic islands lying on the Samoan Ridge. The islands are young (Pliocene or Pleistocene, according to Stice and McCoy, 1968) and have high rainfall (about 6 350 mm). The reefs are narrow (up to 30 m) and formed mainly of coralline algae with few coral heads. Beach rock of cemented calcareous sand is not uncommon

and the beaches are frequently soaked with fresh water. Run off is via the short rivers (and waterfalls) to the sea where broad channels across the reef, usually carry the run off straight out into the ocean. Fresh water does not appear to lie unmixed on the reef or bubble out at the edge of the sea. Swells are mostly from the south east, apparently induced by the SE Trade winds. Mangroves and estuaries are very limited. The tidal range is a little under one metre.

4.3 COASTAL FEATURES AND ZONES

The geological youth of the islands has resulted in a fairly homogenous geomorphology of steep eroded headlands, with narrow flat reefs extending across embayments which usually have narrow calcareous sand beaches. Prominent headlands and cliffs are usually undercut where wave action is strong (e.g. in the region of Leone Pt.). Surge channels dissect the heavily calcified reef edge and broader channels usually cross the reef flat opposite river or stream mouths.

4.4 FINDINGS

4.4.1 Rock Lobster

Panulirus penicillatus is apparently the only species common in American Samoa, and fishermen's discussions support this view. Their habitat is in the caves and crevices beneath the overhang of the reef edge and in deep recesses and holes around boulders on the reef flat. They probably use the narrow surge channels of the reef front as access to the reef flat. At night - particularly on dark nights - they wander over the reef flat. They are also reported from 14.6 m depth.

4.4.2 Fishery Development

Past: In 1965 experimental traps were set off Laulii in about 14.6 m using Aku (small tuna) heads as bait. The traps were constructed of 7.6 cm x 10.2 cm welded wire mesh with smaller mesh for the entrances. The traps measured about 1.2 m x 0.9 m x 0.9 m and were ballasted with iron sash weights. Catches of about fifteen rock lobsters per trap were apparently taken. From a photograph, the specimens appear to be large male, P. penicillatus, the smaller sizes presumably escaping through the 7.6 cm x 10.2 cm meshes. This venture concluded when the traps were stolen. Local fishermen traditionally used round wicker baskets with inverted neck opening to catch rock lobster or fish (Buck, 1928). These are still made at Tutuila today as ornaments for the tourist trade.

Present: Local fishing groups of about four men or boys use a "lobster raft" which carries a pressure lamp on a raised bracket. This is towed over the reef flat at night near full tide and the rock lobster are taken by goggled divers using spears or Hawaiian slings (slingshot and unbarbed steel shaft). Catches of about ten rock lobster for two hours night fishing are usual; thirty a night is good fishing. Consumption is by local Samoans, not hotels or restaurants, as quality and supply are not guaranteed. The hotel (91 kg of tails per month) and restaurants import rock lobster tails from New Zealand and Tonga.

4.5 RECOMMENDATIONS

(1) Exploitation of stocks which are probably sufficient at present to satisfy the local market of one hotel and a few restaurants should be increased. Stocks are most unlikely to support major exploitation designed for overseas markets.

(2) Local fishermen should be encouraged to catch without spearing or damaging the rock lobster, i.e. by hand, trap or net.

(3) The quality of the product on the market should be controlled. Only by such supervision will high prices be offered by the buyer.

(4) Catching techniques should be improved by experimentation with traps, initially similar to the mesh traps previously used and tangle nets - details of tangle net design are available from the Fisheries Officer, South Pacific Commission. Traps set over the edge of the reef from small boats in depths down to about 73 m should be attempted in order to estimate the vertical distribution of the species P. penicillatus and any other species that may occur at depth. Shaded traps with side entrances may be rewarding.

(5) Severe management control at this stage should not be attempted. Records of catch and effort as well as the changes in fishing techniques should be documented so that data will be available on which to base sound management policies in the future. Perhaps licensing of fishermen is the best way to gather such statistics by ensuring regular (monthly) statements of fishing effort and production.

(6) The quality of the product at the market cannot be over-emphasized in view of the high proportion of American tourists insisting on top quality. A sound, well priced market demands a sound product.

4.6 OTHER OBSERVATIONS

Fresh water prawns are present in the freshwater mountain and lowland streams. Female prawns with eggs were taken during the survey period - i.e. at the beginning of the rainy season. The species is thought to be Macrobrachium lar. Experimental culture ponds for this species should be encouraged since the size (up to 17.8 cm), the taste and the tail weight recovery are very satisfactory. Information on growth rate, size of maturity, ecological and culture requirements would be directly applicable to many other territories in the SPC area (if the same species of Macrobrachium does occur).

5. KINGDOM OF TONGA

5.1 SYNOPSIS OF ACTIVITIES

From Nuku'alofa by vessel north along the islands forming the Tongatapu, Nomuka and Ha'apai groups of Tonga. The Consultant visited reefs and dived at Pangai, Lifuka, Ha'ano (Ha'apai Group), O'ua and Foncifua Islands (Nomuka Group).

5.2 GENERAL TOPOGRAPHY AND CLIMATE

The Kingdom consists of 150 small islands the largest of which is Tongatapu (256 km^2). The islands run parallel to the Tonga Trench from SSW to NWE. The coralline and limestone group, consisting of Tongatapu, Ha'apai and Vava'u, are immediately to the west of the Trench and further west again is a line of small volcanic islands, some of which are still active and smoking. Some of the coralline and limestone islands reach 46 m - 204 m and are gentle in relief but the volcanic islands rise more steeply (e.g. 'Eua rises to about 305 m). Rainfall and temperature increase from Tongatapu in the south (1 702 mm approximately 25° C and at 21°8' S) to the Niuas in the north (2 972 mm and approximately 28° C at 15°34' S). Predominant winds are from the east and south east during most of the year. In summer, winds are variable and occasional strong winds from the NW accompany storms or cyclones. The tidal range is about four feet.

5.3 COASTAL FEATURES AND ZONES

The E to SE prevailing wind, crossing the Tonga Trench, results in strong breakers along the southern and eastern shores of the barrier coralline and limestone islands. On these barrier islands, the reefs are smooth, flat and narrow and have on their outer margin a raised rim formed of coralline algae. Coral growth only occurs on the inner ends of the deeper surge channels where conditions are quieter. Along the western shores of the barrier islands and around the islands that form inside the barrier islands, wider coral reefs grow in the quieter waters and gentle surf rolls across them except during summer storms. Estuarine conditions are poorly represented by tidal flats at Tongatapu and mangrove development at Vava'u.

The geological youth and the steepness of the volcanic islands on the other hand has resulted in very restricted reefs or no reefs at all. Run off is negligible except immediately adjacent to the island coast because of the relatively low rainfall, particularly in the southern islands. Fresh water is found in shallow wells on most coralline islands. Beach rock also forms on some shores.

5.4 FINDINGS

5.4.1 Rock Lobster

Three species occur on Tongan reefs. These are, in order of abundance, Panulirus penicillatus, P. longipes and P. versicolor.

P. penicillatus. This favours hard rock conditions such as the coralline reefs on the more exposed sides (mainly east) of the limestone islands visited, (i.e. Lifuka and Ha'ano). Mr. Warner, Managing Director, Fathom Fisheries, Nuku'alofa, reports that:

(a) the best fishermen work the exposed sides of most of the island groups from Tongatapu in the south to Vava'u in the north as well as on the fully exposed two Minerva reefs (lat. 24°, long. 179° E).

(b) Male and female P. penicillatus are generally taken in about equal numbers throughout the Tonga islands and on Minerva Reefs.

(c) Spawning females are present in catches throughout the year.

(d) Best catches generally follow full moon and worst catches are during full moon.

(e) Rock lobsters retained in floating crates (or live boxes) survive poorly if anchored over coral sand and much better if anchored over dark bottom; they are very sensitive to light and always retreat at day time into the darkest crevices available.

(f) Living coral formations are not highly productive of P. penicillatus and often P. longipes is taken with P. penicillatus in the more protected places where the coral formations grow best (i.e. on the quieter reefs and islands inside the barrier).

The places where the Ha'ano (Ha'apai group) fishermen set their traps (funaki) are at the heads of surge channels where the walls of the channels are quite smooth, and are covered with brown and pink coralline algae; no coral grows there. When the surge channel extends deep enough into the reef flat to provide protected water, corals struggle to grow and are constantly being broken by excessive surge. The bottom of the channel is then covered by coral sand. Such conditions were observed while diving on the exposed east coast coralline reef at Ha'ano and Lifuka.

Mr. Warner also reports that fishermen sometimes find a cave with a "family" of P. penicillatus in it with the largest male at the entrance. They spear all the rock lobsters behind the large male first and leave the male till last. If they spear the large male first all the rest scatter and cannot be caught. In addition, caves have been refilled by another "family unit" after a return visit of six weeks (the shortest period for refilling the cave is not known).

P. longipes. Near Mango and Fonoifua islands (Nomuka group) P. longipes is taken in about equal numbers with P. penicillatus. One P. longipes was also taken while diving at O'ua Island (Kotu group). All these islands are fairly well protected as they are inside the eastern chain of islands and reefs that are exposed to the south easterly trades.

P. versicolor. One P. versicolor was observed in a very cavernous coral head (3.7 m diameter) standing clear of the bottom in about 6 m of water.

5.4.2 Fishery Development

Past: Traditionally the Tongans have used the funaki, a beehive shaped pot made of vines with a single opening at the top (see Buck, 1928), similar to the one used on Tutuila in American Samoa. Until Mr. Warner commenced exploratory fishing three years ago, the art of fishing by funaki was limited to a few fishermen at Ha'ano Island (Ha'apai group). Rock lobster were also taken for local consumption at feast times by spearing and by hand at night at high tide on dark nights. Six people would catch twenty lobster in about two hours.

Present: Mr. Warner has established a small mobile rock lobster and wet fish fishery which is based mainly on the lobster. He operates as far north as the Ha'apai Group and as far south as Minerva Reef. Catching methods, using Tongan divers, are:

(a) by wading at low tide in the daytime and pulling rock lobster out of holes on exposed reef areas,

(b) by wading or swimming over the reef at high tide at night,

(c) by diving in daytime under the breakers catching them on the surface of the reef flat at high tide.

Tasmanian beehive rock lobster pots have been tested in about 15 m by Mr. Warner at Maninita and Fomaunga Islands (west sides) (Vava'u Group), O'ua (south side) (Ha'apai Group) and Ataata (Tongatapu Group). These experiments gave only P. longipes (six from ten pots on one night at Ataata Island). It should be noted that these areas are protected from the major swell, have a live coral reef with coral and sand bottoms and for those reasons would not be expected to be set in the best places for P. penicillatus. These pots are not used at the present time.

Funakis were used in 1969 and will be used again in 1971. They are jammed into enlarged parts of the landward ends of the surge channels. Short-spined sea urchins are used for bait and the funaki is surrounded by limestone slabs to wedge it tightly, as well as partially cover the top of the trap. Lobsters returning to the surge channels from the night's wandering presumably find these funaki suitably placed and suitable as shelters. As many as five or six are taken per funaki.

Mr. Warner's production over the past year or so is in the order of 1 016 t of tails per month. Most of this production is sold in Fiji and American Samoa and the present price is U.S.$ 0.15 per 0.45 kg to fishermen for speared lobster. Mr. Warner needs freezer boats or barges nearby to process quickly. His present production is obtained by working along the Tongan islands encouraging fishermen to actively seek rock lobster and fish while he is in the area and in addition he makes seasonal visits to Minerva Reef. The cold waters of Minerva deter the enthusiasm of his Tongan divers during the winter months, and in summer, cyclones have already caused his vessel, the ATA to be grounded. Satisfactory periods are therefore limited to the times of the changes of seasons.

In the Government Development Plan 1970-75 (Govt. Printer, 1970) it states: "The reefs and seas surrounding Tonga are of considerable economic value at the subsistence level but there has been little commercial development of this ..... The only true commercial fishing is the export of frozen crayfish by Australian interests".

5.5 RECOMMENDATIONS

(1) Increased production should be encouraged without strong restrictions on size of rock lobster or on fishing effort, providing the quality of the product and its acceptability on the market can be assured.

(2) For this reason, a limit of 64 mm carapace length (measured in the mid line from the transverse ridge between the supraorbital horns to the rear of the carapace) should be introduced.

(3) For similar reasons very large males should not be processed since large tails are not well priced on the market. In regard to the biological implications, large males probably mate with the majority of the nearby females (a "harem system") so smaller males are less important. Spawning females should be returned alive to the sea.

(4) Catching methods should be improved by encouraging the use of the traditional funaki method and test deeper ground, 85 m to the east of the barrier reefs and islands using experimental traps. The particular areas suggested are off the highest and older limestone islands, of the Vava'u Group and northern Ha'apai. Side entrance traps with covered tops set on dark bottom might be tested. Welded mesh traps 1.2 m x 0.9 m x 0.9 m should be tried (similar to American Samoan traps).

(5) Only when the fishery reaches much improved production levels, and providing some catch and effort figures are recorded, should management limitations be employed. Suitable measures might relate to pots, e.g. escape gaps to allow escape of small rock lobster and neck opening to prevent entry of very large males. It should be noted however that large males might sit over the neck and prevent entry of other sizes so neck size might have to be maximum.

(6) A programme of gathering catch and effort data should be instituted and the existing and changing fishing techniques described as the fishery develops (e.g. an historic record of the fishery should be compiled). The appointment of an officer to the Agriculture Department should be made and he must be responsible for the collection of data relating to the developing fishery. Close cooperation with Fathom Fisheries will be essential.

5.6 OTHER OBSERVATIONS AND ACTIVITIES

(1) Miss June Von Donop's project to hatch and protect rock larvae by erecting a 3.2 mm nylon mesh net around a reef-enclosed lagoon met with failure due to a cyclone eroding the foundations of the net which ran across the entrances to the lagoon. Experiments of this nature should be prefaced by a more detailed study of the natural requirements of the larvae of P. penicillatus. Approval to continue this project has apparently been recently withheld.

(2) The humpback whaling grounds are near Hunga Island (Vav'u Group) which area is suspected to be an eddy or upwelling area. Good bottom fish are taken inside Hunga Island and Juvenile (5.1 cm total length) P. penicillatus are reported on the Hunga Island reefs at night by Mr. Williams.

(3) The Agriculture Department was advised on the draft of their proposed fishing regulations, mainly on the wording of the rock lobster section which was satisfactory and in the final stages of preparation.

(4) Record Sheets were designed to record biological data during the further development of the fishery. See Appendixes 2 and 3.

6. TERRITORY OF PAPUA AND NEW GUINEA

6.1 SYNOPSIS OF ACTIVITIES

The Consultant remained at Port Moresby most of the period for full discussions with Mr. R. Pyne on the lobsters of Papua and New Guinea and with Mr. Craig MacDonald on the rock lobsters of the Trust Territory of the Pacific Islands. He dived at various habitats around Port Moresby harbour and along the Papuan coast between Yule Island and Port Moresby,

besides discussing problems of fishery on P. ornatus at the Yule Island processing factory with Mr. Slaughter (see Appendix 1). Mr. MacDonald was stationed at Koror, Palau since July 1969 working the whole of the Palau chain of islands studying the biology of the rock lobster with particular reference to P. penicillatus. Over the past four months, he visited the other districts at Yap and Woleai (three weeks), Guam, Rota and Saipan (three weeks), Truk (two weeks), Ponape (two weeks) and Kwajalein and Majuro (ten days). He worked with the indigenous fishermen, diving and collecting on the reef both by day and by night.

6.2 GENERAL TOPOGRAPHY AND CLIMATE

High mountain ranges (up to 3 962 m) form the backbone of New Guinea and associated islands. The drainage pattern is complex and very large rivers like the Sepik, Ramu, Fly and Purari are outstanding (Brown and Pain, 1970).

The southeasterly system (the Trades) is the dominant wind system (May to August) producing strong wind and lee effects on opposite coasts. The westerly system (September to April) is much weaker in wind and lee effects. The very high mountain chain acts as a particularly strong climatic control for the whole area. Distinct dry areas (less than 1 524 mm) occur in the lower Fly and Sepik valleys and wet (over 5 080 mm) along the southern face of the central cordillera and southern New Britain (Hart, 1970).

6.3 COASTAL FEATURES AND ZONES

"The vast plains of the Fly, Turama, Ramu and Kikuri Rivers form part of the most extensive swamplands in the world. Of comparable size are the swamps of the Sepik. Raised coral reefs are a feature of the north coast of New Guinea, the south coast of New Britain, Bougainville, eastern New Ireland and many smaller islands including the Trobriands and the Louisade Archipelago." (Brown, 1970).

The waters of the Gulf of Papua are the calmest and siltiest and closest to the swamplands of the Fly. The further one progresses east along the south coast of Papua and the greater the exposure to the Trades, the greater the coastal water movement and the lower the terrestrial silt deposition. This results in the growth of reef flats covered by surf and clear water, e.g. at Tagula and Rossel Islands. Similar conditions prevail on the south coast of New Britain, the southern and eastern sides of New Ireland, the volcanic islands situated in the strong current of the Vitiaz and Dampier Straits and on the Madang coast.

Protected coral "lagoon" formations occur within outer barrier reef systems, e.g. in Louisade Archipelago or behind the north side of large island areas, e.g. New Britain and New Ireland.

6.4 FINDINGS

6.4.1 Rock Lobster

Research on rock lobsters of Papua and New Guinea has been carried out previously by Rapson (1962) and Pyne (1971). The following notes are based on discussions with Mr. Pyne and on his publication - Pyne (1971). Five species of Panulirus occur in Papua and New Guinea: P. penicillatus, P. versicolor and P. longipes femoristriga "are noted for ability to inhabit distant offshore islands" while P. ornatus and P. homarus "are essentially coastal inhabitants". P. homarus was collected in Hall Sound (Yule Is.), Orangerie Bay (SE Papua) and at the mouths of the Ramu and Sepik Rivers (New Guinea); all habitats contain heavy mud bottoms and are adjacent to the extensive swamplands regions. P. ornatus is migratory and serves the basis of a seasonal fishery based at Yule Island. It is recorded around the Gulf of Papua from Daru (143° E) to Hood Point (148° E). It is probably responding to a bottom type seaward of that of P. homarus or at least one that contains less terrestrial silt. Sea grass beds and scattered coral boulders in about 1.2 m - 3.7 m cover the reefs plateau where they appear seasonally during the calm (westerly) season. "Moving eastward from Yule Is., the turbidity decreases and the presence of live coral on the shallow

inshore reef becomes more evident. As coral becomes more evident, the numbers of ornate spiny lobsters found in the area become less, the species being regarded as rare between Port Moresby and Hood Point. For ..... seven months the species occupies as yet an unknown deep-water habitat." P. versicolor occupies many diverse habitats throughout the Territory "inhabiting dense live coral outcrops, or holes in limestone rock; shallow inshore protected reefs plateaux or exposed reef faces in depths of ten metres or more, very turbid or very clear waters." This species appears intermediate between the terrestrial species P. homarus and P. ornatus and the oceanic species P. penicillatus and P. longipes femoristriga.

P. longipes femoristriga is widespread but rare living in depths of 4 - 12 metres "similar to that for P. penicillatus, but in more sheltered or protected areas with minimum turbulence and prolific coral growth".

P. penicillatus is less common in Papua than in New Guinea where wave and surf action from the prevailing southeast Trade winds beat on exposed wellwashed coasts like the south coast of New Britain, the southern and eastern side of New Ireland.

A correlation of the major coastal features (see 7.3) and the distribution of rock lobster species is apparent. Near the vast swamplands and in silty water, P. homarus lives close to the shore and P. ornatus lives further offshore, migrating onshore seasonally.

Raised coral reefs and hard rock islands provide suitable shelter for P. penicillatus where oceanic water movement is strong and the water clear and for P. longipes femoristriga where the water is clear but conditions are partially protected from direct surf.

P. versicolor seems to take up various intermediate habitats between full oceanic and full terrestrial environments. It was reported that in New Britain there is a very short seasonal run of P. versicolor onto shallow reefs.

6.4.2 Fishery Development

Past: Traditional fishing for P. penicillatus is by walking and spearing on the reef flat at night (e.g. south coast New Britain). P. ornatus used to be taken by spearing at night from canoes and eaten or bartered for inland produce, in the Yule Island region. Commercial lobster fishing for P. ornatus commenced at Yule Island in late 1961, firstly as a cooperative and today it is run by the Yule Island Enterprises. An account of the history of the Yule Island fishery is given by Kent-Wilson (1968). Records kept at the factory at Yule Island show marked seasonal variation in abundance. The best catches were 41 000 rock lobster (1966/67) and the poorest were 11 000 rock lobster (1967/68). Rapson (1962) comments that the seasonal run follows special hydrological conditions at the onset of the north west season and this seems indicative of a cause in the variation of seasonal migration of P. ornatus into the shallow water.

Early private ventures to exploit P. penicillatus and P. versicolor throughout the Territory illustrated that these species would not support an industry geared for overseas export.

Present: P. ornatus is taken by indigenous fishermen from Pinupaka, Chiria, Poukami, Delena, Geabada, Oroi and Hisui by lantern and scoop net at night and during the day by diving inside a net which surrounds coral heads. Lobsters are only accepted at the factory alive. Holding crates are often used to hold evening and night catches at the villages. Canoes, under sail, are still the fishermen's means of transport to the fishing grounds. Rock lobsters are transported rapidly from fishing grounds and villages to the factory by speedboat. Distinct fishing grounds in the Yule Island area are traditionally recognized by the seven village groups at the present time.

At Yule Island occasional specimens of P. versicolor, P. homarus, P. penicillatus and P. longipes femoristriga come into the factory. All species are eaten by the coastal and island indigenous population.

6.4.3 Research

Rock lobster research up to 1962 has been published by Rapson (1962) and that report deals with identification, catching, distribution, habitat, seasonal occurrence, biology and commercial development of P. ornatus in Southern Papua. Pyne (1971) has extended the survey throughout the entire Territory, has emphasized the ecological associations of the five species, has closely examined the biology and fishery of P. ornatus and has initiated a hydrological programme to evaluate the seasonal migration of that species. He is proceeding with the analysis of the six years data he has accumulated in order to throw light on the migratory nature and season fluctuations in abundance available to the fisherman.

6.5 RECOMMENDATIONS

(1) The Yule Island rock lobster fishery on P. ornatus requires continued investigation to ascertain the controlling environmental factors of their migration to enable prediction of good and bad seasons.

Research could be directed towards:

(a) The correlation of past catches and past weather patterns in conjunction with the meteorologists and agriculturists,1/

(b) mapping bottom substrates and hydrological events to ascertain the influence of the terrestrial, river-borne sediment in the Gulf of Papua in providing rock lobster habitat,

(c) experimental trawling, trapping and tangle netting in deeper waters to discover the main stock of P. ornatus,

(d) laboratory investigations on environmental preferences for oxygen, temperature, salinity, light values and substrate to support field observations. (Such research would necessitate only slight increases in scientific and supporting staff of the Division of Research and Survey but a research vessel larger than F.R.V. TAGULA for the hydrological and sediment work would be highly desirable.) (It is also important to recognize that future research on the already established prawn fishery in the Gulf of Papua will require the same basic information to account for prawn migrations, stock location and seasonal variation.)

(2) The resources of P. penicillatus and P. versicolor are limited but nevertheless, in places like New Britain, New Ireland, Trobriand Is. and Louisade Archipelago, attempts should be made to establish regular, high quality rock lobster for the main centres. About U.S.$ 0.80 per 0.45 kg total weight could be expected.

1/ P. ornatus is the only viable rock lobster venture at present and the Agriculture Stock and Fisheries Department are available to correlate past catches and weather patterns. A prediction service would enable the processor concerned to utilize to optimum the services of native fishermen. In addition, the Department would be able to apply such knowledge in the prediction of prawn and barramundi "runs" in the Gulf. The recommendations of the consultant were made in close collaboration with the Department but although it is undoubtedly useful to predict catches, this should not have priority over other more important matters.

(3) The necessity for a top quality product for export or for main centre consumption cannot be over-emphasized.

(4) Records of catch and effort of the two rock lobster fisheries (P. ornatus and P. penicillatus/versicolor), as well as prawns, are essential for future controlled management when and if necessary.

(5) At the present time no enforcement regulations are necessary for the rock lobster fishery except if market demands of the quality of the product are jeopardized.

(6) Culture of freshwater prawns (Macrobrachium spp) could be promising. Full encouragement by private enterprise in conjunction with the Division of Research and Survey's assistance would provide maximum commercial orientation.

(7) Deep water prawns probably exist in the Gulf of Papua and experimental trawling and dredging could be rewarding.

7. UNITED STATES TRUST TERRITORY OF THE PACIFIC ISLANDS

This report was compiled with the assistance of Mr. Craig MacDonald, a Peace Corps Volunteer at Palau, who has studied rock lobster resources in Micronesia since 1969. The discussions took place from 19 January 1971 to 1 February 1971 at Port Moresby, during which time field expeditions around Pt. Moresby and Yule Island established a sound basis for ecological assessment of rock lobster habitat.

7.1 GENERAL TOPOGRAPHY AND CLIMATE

The Trust Territory consists of three archipelagoes, the Caroline to the south (10° lat.), the Marshall to the east (170° E long.) and the Mariana to the north (20° N lat.). There are over 2 000 small islands with a total land area of about 1 800 km^2 scattered over about 7 770 000 km^2.

There are three main island types:

Volcanic - e.g. Babilthuap, Palau Group: the major Yap Is.; entire Mariana Group; the central Truk lagoon islands; Ponape and Kusaie.

Limestone - e.g. the Marshall Group and most of the smaller islands of Ponape, Truk and Yap districts in the Caroline Group.

The volcanic islands have high rainfall (e.g. Ponape with about 10 160 mm) and may have large rivers. The limestone islands have less rainfall, generally hold subterranean water supplies and some swamps may be present. The coral atolls are dry and hot and water supply is generally a problem for the inhabitants.

The northeast Trade winds dominate from October to May and during the remainder of the year calms with weak westerly winds occur. Occasionally squalls from the west are sufficient to do considerable damage to the reefs on western sides of islands.

7.2 COASTAL FEATURES AND ZONES

The volcanic islands generally have more run off on the lee (west) side of the island where dense mangroves line the shore. These are followed by extensive eel grass flats, a shallow, white bottom lagoon and the barrier reef. The reef, on the more exposed east side, is narrower without a well-developed lagoon and contains fewer coral heads.

The limestone islets are much smaller than the volcanic islands. Those limestone islets in the open ocean have narrow fringing reefs, little or no lagoon development and very steep slopes beyond the outer algal ridge. The limestone islands at Palau stand in the lagoon, those on the windward side being occasionally interconnected by coral reefs. Those that stand alone are surrounded by coral growth at their base.

The coral atolls are usually larger than the limestone islets, have steep outer sides and deep to shallow coral lagoons inside. Islet and beach formation is better on the windward side of the atoll where the wind, wave and surf action is greater than on the leeside. The leeside usually has the largest exit channels from the lagoon.

7.3 FINDINGS

7.3.1 Rock Lobster

Three species of Panulirus are known - P. penicillatus, P. versicolor and P. longipes femoristriga (striped legs). In addition, fishermen from Truk and Ponape have described a white lobster with olive mottlings on the carapace. These are large and live in deep water (6 - 30 m) in the lagoon. Large, blue rock lobster have also been reported from deep water (18 - 24 m) on the outside of atolls (Ngulu, Woleai and Truk) and from the inside of the lagoon (6 m) at Ulithi. These may be P. ornatus, a large species which is variable in colour. P. penicillatus has been found in situations where their shelter is exposed to prevailing winds and heavy surf. Shelter may be provided by conglomerate boulders, hollowed and eroded coral clumps, ledges bordering surge channels and collapsed rock ledges adjacent to limestone islands. P. penicillatus is the most abundant species but it can only be fished profitably during the calm months between June and September because of the heavy seas on the reefs during the Trades. They occur on reef flats at night and as deep as 4.6 m. Clear, cool and well aerated water seems to be preferred.

P. versicolor is not as abundant as P. penicillatus and lives in calmer water inside and outside the lagoons to a depth of 21 m. Inside the lagoons, the shelter can be large spacious holes at the base of coral heads. On the windward side on the seaward slope, it lives below the P. penicillatus surge zone, amongst boulders and coral heads. On the calmer steeper leeside it frequents coral ledges and short surge channels in shallower conditions than on the windward side and can tolerate turbid conditions easily.

P. longipes femoristriga appears intermediate in ecological preferences between P. penicillatus and P. versicolor inasmuch as it lives in clear water just on the lagoon side of the active reef edges amongst dense coral growth. It also occurs in shallow water (not more than about 1.8 m) along seaward channel mouths and in well washed limestone caves along limestone islands. It is the least common species.

7.3.2 Fishery Development

Past: Traditionally rock lobsters were actively sought for festive occasions only, when villagers caught them by hand or spear on reef flats at night. This was not possible at Palau and Yap because the reefs are unsuitable for this method. It was not until goggles were introduced that rock lobsters were caught with any regularity at Palau and Yap.

Rock lobsters are taken in low quantity (the best daily catch was about 27 kg per man) using goggles and spear during the day and walking the reef at night (when and where possible). The only places where they are actually marketed in any number are at Palau where the product is frozen at the Palau Fishermen's Cooperative and at Truk where they are marketed alive at the Piis Cooperative. All rock lobsters are sold to American and Government personnel at the price of U.S.$ 0.85 per 0.45 kg at Palau and U.S.$ 0.70 per 0.45 kg at Truk. P. penicillatus is the main species. Annual production is about 900 kg of whole rock lobster at Palau and Truk.

7.4 RECOMMENDATIONS

From discussions with Mr. MacDonald, it would appear that recommendations similar to those made for P. penicillatus development in the areas previously visited would be equally applicable in the Trust Territory of the Pacific Islands (TTPI).

(1) The resource appears limited and probably would only satisfy local demands.

(2) Management controls at this stage should not be made.

(3) Increased exploitation with proper documentation of catch and effort should be encouraged to test the size of the stock correctly.

(4) Habitat is probably the most important limiting factor and experiments to provide artificial shelters might be warranted at selected sites.

8. BRITISH SOLOMON ISLANDS PROTECTORATE

8.1 SYNOPSIS OF ACTIVITIES

The coastline at and around Honiara (Guadalcanal), Tulagi (Florida Is.), Gizo (Western Solomons) was studied by boat and by road. An air survey of Western Guadalcanal, Russell Islands and New Georgia was carried out during the commercial flights from Honiara to Gizo.

8.2 GENERAL GEOGRAPHY AND CLIMATE

The Solomon Islands lie on the Solomon Plateau which is flanked by the deep, long oceanic trenches on the north and south sides. The Solomon Islands "consist of a double chain of elongated islands in the form of a bow whose apices lie in the single islands of Bougainville in the west and San Cristóbal in the east. The length of the main island chain is 650 miles if Bougainville ... is included."(Thompson and Hackman, 1969 p. 189.) The oldest sediments overlying the basic basalt or basaltic andesite is Upper Cretaceous. Most of the islands are high with a central ridge rising from approximately 900 to 1 500 m and Guadalcanal rises to over 2 300 m.

A seasonal rainfall pattern for the whole group is difficult to describe since the times of "wet" and "dry" periods apparently reverse when comparing one island with another (Brookfield, 1969), but the Solomons are among the wettest regions of the world, few regions receiving less than 2 540 mm per year. The southeast Trade season from April to November can be accompanied by quite exceptional cloudiness and during the summer months the winds are variable westerly; occasionally small tropical cyclones originate around the Solomons area; "these also can bring exceptional cloud, rain and wind." (Brookfield, 1969 p. 207.) Most of the large islands are volcanic but the outlying islands, e.g. Rennell and Bellona, are limestone. Raised limestone, coral reefs or debris exist on the coasts of many islands. Run off from the volcanic islands produces little silt and the limestone islands generally have no streams at all. The tide is diurnal and the time of the day at which low tide occurs is reversed for summer and winter.

8.3 COASTAL FEATURES AND ZONES

The recent report of the Royal Society Expedition to the British Solomon Islands Protectorate from June to December, 1965 (Corner, 1969) contains many excellent papers on tropical biology, geology and climatology but those of Stoddart (Coral Reef Geomorphology), Womersley and Bailey (Biotic Reefs) and Morton and Challis (Shore Biomorphology) highlight the dynamic nature of reef formation, caused by interaction of the surf intensity and the diurnal tidal regime on the plants and animals forming the reefs. Stoddart states "The poverty of modern coral growth is one of the most striking features of reef shores in the Solomon Islands." The highest surf action is on the weather coasts, i.e. the south and east coasts of the Southern chain (New Georgia, Guadalcanal, San Cristóbal) and the outlying islands (Rennell, Bellona, Santa Cruz and Ontong Java). At such places a coralline alga Porolithon onkodes "is the dominant organism of the reef, rim and corals are virtually absent under the constant surf." (Womersley and Bailey, 1969 p. 437.) The reef is relatively narrow, about 25 metres, with "rough water" alga and small and scattered corals confined to deeper pools and protected areas of the moat; rocks at the rear of the reef support animals (molluscs and chitons) rather than alga; the reef edge is often dissected by deep narrow channels.

According to Womersley and Bailey (1969), in "moderate wave action localities" (waves 0.5 to 1.0 m high at most times) the reef is moderately wide (about 30 m), the reef rim is made up of a diversity of corals with crustose coralline alga; coral debris, corals and calm water algae inhabit the reef moat and at the reef rear inter-tidal rock when present supports mat algae.

Womersley and Bailey's (1969) third category of "calm localities" have very wide moat (100 - 300 m) with few coral species, a reef rim characterized by corals (and little coralline algae) and is backed by sandy beach or sand-mud flats with sea grass beds and mangroves near streams.

Morton and Challis (1969) have presented a full account of the biotic zonation across and along the different types of reef and have presented an excellent schematic view of these Solomon Island shores (Morton and Challis, 1969, Fig. 160).

The effect of the tidal regime of the area on the making and breaking of the reefs is fully appreciated by all those workers mentioned above and discussions on reef breakdown and control of reef growth is presented by them. Womersley and Bailey (1969, p. 440) state "During winter (the period of the Expedition) the low tide in the Solomon Islands occurs during the day, whereas in summer the low tide is during the night." A similar tidal pattern is reported for the northern Queensland coast (Fairbridge and Teikert, 1948, p. 71). Also the mean sea level in the Solomon Islands is lower in winter than in summer (Stoddard, 1969, Honiara Tide Tables). Consequently reef organisms are subject to greater daytime emergence (probably by 10 or 20 cm) during the winter with greater dessication or rain influence in this period of the year. Morton and Challis (1969) reach similar conclusions and indeed state (p. 487) "the most profitable single operation with which to follow up the Expedition's work will be an investigation into fluctuations of tidal levels and patterns over one or more full years, and a correlation of this data with short term events on the reefs. Such a programme properly directed could be well within the range of secondary school or local naturalists in the Protectorate."

Stoddart, (1969, p. 376) also points out that actual weekly mean low tide levels can be above mean low level for as much as 10 consecutive weeks (April and May) and that other periods (November to February and late May to July) the lowest levels can be below the mean; he had no data for the period late July to early November. High water and mean levels were relatively invariant.

8.4 FINDINGS

8.4.1 Rock Lobster

The popular English name in usage is Crayfish. Four species of Panulirus are known: P. penicillatus, P. versicolor, P. longipes femoristriga and P. ornatus.

P. penicillatus forms the basis of the small developing fishery centred at Honiara. The species occurs on the slopes of reefs washed by strong currents (e.g. Sandfly Passage in the Florida Group and Manning Strait in Georgia Sound) and on the weather coasts of the islands where the highest surf action surges across the reefs.

Regular visits by the Coral Sea Fisheries to pick up P. penicillatus are made to San Cristóbal, Santa Anna, Santa Catalina, Rennel, Bellona, Vanguna and New Georgia where the south and east coasts are productive, as well as to the east coasts of Santa Isabel and Choiseul. It has been reported from most of the "outer" coasts or islands from Shortlands in the West, Ontong Java atoll in the north to the Santa Cruz Is. in the east.

They are taken on the surface of the reef flat at night and the tide height, moon phase and surf intensity influence nightly catches. Best catches in some places are reputed to occur during the high tides at night (winter season when there is no moon and when surf action permits the reef to be worked). Strong surf areas are apparently best worked at low tide (summer). During the day, P. penicillatus inhabits deep and/or dark shelters on or over the reef rim or in deeper, well aerated pools or channels. Presumably day time catches will be worse during the winter season of greatest reef emergence and coral kill (due to day time low tides and low sea level) than in summer when day tides are high and the reefs remain covered.

However, surf action may be too little during the summer season in some of the moderately protected regions and the rock lobster may not come up onto the reefs. Some experimental baits have included chitons (the best according to the fishermen), coconut, green mango leaves and the meat of green snail or trochus.

Fishermen report that spawning seems to occur all through the year and about 40 percent of females are in berry.

P. versicolor is occasionally taken by divers during the daytime in reasonably protected regions, equivalent to Womersley and Bailey's "moderate wave action localities." P. ornatus is rare and is apparently restricted to silty, semi-lagoonal habitats such as exist near Wana Wana in central New Georgia.

P. longipes femoristriga is also apparently rare but interestingly, it differs from specimens previously seen at Fiji and New Caledonia in that the front of the carapace and the base of the feelers are a distinctive rich pink colour and the antennules are not banded, the inner ramus being pale and the outer dark. At night, the antennai and antennules are very white and stand out clearly.

8.4.2 Fishing Development

Past: Traditional rock lobster were caught by a vine hoop (0.9 m in diameter) baited with chitons, lowered over the reef (e.g. at Malaita). After two to three days, they were hauled up gently and the hoop, with rock lobster clinging to it, landed in the canoe. Long sticks with chitons attached were also used to catch single rock lobsters.

Present: Coral Seas Fishing Company commenced operations in April 1970, to develop the rock lobster resources throughout the Solomon Islands. Indigenous fishermen from villages scattered along the south and east coasts of New Georgia, Russell, San Cristóbal and Rennell Islands, catch them on the fringing reefs mainly at night using coconut flare torches. They are not speared but taken alive and kept alive in submerged wire netting traps to await pick-up by the freezer vessels. Care must be taken to place holding traps in well-aerated, dark places to avoid losses. These pick-ups are maintained about every four weeks and result in about 2 000 - 4 000 rock lobsters per trip. They are processed on board, frozen and later repacked in Honiara, the Company's base. In the first nine months of the operation four tons of rock lobster tails were exported to the United States.

8.5 RECOMMENDATIONS

(1) Every encouragement should be given to support exploitation of the P. penicillatus stock by the indigenous fishermen and top quality processed product by the fishing company.

(2) Management regulations should only be introduced where market or quality of pack control demands it.

(3) Exploitation of the outer islands like Ontong Java and Santa Cruz could be gradually increased and the existing fisheries at Western Solomons, San Cristóbal and Rennell are worthy of further consolidation and expansion.

(4) The stock will probably not support a huge export like the multi-million dollar industries of Australia, New Zealand or South Africa but closer markets (e.g. New Guinea, New Hebrides, New Caledonia) may also be economically sound.

(5) Catch and effort data should be maintained and the history and development of the fishery, particularly with respect to changes in fishing techniques should be recorded. Only by such collections can future management procedures, based on biological reasons, be wisely introduced, if necessary.

(6) Experimental catching methods by traps or special shelters designed with a view to the rock lobsters' desire for good wave action, dark caverns and silt-free cool oceanic water should be supported. The success of baited hoops and the tenacious clinging behaviour should be noted.

(7) Daily tidal records, weather observations, wave action and moon phase data should be maintained at two or three localities to ascertain the proper correlations of these factors with rock lobster appearances on the reef. As noted by the Royal Society Expedition (Morton and Challis, 1969) local naturalists or secondary school projects could be useful, if properly directed.

8.6 OTHER OBSERVATIONS AND ACTIVITIES

(1) Penaeid prawns are not abundant by local reports and the fact that most rivers are clear and silt-free would not suggest a penaeid prawn potential.

(2) The freshwater prawn, Macrobrachium, is reported generally throughout the Solomons and particularly in Lake Tegano on Rennell Island (Wolff, 1969). Cultivation of these prawns could provide an economic source of highly esteemed crustacean meat for local or even overseas export. Initial experiments have been carried out in Malaysia and Hawaii.

It was reported that on new moon nights, the people of San Cristóbal gather immature prawns entering the rivers from the sea. These may be the young of Macrobrachium, a good source for growing Macrobrachium in ponds or other suitable enclosures.

(3) Oysters are present naturally in most of the shallow sheltered situations, e.g. Tulagi, Florida Island and cultivation could be rewarding.

(4) A Pearl Shell Operation exists in the Manning Straits (between Choiseul and Isabel Island). Natural shell is harvested at neap tides (slack water) and pearl shell cultivation has been initiated.

(5) Turtles are commonly eaten by the villagers. Green and Hawksbill are about equal in numbers on the laying beaches on both sides of Choiseul and Isabel Island. The leather-back has been recorded on the surf-beaten, deep-water-adjacent beaches on Malaita, Guadalcanal and San Cristóbal Islands (the more exposed southeastern islands).

(6) Fishing with explosives has been a common practice, particularly in areas adjacent to the more active war time islands (e.g. Guadalcanal) where extensive ammunition dumps were maintained. These activities have been considerably reduced through the Fisheries Explosive Ordinance, 1964 and more recently with the introduction of a regulation to stop the import of fireworks into the Solomons.

(7) Trochus shell was reported by Mr. Palmer (Western Solomons) to move fairly rapidly up on the reef flats at night via the surge channels in much the same way as the P. penicillatus moves. Trochus is harvested at the present time and exported to France and Japan.

(8) There are quite substantial and high quality ship repair and ship building yards at Tulagi and Taroniara, Florida Group.

(9) A local timber (Parinari spp.) is reported to be virtually shipworm (Teredo) resistant and such timbers might be worthy of investigation as holding caufs or other marine constructions.

(10) Difficulties facing the expansion of fishing activities include:

(a) the distances between the Honiara main base and the known or potentially important fishing areas at Russell Islands (84 km), Vangunu Islands (193 km), Gizo (354 km), San Cristóbal and Santa Anna Islands (322 km), Rennell Island (290 km), Santa Cruz Group (587 km), and Ontong Java (467 km);

(b) the shortage of freezer holding space in Honiara and lack of it in other places;

(c) the varied responses by the many different villages to the new concept of supplying a regular production of rock lobsters on a regular pick-up basis.

9. CONDOMINIUM OF NEW HEBRIDES

9.1 SYNOPSIS OF ACTIVITIES

Three of the major islands were visited and the coast near Luganville (Espíritu Santo), the Efate Island Coast and the coast of Tanna from Lenakel to Whitesands (Port Resolution) were studied.

Aerial surveys along the west sides of Malekula and Eromango Islands were also made in transit between Santo and Tanna Islands.

9.2 GENERAL TOPOGRAPHY AND CLIMATE

The New Hebrides block consists of a double chain of islands flanked on the "reverse" side (continental) by the New Hebrides and Torres Trenches. The Block runs N - S from 13° S to 21° S and rises to heights of 1 829 m (Mt. Tabwemasana, Santo). There are 12 major islands and about 60 smaller islands. These are of volcanic origin and are geologically young, the oldest being Malekula, Santo Maewo and Pentacost which have thick deposits of Miocene age. Many of the youngest islands are still volcanically active and form a chain between the older islands from Banks Group through Aobi, Ambryn, Epi, Efate, Eromango and Tanna Is. to Aneityum Is. Most have raised terraces of limestone (coralline algae with some compact corals) close to the coast and older limestone terraces are much higher (at 610 m on Efate for example).

The "weather sides" of the islands are the east and south due to the SE Trades which blow from April to November. The SW coast of the more exposed southern islands also receives moderate surf action. Annual rainfall is less on the southern islands (2 286 mm) than in the northern (3 937 mm) and falls mostly in the summer, westerly variable (and occasional cyclone) season. Maximum air temperatures are also lower in the southern (approximately 25 - 30° C) than in the northern (approximately 29 - 31° C). According to Mr. Barley, sea water temperatures are also lower south than in the north.

9.3 COASTAL FEATURES AND ZONES

There seems to be reason for separating the northern and southern islands into two groups for description since latitude, tidal regime, rainfall, water temperatures and wave action are differently combined from north to south.

The southern islands have better developed fringing reefs than the northern because of the greater effect of the prevailing SE Trades. Poralithon reefs abound on the east, south

and southwest coasts of these islands. The east coast of the eastern northern islands (Maewa and Pentecost) are also reported to have good fringing reefs with breakers. The added factors of lower rainfall of the southern regions, the proximity of the New Hebrides Trench and lower water temperature all contribute to the present coralline algal reef formations. Where protection is given by other islands or by coastal aspect, the coasts are sandy with some silt, and coral growth is not abundant. This is the most common coastal effect in the northern half of the New Hebrides.

Inside the northern islands, sea grass meadows abound but these are sparse in the southern islands.

The tides in the northern part of the Group are similar to those of the Solomons according to reports; low tide times changing with the season where there is low tide at night time in summer and at day time in winter. Also lower average low tide prevails in winter than in summer. Reef growth, due to daytime emergence of reef at low tide in the winter, must be inhibited or negated except where surf action is able to wash over the reef surface. A "normal" diurnal pattern is apparent at Tanna in the southern part.

9.4 FINDINGS

9.4.1 Rock Lobster

Three species of Panulirus, P. penicillatus, P. longipes and P. versicolor, and Parribacus caledonicus (butterfly crayfish) are known throughout the New Hebrides Group.

P. penicillatus lives on the weather sides of the islands (as does P. caledonicus) amongst the surf, surge channels and undercut Porolithon alga reef. Good shelter away from light and good water circulation are guaranteed in these situations. P. penicillatus and P. longipes have been trapped off Tanna Island in shallow holes (19 m deep) of the fringing reef and at offshore depths to 122 m. Best places were spurs of reef running offshore and these spurs are interpreted as old lava flows. P. penicillatus is also taken by hand or spear on the reef flat at night where the large males seem to accumulate close to shore. Best catches, by put and by hand, are on dark nights (neaps) particularly following a heavy swell.

The males are usually brown and the females green/yellow. Females with eggs only constitute about 5 percent of the total catch by pot and these females occur all through the year - not seasonally. More males than females are taken in the pots set at the reef edge; perhaps the females, whether carrying eggs or not, migrate up onto the reef less regularly than the males.

P. penicillatus is known from all around Aneityum, Futuna, Tanna, Eromango, the south and east coasts of Efate, Epi, Ambryn, Pentacost, Maewo and south and west coast of Malekula and Espíritu Santo.

P. longipes femoristriga is described by Mr. Paul from Tanna as smaller than P. penicillatus, dark, brownish/red with banded antennules. It can be trapped in about the same numbers as P. penicillatus in deep water (to 122 m) and in much lower numbers on the shallow reef flats. Mr. Stephen recognized a similar description of a small darker, brown species in the northern region. Mr. Barley recognized a small P. longipes with pink front, pink antennal peduncles, on the Maskelyne Is., Malekula and along the west coast of Espíritu Santo where it dominated, in abundance, P. penicillatus. The reef there is more compact, received moderate regular surf action and has small blowholes through the narrow fringing reef flat. Such a description matches a specimen from Honiara photographed by Mr. Gibbins (see Appendix 1).

P. versicolor was reported by Mr. Stephens from the northern islands as the "painted crayfish" with a rank "gamey" taste compared with P. penicillatus. It lives in quiet, turbid or clear waters down to 37 m. It is much larger than P. penicillatus. Mr. Barley reported it from around Efate and Mr. Paul from Tanna and other southern islands. It is very large, cannot be introduced into pots and lives in silty quiet lagoon waters, often near stream mouths or deeper on the outside face of reefs receiving moderate to high wave action. Mr. Barley also reported a migration of small-medium sized blue P. versicolor up onto the reef near Pt. Vila.

9.4.2 Fishery Development

Past: A few years ago, a small experimental fishery was initiated at Tanna and other southern islands. The main catching method adopted was a beehive cane or wicker pot two to three feet in diameter, baited with chitons or sea urchins. This design was based on the traditional pots of the region. Other pot designs were tested. The pots were set on the reef edge in reasonably sheltered pools or crevices, often covered with stones, and out beyond the reef to at least 122 m. Many baits including coconut, green mango leaves and Trochus meat were also tested. On the shallow reef Mr. Paul noted that if the reef was worked regularly by fishermen at night with torches, the catches in the pots set at the reef edge was considerably lower. This clearly indicated that these two methods of fishing compete with one another and that lights of these quite low strengths disturb the normal behaviour of P. penicillatus.

The best catches were several hundred rock lobster per month from about 20 traps which were only set during the optimum quarters of the moon, i.e. around neaps. About four men were casually employed to work the pots. The size, number taken and sex ratio of the catches by pots showed no change on the Tanna experimental area over a period of several years. The product was marketed at Port Vila when quality and quantity of processed rock lobster warranted shipment. Problems of fishing rights and ownership of the areas fished (according to French Law, British Law and native customs) were sufficient to halt further expansion. Rock lobster (and Octopus) are reported to be frightened out of their holes in the reef by a "rat" which is fashioned by the natives from an "egg cowrie" (Ovula ovum) with a black stick "tail" attached.

Present: Local fishing is carried out to supply a few rock lobsters to Port Vila hotels. Sport fishing around Port Vila and other centres is also carried out.

A Joint Control of Crayfishing Catching Regulation No. 17 of 1968 prevents catching of any female with eggs and any rock lobster less than 63 mm in carapace length (measured from rear of horns to back of carapace) and imposes a closed season (thought to be based on a definite spawning season of females) from 1 December to 28 February of the following year.

9.5 RECOMMENDATIONS

(1) Since P. penicillatus, the main rock lobster species, is an oceanic species whose larvae are very widely distributed throughout the Pacific (and Indian) Ocean and the females are producing eggs all through the year rather than in a definite season, the regulation of a closed season should be waived to encourage regular exploitation and supply to the local markets. The regulations of minimum size (63 mm carapace length) and protection of females with eggs should be retained and in fact adopted throughout the Pacific to be fully effective since inter-territory recruitment occurs.

(2) In order to facilitate exploitation of the limited, moderate stocks of rock lobster, the legal situation governing the rights of fishing in coastal waters must be clarified. Until testing of coastal waters is carried out and regular records of catch and effort are kept, management controls will not be required. At present, with the existing fishing techniques and the natural difficulties of fishing among surf and strong currents, the stock is underfished.

(3) The stock can support a small fishing operation to supply local hotels with possible expansion, for example, to New Caledonia but it will not support a substantial overseas export market.

(4) Data on tides in this region are sparse so in addition to the recent records kept at Vila, tide stations should be introduced at several places throughout the Group. It is suspected that the tidal regime is different in the northern compared with the southern parts. Such data would be of value to studies of reefs and fish movements as well as navigation.

9.6 OTHER OBSERVATIONS AND ACTIVITIES

(1) Freshwater Prawns (Macrobrachium sp.) are plentiful in the streams of the northern islands, e.g. Santo, and experimental culture and/or natural harvesting the resource might be worthwhile.

(2) Coconut Crab (Birgus latro). Farming techniques or fattening of small crabs in drums might be examined to encourage increased yield of these crustaceans.

(3) Turtles. Many turtles (mainly greens) feed on the extensive sea-grass beds on the inside of the northern islands (e.g. Santo). Reports indicate that the turtles move south to lay their eggs on the drier, more exposed southern islands where beaches are more common than sea grass flats. The natives dive for them at night and occasionally find black and white banded sea snakes coiled around the turtles' necks also asleep under the ledges. Sucker fish (Remora) also use turtles as anchoring places at night.

(4) Trochus shell come up on the reef at night like the reef crayfish but are less inhibited by the moon than the rock lobster. They can move fairly fast and retreat off the reef during the day.

(5) Dugong. These are still plentiful, feeding in the same sea-grass beds as the turtles. On the northern islands they were caught traditionally by chasing them in a canoe and when they were tired, asphyxiating the dugong by jumping overboard to force two coral plugs into the animal's nostrils. Death occurs fairly shortly afterwards by this method.

(6) Whales (species unknown) were described by Mr. Stephens of Santo as mating vertically. Earlier whaling operations in the New Hebrides used to be operative on Tanna Is. where trypots still remain as evidence.

10. FRENCH POLYNESIA

10.1 SYNOPSIS OF ACTIVITIES

Tahiti was surveyed by road and by diving on the mid east and mid west coasts and on the mid west coast of Moorea. At Rangiroa diving was performed inside the lagoon on north, south and west sides, also working the north reef at night. At the Service de la Pêche headquarters, the freshwater prawn culture experiments were visited. Valuable impressions of marine faunal characteristics throughout French Polynesia were also gained from discussions with Prof. J. Gooding who has spent seven months throughout the area, studying microfauna associated with sea urchins.

10.2 GENERAL TOPOGRAPHY AND CLIMATE

The islands are easily separated into "high volcanic islands" and "coral atolls" although raised limestone islands such as Makatea and the Austral Group also occur. The larger high islands of volcanic origin are Tahiti (1 000 km^2), Raiatea (241 km^2), Moorea (132 km^2) and Bora Bora (38 km^2). These and other volcanic islands of the Society, Marquesas and Gambier Groups, usually have permanent cloud on the mountains which may rise very steeply to over 2 100 m (Mt. Orohena, Tahiti) and over 1 200 m (Mt. Keauri, Marquesas).

Such mountain slopes are heavily dissected and well vegetated. Run off is from short, fairly silt-free rivers. With the exception of Marquesas, these islands have a well-developed microatoll lagoon and an offshore barrier reef.

Eighty coral atolls of the Tuamotus are widely scattered over nearly 2 600 000 km^2 in the central region of French Polynesia. Land area in relation to the size of the atoll is small and the reefs surrounding the atol are formed of coralline algae and some corals.

The islands are influenced by the seasonal pattern of the south east Trade winds from March to September alternating with the calmer, wetter period from October to December. Rainfall is not high; Papeete on the lee side of Tahiti receiving an average rainfall of 1 626 mm.

The low tidal range throughout French Polynesia is very small - only 38 cm and the tides are semidiurnal. Sea water temperatures are much lower at the southern Gambier and Austral Islands according to Mr. Reed and Prof. Gooding and the reef fauna is entirely different from the other island groups.

10.3 COASTAL FEATURES AND ZONES

The low tidal range is apparently responsible for the very flat, gently sloping fringing reef of the atolls, as seen at Rangiroa. Only excessive storms (which apparently are not common) would wash the reef right up to the coral rubble which forms the basis of the land. Consequently only a narrow seaward edge is "active" as judged by pink coralline algal growth, a few Turbo and slate pencil urchins. Inside the lagoon the water is silty from coral breakdown and coral growth is restricted to isolated scattered coral heads throughout the lagoon and to areas adjacent to the major outflow passages of the atoll.

Around the high islands, the microatolls are caused by the mixed water from the terrestrial fresh water run off and the seawater flowing over and along the barrier reef. The barrier reef is narrow, usually gently washed by surf and also shows active growth of coralline algae only along a narrow seaward front. Inside the microatoll near the barrier reef, corals grow in the more protected waters. Fish life is most abundant amongst the surf of the barrier reef.

The Gambiers, Australs and Marquesas were not visited but reports suggest that the marine faunas and coastal habitats are quite different from those of the high islands or the coral atolls.

10.4 FINDINGS

10.4.1 Rock Lobster

Panulirus penicillatus is the most common species throughout French Polynesia. It was seen at Tahiti, in the Society Islands, and at Rangiroa, in the Tuamotus. M.A. Michel of ORSTOM at Noumea reported that he had collected P. penicillatus at Gambier and that at Marquesas he had speared P. penicillatus, P. longipes and P. homarus in the same caverns in the reef. These identifications were confirmed after examining one specimen of each at ORSTOM, Noumea. The P. longipes has a distinct deep pink base to the antennae and unbanded (one pale, one dark ramus) antennules. Neither Gambier nor Marquesas were visited on the tour but both areas appear potential rock lobster areas. According to a previously circulated South Pacific Commission Questionnaire "Spiny Lobster Resource Survey", a promising day fishery might exist on Marquesas where 80-100 rock lobster per day can be taken by hand or spear.

During the day P. penicillatus shelter near the surf-washed edges of barrier and fringing reefs and they move up onto the narrow active reef flat at night, mostly on dark nights, particularly just after full moon. Restrictions to its movements across the reef, in addition to light would be the poor flow and depth of water across the reef and the narrow, fauna - poor Porolithon zone at the edge of the reef.

All species of rock lobster appear to be more abundant around islands other than the high islands which have the well developed microatoll.

A sample of P. penicillatus (31 males and 11 females) from Rangiroa atoll was measured on 13 March 1971 and the reproductive state of the females noted. Males were larger, usually dark brown in colour and more abundant (3:1) than females. All females were pale green-cream and all were mature and in a reproductively active phase. They had either just released larvae, were newly moulted, had recently mated or had recently carried eggs. Fishermen report best conditions for fishing are noon, high tide to flood the reef as much as possible and not too much surf (just enough to keep water moving across reef but not strong enough to interfere with visibility or stability of the fisherman). They report that no rock lobsters occur inside the lagoon.

10.4.2 Fishery Development

At Rangiroa up to 10-20 fishermen walk the reefs at night carrying pressure lamps and light-weight metal boxes for the catch on their backs. The rock lobsters are picked up by hand and later placed in almost fully enclosed wooden caufs which they float in well-aerated, clean-water current. Catches up to three days are kept in this way. Unfortunately, fishermen recognize clearly the heavy mortalities resulting in caufs which are unshaded from the direct sun or which are placed in poorly circulating water. On optimum nights - dark, high tide and light to moderate surf one fisherman can catch 20 kg per night. These are mostly marketed at Papeete at Fr 400 per kg (U.S.$ 1.80 per 0.45 kg) after transport by plane or boat. The 42 P. penicillatus taken by the two men over two nights at Rangiroa were on the worst conditions of full moon (13 March 1971) and high surf. Consequently only the shore pools could be worked.

The major problem for further development is one of transport from the atoll areas (where human population is low and reasonable lobster resources exist) to the high island centres (where human population is higher and rock lobster resources lower).

10.5 RECOMMENDATIONS

(1) Transport, holding and storage facilities at the major resource areas of rock lobster, i.e. the atolls and probably the Gambiers and Marquesas as well, should be improved. These stocks appear to be little exploited at present and expansion can be expected to have little impact on the stock until more efficient catching techniques are designed.

(2) The natural stocks of rock lobster are limited by the relatively narrow active edge of the reefs around the islands due mainly to the low tidal range. Nevertheless underfishing seems to be the present situation.

(3) Experimental trapping off the seaward reef front to about 80 m should be carried out to establish the depth range of the stock.

(4) Separate surveys at the Tuamotus and Gambier Groups should be made to estimate stock size, dominant species, width and extent of active reefs, water temperature and water movement. Both areas are worthy of this effort if transport is improved and reports are accurate.

(5) The experiments at Papeete on fresh water prawn culture should be encouraged and advice from consultants should be made available when required.

(6) The existing regulations of a closed season should be waived since the evidence indicates that spawning is continuous all the year. The size limit of 16 cm from eye to telson and protection of females in berry should be retained.

10.6 OTHER OBSERVATIONS AND ACTIVITIES

(1) Fish abundance is most obvious near the more active environments, i.e. amongst the surf breaking on the seaward reefs at Tahiti and in and nearby the major lagoon outflow channels at Rangiroa. Other fish concentrations of much less extent are around the separated, isolated coral heads within the lagoons.

(2) At the Service de la Pêche, Papeete, the initial tests on Macrobrachium show that adults can be kept and grown satisfactorily in large 3 x 2 m wooden boxes, with stones and fresh water plants added. Freshwater prawns from Hawaii and the local species are both being kept this way. Several broods of eggs have been obtained from aquarium-held females but the larvae are dying after the second stage. These early stages are being fed Artemia larvae. Pond experiments are also being conducted on the east coast, using young prawns that are netted near the river mouths.

(3) Trochus shell has been previously introduced and is commercially harvested for trinkets and export. The habitat requirements of the Trochus is very similar to that of the rock lobster P. penicillatus and its movements on to the reef at night are also comparable.

11. THE COOK ISLANDS

11.1 SYNOPSIS OF ACTIVITIES

Reefs around Rarotonga were surveyed, diving was carried out on the west coast at Arorangi and the fisheries vessel RAVAKAI travelled to Palmerston (diving in the day time and catching at night on the west reef) and to Aitutaki (catching at night on the south reef). At Rarotonga, the Consultant discussed fisheries development with Dr. White and visited the site of the proposed fish and oyster culture project at Ngatangiia Harbour.

11.2 GENERAL TOPOGRAPHY AND CLIMATE

Of the fifteen small islands scattered north-south from 8° - 23°, all are atolls except the southernmost islands of Mangaia, Rarotonga, Mauke, Atiu, Mitiaro and Aitutaki. The volcanic islands are surrounded by reefs and only the western islands of Aitutaki and Rarotonga lack a well developed elevated reef or Makatea behind the coastline.

The islands lie in the zone of the south east Trades and more rain falls from November to April, the season when occasional tropical cyclones develop. Annual rainfall is low, varying from 1 803 mm at Rakahunga to 2 769 mm at Palmerston and the average temperatures are milder in the south (25° C at Rarotonga) than in the north (29° C at Rakahunga). Citrus fruits are grown in the southern volcanic islands. The tidal regime is semidiurnal with a low range of about 38 cm throughout the group.

11.3 COASTAL FEATURES AND ZONES

All the islands are small enough (about 5 - 19 km at widest part) and rounded enough to provide some wave action on all coasts from the prevailing south east Trades. Wave action is strongest on the south and east coasts where raised Porolithon algal ridges and buttresses are best developed. The atolls have outflow from the lagoons on the lee (east side and/or north sides) where the boat passages and landings are made. The lagoons are carpeted with coral silt and the waters are usually turbid. Around the volcanic islands with a raised Makatea reef there are narrow fringing reefs whereas the other two volcanic islands have microatolls formed, particularly on their southeast sides. The microatoll is small at Rarotonga but quite extensive at Aitutaki.

11.4 FINDINGS

11.4.1 Rock Lobster

Only one species of rock lobster, Panulirus penicillatus, was caught but a second species was described by I. Marsters as being brownish red, longer and narrower than P. penicillatus and with cross-banded antennules; it is probably P. longipes femoristriga. Three fawn coloured butterfly lobster Parribacus sp. with red blotch markings on antennae and body were also collected on the outer reef at Palmerston and Aitutaki, one female carried orange eggs externally, another carried a new spermatophore across the first abdominal sternum and the third specimen was a male.

Of the 23 specimens of P. penicillatus collected on the outer reefs at night, 13 (4 males, 9 females - 8 in berry) were caught at Palmerston on 22 March 1971 and 10 (7 males, 3 females - all in berry) were caught at Aitutaki on 24 March 1971. All the females are mature, all but one carried eggs and two in berry were newly mated again. Reports from the fishermen indicate that females carrying eggs are present all the year round. The high proportion of females in the sample at Palmerston is apparently indicative of the usual situation there.

During the day the rock lobster apparently live on the seaward reef edge amongst the surf and come up onto the reef flat at night. Best catches are on dark nights particularly just after full moon. Reports and diving observations indicate that lobsters do not occur around the coral heads in the lagoons of the group.

11.4.2 Fishery Development

P. penicillatus is caught by hand on the reef at night and trial catches of 800 over a two-week period by five men at Palmerston were reported. The fishing community at Palmerston Atoll, about 315 km from Rarotonga, consists of about 50 men, women and children. A small fishery on rock lobster would be of great economic value to them and the spawning females on their isolated atoll are probably worth sacrificing. The effect on distant potential recruit areas would be insignificant; it is also most probable that the Fisheries Department would make arrangements for data collection. Good catches of rock lobster are also reported from Penrhyn but no details were available. Men using underwater torches work the reefs at night mainly for fish, on a casual basis at Aitutaki but occasional catches of 40 rock lobster by three men a night are made when conditions are optimal. At Rarotonga, amateur fishermen work hard for a few rock lobster either by spearing in the surf zone during the day or walking and diving along the reef at night using underwater torches.

Future development of the lobster resources necessitates improved transport facilities to Rarotonga which is anticipating major tourist traffic on completion of the international airport. Except at Rarotonga, the rock lobster stocks appear to be underfished and capable of increased exploitation.

11.5 RECOMMENDATIONS

(1) Rock lobster and scale fish development at atolls should be encouraged by increasing the transport facilities to Rarotonga. Initial steps could include the service of the 17 m fisheries vessel RAVAKAI to service Palmerston. Ice holds or cooling coils could be fitted and only slight modifications to the vessel superstructure to keep decks cool would be required. Such development would contribute considerably to the economy of Palmerston and to the fish-hungry local and potential tourist market at Rarotonga. If successful, the RAVAKAI experiment could be extended to other atolls, perhaps utilizing light aircraft in the future.

(2) Since recruits of pelagic larvae to isolated atolls like Palmerston almost certainly originate in areas outside Cook Islands, the protection of spawning females may be unwarranted. If the sample of P. penicillatus examined at Palmerston is truly representative of that area, regulations prohibiting the taking of berried females (61 percent of the catch) would nullify the fishery there. Records of sex ratios and the reproductive state of females should be kept to ascertain seasonal variations of these factors.

(3) Regulations may be necessary to safeguard the quality and acceptable size at the market (Rarotonga). Rock lobsters may be held alive in darkened floating boxes in well aerated silt-free passages and should remain alive for the two-day voyage to Rarotonga in tightly packed dry sacks stored in an iced or cooled hold. Further processing of the live product (with cooking or tailing) could be carried out at Rarotonga. There would also be some local demand for live rock lobsters.

(4) The stock of lobster, although limited to local markets, should be fished much more than at present and management restrictions should be implemented only when evidence of overfishing is shown. Records of catch and effort data should therefore be kept and any improvements in fishing techniques and efficiency carefully noted.

11.6 OTHER OBSERVATIONS AND ACTIVITIES

(1) The proposed fish and oyster culture project at Ngatangiia Harbour is supported by the Oceanic Foundation and if successful at Rarotonga, mullet and oysters may be transplanted to other areas such as Aitutaki.

(2) Aitutaki is one of the rare oceanic islands in the world where a volcanic high island is surrounded by an atoll lagoon. The zones of terrestrial run off water, lagoon water, coral silty water, reef flat and oceanic water are clearly seen from the top of the island. Experimental ponding in such an area would be of great interest and a study of the influence of a high island on atoll formation would also be scientifically rewarding.

(3) Fresh water prawn (Macrobrachium) culture would be a natural extension of the fish and oyster culture project if funds and personnel could be made available. Extension of such culture would be initially possible for high islands where fresh water supplies are adequate. It should be noted, however, that integrated sanitation schemes such as those proposed by Dr. G. Chan of SPC for atolls in the U.S. Trust Territory (Chan, 1971) include fresh water fish ponds where fresh water prawns may also be successfully cultivated.

12. NEW CALEDONIA

12.1 SYNOPSIS OF ACTIVITIES

Discussions were held with Messrs. Eude and Legand on the amateur fishery and fishery tests that had been conducted at New Caledonia. A two-day diving trip (13-14 April 1971) to Ile des Pins with Mr. Michel was carried out, using the vessel of the Maritime Affairs Department. The main barrier reef to the south of Noumea was also investigated for rock lobster during the period of the SPIFDA Consultative Meeting in October 1970.

12.2 GENERAL TOPOGRAPHY AND CLIMATE

The main island of New Caledonia runs north-west to south-east and is 400 km long and 40 km wide. It is very old, rising to mountains of over 1 524 m. The north-east side is steeper than the south-west side where there are small rivers and some alluvial flats, bordered by mangroves. A barrier reef lies offshore and is the longest insular coral reef in the world. The south-east Trade winds cause rougher sea conditions on the north-eastern and southern sides as well as higher rainfall being present on the eastern, southern and higher parts. June to November is the drier and calmer season.

12.3 COASTAL FEATURES AND ZONES

The southern and eastern sides of the islands being more exposed to the south east Trade winds have surf breaking on relatively narrow coralline algal reefs. At Ile des Pins, such reef flats have been elevated in the past to form the raised "makatea" limestone reef characteristic of the area. On the western and northern sides of the islands where the conditions are more favourable, corals are more prolific and form the barrier reefs so well developed along the entire west and north coasts. On the coast in these protected regions, mangroves are often the characteristic feature. A noticeable feature of the reefs around Ile des Pins, in particular, is the abundance of red, brown and green algae, indicative of the cooler water temperatures.

12.4 FINDINGS

12.4.1 Rock Lobster

Five species of Panulirus occur in New Caledonia which are in order of habitat conditions, from the roughest and oceanic to the calmest and muddiest: P. penicillatus, P. longipes femoristriga, P. versicolor, P. ornatus and P. homarus.

P. penicillatus was collected in the surf under surge conditions on the south side of Ile des Pins and on the outer barrier reef to the south of Noumea. Mr. Legand reported that they were the dominant species caught in tangle nets set overnight on the surf washed reef of the east coast of New Caledonia. At Ile des Pins they were living deep in limestone undercuts whereas on the barrier reef off Noumea they were sheltering amongst extensive plate corals.

P. longipes femoristriga were taken on the barrier reef south of Noumea and on north and east sides of Ile Bayonnaise (Ile des Pins). They were also taken in the tangle nets set overnight by Mr. Legand on the east coast of New Caledonia. The sea conditions are generally calmer for P. longipes femoristriga than for P. penicillatus although both can be taken in close proximity. All seven specimens taken at Ile Bayonnaise had brown and cream banded feelers on the antennules and a distinct purple patch near the stridulating pad on the base of the main antennae. Mr. Michel suggested that spawning times for this species may be seasonal and had just taken place (reported April 1971). The two females taken in the sample had fibrillar pleopods, but no eggs or sperm packets were present.

P. versicolor were taken at Ile Bayonnaise (Ile des Pins) in very sheltered areas amongst the corals on the north side. Two male specimens were collected.

P. ornatus were reported by Mr. Michel from the small lagoon or channel that forms the break through the reef to the landing on Ile Bayonnaise. The water is milky and a small creek with general seepage from the island leads on to this reef area. The rock lobsters are apparently seasonal in occurrence as 20-30 may be taken at times. There were none in this area when it was searched on 13 April 1971.

P. homarus specimens from Bourail were examined at ORSTOM headquarters in Noumea. These have little sculpturing in the median section of the abdominal grooves and were green in life. Mr. Michel states that at Bourail there is a break in the barrier reef opposite a river and that the P. homarus live very close to the shore in the brown muddy water. This is the only place he has seen this species in New Caledonia.

12.4.2 Fishery Development

There is no established fishery for rock lobster in New Caledonia. Catches are usually made for home consumption although a small regular trade exists with some hotels (e.g. at Ile des Pins). Fishery statistics which were maintained by the gendarmes of the provinces show that the east coast is much more productive than the west coast. There, P. penicillatus is the dominant species of the more exposed reef system. P. ornatus may be the important

species in the Ile des Pins catch. The average price is CFP francs 0.194 per kilo (U.S.$ 0.90 per 0.45 kg).

12.5 RECOMMENDATIONS

Without a more intensive survey, the full potential of the fishery cannot be gauged but it is likely that more rock lobster could be taken, especially from the east coast, if the economics of such operations were sound. The main market would presumably be Noumea but economic problems of transport across the island are probably prohibitive at the present time. However, at best, the rock lobster fishery could only supply local markets and cannot be regarded as a major export potential.

13. DISCUSSION AND CONCLUSIONS

(1) The common names currently used through the Pacific are either lobster or crayfish. The species encountered all belong to the genus Panulirus and the common names rock lobster, spiny lobster, reef lobster and crayfish are used in other parts of the world for members of this genus. "Rock lobster" is the name adopted in this report since this is the name acceptable in the United States for the frozen product and has been adopted in Australia as the common name.

(2) The production of rock lobster in the South Pacific is very small in comparison with the large export industries of Australia, New Zealand and South Africa. Small private industries are operating at Papua, Tonga and British Solomons based on mixed fishing (rock lobster, wet fish, Trochus shell) and general trading practices.

(3) Limitations on the potential are due mainly to practical difficulties in exploiting the resource (either due to seasonal onshore migration (P. ornatus) or surf, moon and tide factors) and the availability of adequate transport from best resource area to best local market under tropical climatic conditions.

(4) Statistics relating to catch of rock lobster and effort expended are available for only a few territories. The fishery at Yule Is., Papua, is seasonal and very variable (from only 11 000 rock lobsters in 1967/68 to 41 000 rock lobsters in 1966/67), that at Tonga yields about 1.016 t frozen tails per month and recent catches of the developing industry at British Solomons are in the order of 2.032 t of whole rock lobster a month. In New Caledonia for 1968, 8 617 kg were taken on the west coast and 1 900 kg on the south and east coasts.

(5) The resource of rock lobster is based primarily on two species of Panulirus, P. penicillatus which is widely spread throughout the South West Pacific and P. ornatus in the Gulf of Papua. These stocks would appear to support increased fishing effort due to the present practical difficulties of harvesting these species. They are mainly taken by hand (labour intensive operation) and either appear seasonally (P. ornatus) or live in the surf zone of outer reefs exposed to prevailing winds (P. penicillatus). Modern traps have been used with limited success but the small traditional beehive pots, set on the reef flat and covered with rock slabs are quite successful.

(6) Improvement in techniques for catching lobster and increasing the natural stock will be significantly assisted by further investigations particularly on the behaviour of the species concerned. P. penicillatus responds adversely to light of even quite low strength and is most active on moonless nights, leaving the protection of their dark daytime shelters to forage on the reef flats. It is for this reason that the traditional traps, covered by the rock slabs, are so attractive as shelter for the rock lobster returning from the reef flat to the reef edge as daylight or a falling tide starts.

(7) Hatchery prospects for rock lobster are extremely poor. The species that are more closely associated with the land (e.g. P. homarus and P. ornatus) are thought to be a better possibility than the more oceanic species because they probably have a shorter larval life and live in mixed water conditions which would be easier to reproduce under laboratory or hatchery conditions. But even after many years, Japanese efforts to grow larvae further than about half way through the pelagic phase have not been successful and P. penicillatus is even more oceanic than P. japonicus.

(8) The number of species of Panulirus in the South Pacific is five and these can be arranged in order from those with an "oceanic affinity" to those with an affinity toward the "terrestrial", as follows: P. penicillatus, P. longipes femoristriga, P. versicolor, P. ornatus and P. homarus.

(9) P. penicillatus is widespread throughout the Indian (as far west as the Red Sea) and Pacific Oceans (as far east as the Galapagos Islands). It lives in a truly oceanic position in the outer reef edges or channels which are subject to high energy water movement by surf, swell or strong current. It is sensitive to even low levels of light intensity and in daytime seeks dark recesses in the substrate of volcanic rock, coralline algal ridge, coral "mushrooms" or eroded limestone. Movements onto the reef at night are usually correlated with the absence of moon and a tide height that supplies a flow of water across the reef flat. The males attain a much larger size than females and it is probable that the largest male guards a "harem" of mixed sexes where suitable shelter allows aggregation of numbers of lobster. It is the strongest species of Panulirus with well-developed carapace and legs, well adapted to living amongst surf and strong currents. Females are reproductively active all the year round according to fishermen's reports and females can be mated again before moulting and while carrying a developing brood of eggs on the tail swimmerets. Parribacus caledonicus shares the surf reef zone with P. penicillatus.

(10) P. longipes femoristriga is the striped leg Pacific Ocean species and can be easily separated from the Indian Ocean species which possesses spotted legs. But in the Pacific P. longipes femoristriga, two forms were pointed out by Mr. Gibbins - one with a rich pink front and one pale and one dark ramus on the antennule; and another with pale pink and brown front, not particularly different from the rest of the body, and distinct pale bands across both feelers of the antennule. Only few specimens were encountered in this survey and habitat differences of these two forms were not able to be ascertained but it appears to live in oceanic waters, slightly quieter than the conditions for P. penicillatus. It lives in shallow waters on the inside of surf washed outer reefs, along the outer edge of quieter oceanic coasts (e.g. west coast of Santo) or in deeper water below the outer surf zone (e.g. down to 122 m at Tanna Is.). Like P. penicillatus it will enter baited pots and both species can be caught together (e.g. at Tanna). It may be seasonal in appearance and in spawning time.

(11) P. versicolor was encountered in all territories west of and including Tonga. It lives in moderately sheltered conditions, outside the reefs in deep water, amongst coral heads (inside lagoons for instance) and does not appear to aggregate in large colonies. At New Britain and on the west coast of Efate, New Hebrides, a short migration of middle-sized P. versicolor onto the reef flat have occasionally been reported. It does not enter traps.

(12) P. ornatus is most abundant in the Gulf of Papua where it migrates onto shallow sunken reefs seasonally. It extends further east to New Caledonia and to Fiji but is apparently very rare or unknown in other territories. It is usually associated directly with lagoons and run off from relatively large land masses or islands where waters are mixed, containing much fine coral and terrestrial silt. It does not enter traps but does aggregate into colonies.

(13) P. homarus is a variable species throughout the Indo-West Pacific. In Natal, South Africa, it is red and heavily sculptured across the transverse grooves of the tail segments; in Saudi Arabia, it is blue/green and heavily sculptured and in Ceylon, Java and Sumatra it is dull olive green with very poorly developed sculpture on the tail. The specimens examined from Papua, New Caledonia and Marquesas are similar to the Ceylon-Java-Sumatra description but it was also noted that the Marquesas specimens were more spotted on the tail and were grown/green rather than light olive green like the New Caledonian specimens. It seems restricted in its distribution in the Pacific region to shallow, brown muddy bays at New Caledonia, Papua, New Guinea and North Queensland.

(14) New grounds are most likely to be found where P. penicillatus or P. longipes femoristriga occur or if the "out of season stock" of P. ornatus can be discovered. Oceanic areas preferably down to deep trenches would have more potential particularly where water movement (by current or prevailing wind) is good, where rainfall is low and where the tidal regime is conducive to deep rather than shallow reef formation, i.e. good range of tide and diurnal type of tide. Such conditions exist at Southern Solomons, New Hebrides and probably the Loyalty Islands. It is noteworthy that Mr. Michel found a high phyllosoma population centre for P. penicillatus just east of New Hebrides.

(15) A correlation of climate, terrestrial run off, coastal features and zonation with the distribution and relative abundance of the different species of Panulirus can be shown.

14. CONSOLIDATED RECOMMENDATIONS

14.1 FOR LOCAL GOVERNMENT AUTHORITIES

Improvements should be made in transport facilities between the main resources areas (usually atolls or dry islands) and main population and tourist centres (usually high islands). Government assistance should be continued towards both private industry services (e.g. in Tonga and British Solomons) and to the existing Government services (e.g. Fiji) and shall be initiated in regions where no services currently exist (e.g. from Palmerston Atoll, Cook Islands).

It should be agreed to retain only those fishing regulations that relate to ensuring (a) top quality product at the market (e.g. ban spearing if no freezer facilities are available and ban processing of dead rock lobsters) or (b) acceptable size at the table (e.g. legal minimum carapace length about 70 mm and possibly total maximum about 140 mm). Since the nonstatistical evidence collected indicates clearly that spawning female P. penicillatus are present in the catches all through the year, the regulations concerning a closed season to protect spawning females (e.g. New Hebrides and French Polynesia) is unwarranted and should be revoked. If P. penicillatus had a definite and limited spawning season, limiting fishing for that short period might even be advisable since the production of non-spawning animals is low during that period. (In other words, the fishermen are obliged to avoid an uneconomic operation.) However, when females spawn throughout the year, the objective of a closed season cannot be achieved. It is yet unknown as to whether or not the protection of spawning females materially contributes to the future recruitment of P. penicillatus in the South Pacific. The regulations protecting females in spawn should be retained but since the larvae lead a long pelagic life, it is doubtful whether larvae originating in a given area will recruit to that area. In places like Palmerston Atoll - a small fishery would probably falter if the sample obtained (berried females represented 60 percent of the catch) is indicative of the yearly situation.

Statistics of catch and effort should be set up and maintained as the fisheries develop and basic biological data of length frequency and reproductive state (see Appendixes 2 and 3) should be recorded for future evaluation, if and when the fishery can be shown to suffer from overfishing.

Most centres do have competent Fisheries or Agriculture personnel who could collect the simple data and in areas where such officers are not available, small honoraria could be paid to a local fisherman or store-keeper after a brief training at the main centre. Fishing rights relating to reefs and offshore waters where these confuse and inhibit exploitation (e.g. New Hebrides), should be clarified.

14.2 FOR INTERNATIONAL AID ORGANIZATIONS

Biological research on P. penicillatus should be carried out on

(a) reproductive cycle,

(b) horizontal and vertical distribution,

(c) field behaviour (e.g. light tolerance, oxygen requirements, food requirements) which will lead to better understanding of its natural habitat requirements, how to improve fishing techniques and how to provide good conditions for live transport,

(d) post larval settlement and juvenile growth,

(e) fishery management by coordinating statistics on fisheries in the area, indicating fishing pressures and advising on management procedures.

Such a project would be best situated at Fiji where a wide variety of marine habitats exists and actual or potential fisheries at Tonga, British Solomons and New Hebrides are nearby. At least two years would be needed to obtain worthwhile results.

Research on fishing techniques for P. penicillatus should be carried out. This could be coordinated with the behaviour studies conducted by the biologist as improvements to traps and the success of artificial shelters depend on a knowledge of the rock lobsters' responses to these artifacts. Such research should lead to an improvement in lobster stocks by providing additional suitable shelters to supplement the natural shelter which is apparently one of the main factors limiting the resource at present. One year should be sufficient to indicate the possibilities of improving on the existing catching methods and of providing artificial shelters.

Resource surveys of the rock lobster potential at Marquesas and Gambier in French Polynesia should be supported. Confirmation of identity and the extent of the preferred habitat would be the main lines of investigation. About two months would be required.

In regard to the cultivation of rock lobsters, the difficulties of raising larvae through about 30 moult stages in a simulated "pure" oceanic environment over a period of at least six months and then growing the 25 mm long post larvae to maturity in an estimated three years is not feasible at this state of our knowledge of rock lobster biology. The Japanese have spent 20 or so years in this research field and have not yet successfully hatched and grown larvae under laboratory conditions.

However, prospects of cultivating crustacean meat in the form of freshwater prawns (Macrobrachium spp.) are very promising for the South Pacific area and research should be intensified and expanded. The product is of good quality, highly priced and could reach export quantities. The site of study could be centred on French Polynesia where experiments have recently been initiated, at American Samoa or the Cook Islands where Government officers showed considerable interest, or Fiji where they are already being harvested from the rivers and available at the market. The potential for cultivation of freshwater prawns appears sound and it would have immediate and widespread application to all areas of the Pacific eventually including the more arid atolls. It could possibly be farmed in the freshwater fish ponds associated with integrated sanitation programmes such as are being studied by the South Pacific Commission.

Appendix 1

PERSONS INTERVIEWED

FIJI	Mr. B. Bunibobo, Director of Agriculture, Suva
	Mr. A. Adams, Senior Fisheries Officer, Department of Agriculture, Suva
	Mr. R. Stone, Fisheries Officer, Department of Agriculture, Suva
	Captain Frazer, Master Pilot, Suva
	Mr. Costello, Beachcomber Cruises, Lautoka
WESTERN SAMOA	Mr. W. Meredith, Director of Agriculture, Forests and Fisheries, Apia
	Mr. W. Travis, Fisheries Officer, Department of Agriculture, Forests and Fisheries, Apia
AMERICAN SAMOA	Dr. S. Swerdloff, Supervisor, Department of Marine Resources, Pago Pago
TONGA	Mr. J. Pitman, Director of Agriculture, Nuku'alofa
	Mr. P. Warner, Managing Director, Fathom Fisheries, Nuku'alofa
	Mr. L. Williams, Peace Corps Volunteer, Nuku'alofa
	Miss J. van Donop, Mango Island
TERRITORY OF PAPUA AND NEW GUINEA	Mr. G.L. Graham, Deputy Assistant Director, and Mr. R.R. Pyne, Marine Biologist, Division of Research and Surveys, Department of Agriculture, Stock and Fisheries, Konedobu, Papua
	Mr. Slaughter, Manager, Yule Island Enterprises
	Mr. Craig MacDonald, Peace Corps Volunteer, c/o Fisheries Management Biologist, Koror, Palau, Western Caroline Islands
BRITISH SOLOMON ISLANDS PROTECTORATE	Hon. D. Kausimai, Chairman of the Natural Resources Committee of Governing Council, Honiara
	Mr. J.L. Pepys-Cockerell, Senior Assistant Secretary (Natural Resources), Honiara
	Messrs. B. Fox, A. Rheault and B. Strong, Coral Seas Fisheries, Honiara
	Mr. E. Palmer, Gizo, Western Solomons
	Mr. W. Gibbins, Marine Salvage, Honiara

FI:RAS/69/102/9

Appendix 1 (Cont'd)

NNEW HEBRIDES	Mr. Langlois, French Resident Commissioner, Port Vila
	Mr. Sorin, Administrator, French Residency, Port Vila
	Mr. J. Balmain, Assistant Secretary, Natural Resources, British Residency, Port Vila
	Mr. A. Thevenin, Chief Agriculture Officer, Port Vila
	Mr. D. Allen, Deputy Senior Agriculture Officer, Port Vila
	Dr. D. Mallik, Senior Geologist, Port Vila
	Mr. D. Bick, Agriculture Extension Officer, Port Vila
	Mr. M. Ratard, Agriculture Extension Officer, Santo
	Captain J. Barley, Master Mariner, Port Vila
	Mr. R. Paul, Trader, Tanna
	Mr. J. Stephen, Trading Vessel TAMAHAI, Santo
	Mr. K. Hutton, Businessman, Santo
FRENCH POLYNESIA	Mr. Stein, Director, Mr. W. Reed, Biologist, and Mr. Tapu, Technical Assistant, Service de la Pêche, Papeete
	Prof. J. Gooding, Visiting Marine Biologist
COOK ISLANDS	Hon. Albert Henry, Premier of Cook Islands
	Dr. B. White, Fisheries Officer, Mr. T. Marsters, Technical Officer, and Mr. I. Marsters, Skipper Fishing Vessel RAVAKAI, Fisheries Department, Rarotonga
	Messrs. T. and J. Marsters, Palmerston Island
	Mr. J. Teaukura, Resident Agent, Aitutaki Island

Appendix 2

ROCK LOBSTER RECORD SHEET

Locality

How caught: Hand/Spear/Trap Date .....

SPECIES PANULIRUS Penicillatus/Longipes

Sex	Head length	Eggs	Tar Spot	Shell	Remarks

Appendix 3

NOTES FOR USE WITH ROCK LOBSTER RECORD SHEET

SPECIES: P. penicillatus is green or green brown with four almost equal spines on the flat plate below and in front of the eyes. P. longipes is reddish brown with only two major spines on the plate.

SEX: Males have sex opening on base of last leg and no little claw on that leg. Females have a tiny sex opening on the base of third leg and a little claw on the fifth leg.

HEAD LENGTH: Measure from middle of ridge between horns in middle to back of head (carapace).

EGGS: Give colour of eggs - orange or red or brownish orange (tiny black spots in eggs) if present. Otherwise record nil.

TAR SPOT: This is the sperm packet that the male places on the "chest" of the female. Record colour (grey or black) and whether smooth or broken if present, otherwise record nil. It is large and quite distinctive and a soft or hard shell is equally simple to recognize.

SHELL: Squeeze shell. Record hard, brittle (a new shell will be underneath) or soft (if newly moulted).

Appendix 4

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