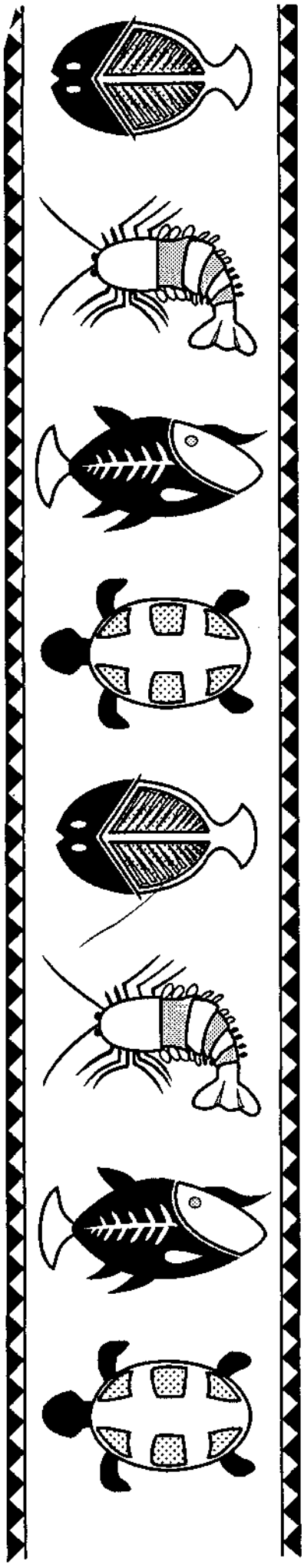

Inshore Fisheries Research Project
Country Assignment Report

PEARL OYSTERS IN CHRISTMAS ISLAND AND THE POTENTIAL FOR DEVELOPMENT OF A PEARL CULTURE INDUSTRY

South Pacific Commission
Noumea, New Caledonia

PEARL OYSTERS IN CHRISTMAS ISLAND, KIRIBATI, AND THE POTENTIAL FOR DEVELOPMENT OF A PEARL CULTURE INDUSTRY

N. A. Sims
Zoology Department
University of New South Wales
P.O. Box 1, Kensington, 2033
AUSTRALIA

G. L. Preston
Inshore Fisheries Research Project
South Pacific Commission
B.P. D5, Noumea Cedex
NEW CALEDONIA

B. M. Yeeting
Fisheries Division
Ministry of Natural Resources Development
Box 64, Bairiki, Tarawa
KIRIBATI

R. Alfred
Marine Resources Authority
Ministry of Resources and Development
P.O. Box 860, Majuro
MARSHALL ISLANDS

South Pacific Commission
Nouméa, New Caledonia
January 1990

SUMMARY AND RECOMMENDATIONS

The main points of this summary were presented for discussion at a meeting between representatives of the Ministry of Natural Resources, the Ministry of the Line and Phoenix Islands, the Marine Exports Division, and the survey team, held at London, Kiritimati, on September 12, 1989[1].

1. INTRODUCTION

A two-week survey of the pearl oyster resources of Kiritimati was carried out during September 1989 by the Kiribati Fisheries Division and the South Pacific Commission. This summary presents the reports main conclusions and recommendations.

2. LOW ABUNDANCE

The survey showed that pearl oysters are present in low abundance in Kiritimati lagoon. There is some evidence that stocks were very much higher about a century ago, but they have never recovered from the heavy fishing at that time. The stocks are exploited very lightly at present, and are maintained at low densities by natural limitations.

3. NO COMMERCIAL FISHING POTENTIAL

There is NO potential for a commercial fishery for pearl shell based on wild stocks in Kiritimati. Present levels of incidental exploitation could probably be sustained if no other development of the resource is envisaged.

4. POTENTIAL FOR PEARL CULTURE

There may be potential to develop economically viable pearl culture activities in Kiritimati lagoon. The supply of pearl oysters for culture would, however, depend on the success of the re-establishment of wild stocks. This requires a long-term commitment on the part of the Kiribati government. It is envisaged that a programme of stock re-establishment will have to operate for at least five years before pilot farming activities may be feasible.

5. STOCK RE-ESTABLISHMENT PROGRAMME

If the Kiribati Government wishes to develop a pearl farming industry in Kiritimati, the following steps should be undertaken to promote re-establishment of the wild stock and provide juveniles for farming purposes:

(i) Prohibit all fishing for pearl shell (to protect breeding adult pearl oysters);

(ii) Deploy and maintain spat collectors throughout the lagoon (to enable collection of spats, and limit predation on juveniles);

(iii) Construct and maintain culture platforms in protected sectors of the lagoon. These could be stocked immediately with a broodstock of adults collected from the wild (to improve spawning synchronisation, fertilisation success and larval retention in the lagoon) or, over a period of years, with spat from the spat-collector programme.

These steps should foster increasing spatfalls both on the collectors, and in the wild. Spatfalls will be irregular, but sufficient spats should be available within a period of five years to allow the commencement of the pilot pearl culture programme.

---

1 Meeting participants were:

Apureti Takaio, Second Assistant Secretary, Ministry of the Line and Phoenix Islands (Kiritimati);
Mine Awira, Resource Economist, Ministry of the Line and Phoenix Islands (Kiritimati);
Being Yeeting*, Research Officer, Fisheries Division, Ministry of Natural Resource Development (Tarawa);
Michael T. Tekanene, Fisheries Officer, Fisheries Division, Ministry of Natural Resource Development (Kiritimati);
Torua Aaron, Assistant Manager, Marine Exports Division, Ministry of the Line and Phoenix Islands (Kiritimati);
Neil Sims*, Consultant Biologist, University of New South Wales (Sydney);
Garry Preston*, Senior Inshore Fisheries Scientist, South Pacific Commission (Nouméa);
Ronald Alfred*, Fisheries Officer, Marshall Islands Marine Resource Authority (Majuro).

* Survey team members

6. TRAINING

To enable the stock re-establishment programme to be effectively implemented, it would be necessary to have a local Fisheries Officer designated as responsible for the project on a full-time basis. Together with a supervising biologist from the Fisheries Divisions Research Unit, the officer should be sent for attachment training to a pearl farm overseas, probably in the Cook Islands. It should be stressed that the person selected should be a competent diver and will be required to spend a lot of time carrying out underwater equipment maintenance, checking of culture animals, etc. The officer will also be required to undergo training in SCUBA diving.

7. PILOT PEARL CULTURE PROGRAMME

A pilot pearl culture programme would then be established, to trial pearl culture methods and locations in Christmas lagoon, and to provide extension and demonstration facilities to pass on pearl farming methods to local people. The government would profit directly from the pilot pearl farm, and revenue could be used to foster the establishment of local private or co-operative farms.

The pilot pearl culture programme would involve :

(i) Establishment of a series of culture platforms in various locations across the lagoon, to conduct growth trials and determine the extent of viable farming areas. These platforms would be separate from the broodstocks (para 5.ii above), using only juveniles taken from the spat collectors;

(ii) After two years of on-growing, technicians would be engaged to seed the oysters with pearl nuclei. Within a further two years, the first pearls could be harvested.

8. COSTS

The capital cost of establishing a small pearl farming operation is not high (A$5,000 - 10,000). Small private farms and co-operatives have proven successful in French Polynesia and the Cook Islands, with only minimal capital investment in the first stages. The major cost involved is in the provision of Japanese technicians to do the pearl-seeding operations. Seeding and marketing services could be organised on a collective basis, with the Kiribati Government assuming responsibility for the provision of such services over the initial start-up period.

9. LONG-TERM DEVELOPMENT

The structure of a pearl farming industry in Kiritimati, the degree to which government should be involved, and the amount and type of support to be given to encourage the establishment of private or co-operative local pearl farms, would all need to be considered at a later stage. Marketing and investment options would also need to be identified before expansion of the pilot programme.

Other islands in Kiribati, in particular Butaritari, Abaiang, Onotoa, Fanning and Canton, may also have potential for pearl culture. Assessments of stocks in these islands should be undertaken by the Fisheries Division in the near future.

ACKNOWLEDGEMENTS

This work would not have been possible without the support of numerous organisations and individuals. The British Government funded all activities other than local operating costs and staff inputs, which were covered by the Kiribati Fisheries Department, and the participation of Neil Sims, which was funded by the United Nations Development Project. The University of New South Wales permitted the loan of diving gear, while the Japanese Overseas Fishery Cooperation Foundation generously donated buoys and ropes for the spat-lines, as they were required. Mr Philip Wilder kindly provided SCUBA tank fills free of charge.

We would like to particularly thank Michael Tekanene and his family for their wonderful hospitality and victualing of the team.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Development Perspective

Fisheries and marine resources assume a high profile in Kiribati development goals. Assessments of the potential for pearl shell, trochus, and precious coral exploitation are identified as specific areas of emphasis in the Sixth National Development Plan (1987 - 1991).

Christmas Island, or Kiritimati, (Figure 1) is the centre for commercial developments in the Line and Phoenix Group, and represents an important component in the government policy of decentralisation and resettlement Current commercial activities on Kiritimati revolve around copra, the tourist traffic (almost exclusively sport fishermen), and the export of frozen fish and shellfish to Hawaii.

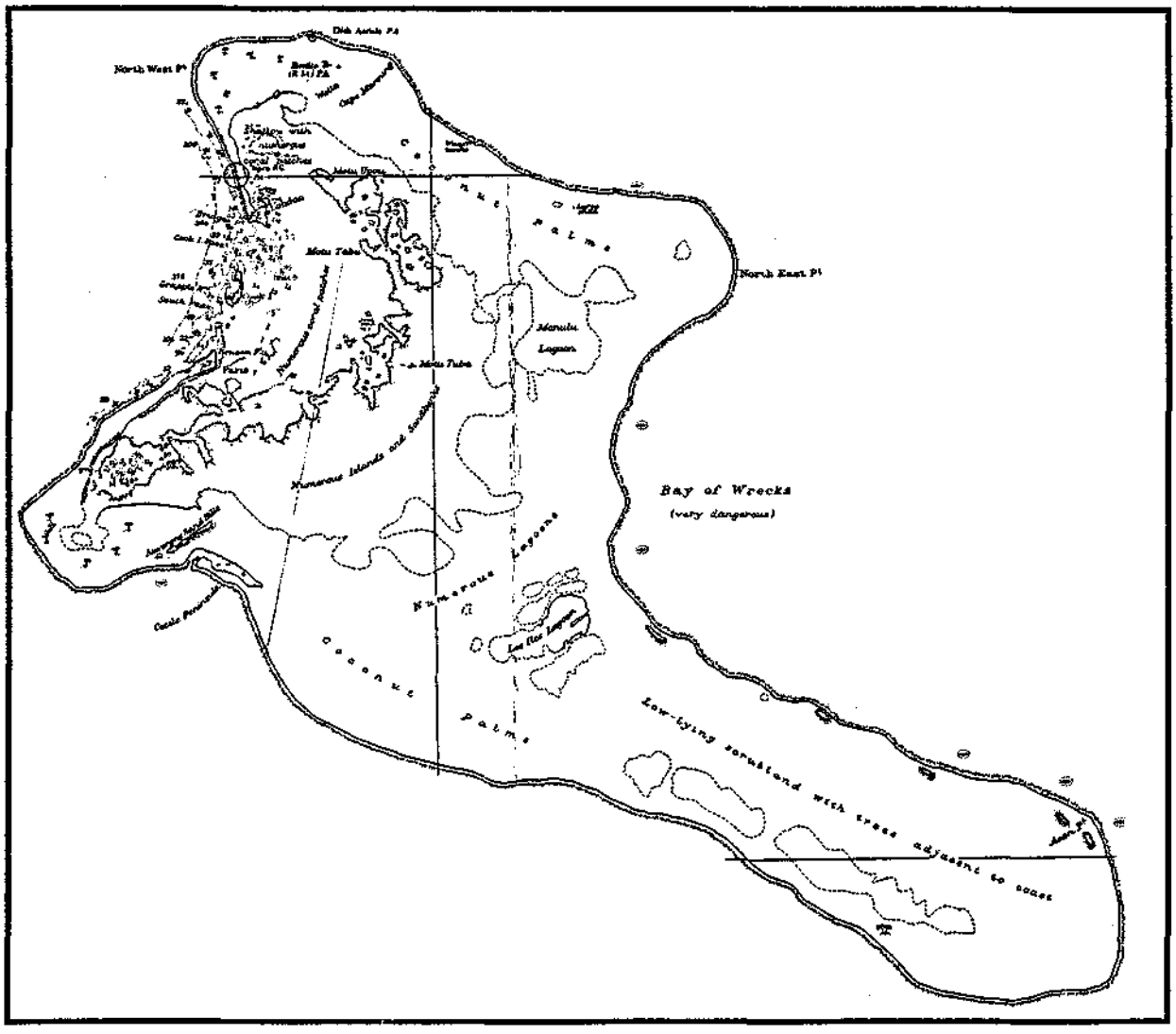

Figure 1: Kiritimati (Christmas Island)

Kiritimati is one of seven atolls in Kiribati which are reported to possess stocks of pearl oysters (baeao), which also reported from Butaritari, Abaiang, Onotoa (in the Gilberts Group), Fanning, Canton (in the Line Group), and Caroline Atoll (in the Phoenix Group). Having received reports of renewed commercial pearl shell harvesting activities in Kiritimati, concern for the sustainability of any commercial pearl shell fishery on the island led the Fisheries Division to seek means of obtaining baseline information on stock abundance. The Fisheries Division also wished to assess the potential for a pearl culture industry, in emulation of French Polynesia and Cook Islands, where stocks of the black-lip pearl oyster have provided the basis for development of black pearl culture industries. The South Pacific Commission's Inshore Fisheries Research Project was approached to provide assistance with the survey, in the form of financial, logistical and manpower support, and through the provision of a consultant pearl oyster biologist.

1.2 Geographical Overview

Kiritimati is the southern-most island of the Northern Line Group, in the Central Pacific. It is located 3,280 km east of Tarawa Atoll (the capital of Kiribati), and about 2,000 km south of Hawaii. Kiritimati is known as the largest island of purely coral formation in the world, with a land area of over 320 square km. The island is very flat, with poor limestone-based soil, and low rainfall. There are nevertheless scattered guano deposits, which are not presently exploited.

Of the population of 1,737 (1985 census), almost two-thirds live in the administrative centre of London. Residents of Kiritimati are predominantly government employees, except for a few copra-cutters working land leased from the government. All land in Kiritimati is government owned, since the island was uninhabited until recent times. Although the lagoon covers an area of 318 square km, much of this consists of shallow, highly saline ponds (Helfrich, 1973; Smith, et al., 1984; Schoonmaker et al). Brine shrimp *(Anemia salina)* culture was previously attempted in these ponds, but has since been abandoned. Commercial salt production is currently being developed.

Fish are abundant and relatively unexploited in Kiritimati lagoon, reef and surrounding waters. Tuna, trevallies and milkfish make up most of the exports to Hawaii, which may total 1-4 tonnes per week. Subsistence fisheries appear to be highly productive, with catches that comprise mainly of bonefish *(Albula* sp) and milkfish *(Chanos chanos).*

1.3 History of pearl shell exploitation

Between 1882 and 1886, ten divers from Penrhyn in the Cook Islands collected about 200 tons of black-lip pearl shell *(Pinctada margaritifera)* from Kiritimati. The firm of Messrs Henderson and Macfarlane, of Auckland, held the exploitation rights to Kiritimati, but in 1892, leases were granted to a London firm for "removing guano, planting coconuts and collecting pearl shell" (Bailey, 1977, p 39). In 1897, six native Manihikians were employed on Kiritimati to "dive for pearl shell and collect shark fins and tails" (Napier, in ibid). £400 worth of pearl shell (estimated at between 50 and 100 tons) was produced in eight months.

The island was reportedly the site of an attempted introduction of gold-lip pearl oysters *{Pinctada maxima)* from the Torres Strait in 1904 (Kent, 1905; Gopalakrishnan, 1977 b, in Uwate, et al, 1984). Over 1,500 live gold-lip were shipped from Red Island, on the Cape York Peninsula, to Suwarrow (in the Cook Islands) and Kiritimati, which was over 3,000 miles and three weeks steaming away (Kent, 1905: Some authors claim that over 30,000 pearl oysters were shipped, e.g. Anon, Sept, 1935, and Anon, Nov, 1935). The attempt seems to have been motivated by the higher price for gold-lip shell (then around £90 per ton), together with a desire to re-establish pearl oyster stocks in both lagoons. Heavy spatfalls of gold-lip were reported in Suwarrow within six months, with as many as thirty *P. maxima* spat attached to individual shells of the original pioneers (Kent, 1905). No information is available on the outcome of the stocks planted in Christmas. Although obviously unsuccessful, this introduction gave rise to the belief that gold-lip existed in Christmas lagoon.

Further pearl oyster introduction attempts (presumably of *P. margaritifera)* were reported in 1977, with two beds established in 3 m and 4.6 m depth. No details of the methods or outcome of the introduction are available (Uwate, et al., 1984).

The pearl shell fishery in Christmas lagoon was apparently never again of any commercial significance. Stocks were assumed to be exhausted, with only small quantities sent infrequently to Tarawa for manufacture of traditional pearl shell lures.

Recently, reports indicated that Kiritimati Islanders were diving for pearl shell on a semi-commercial basis. Pearl shell was purchased by the Marine Export Division at the price of AS2 per piece, although none was exported. At least 200 pieces (100 pearl oysters) were purchased during the first half of 1989.

2. SURVEY AIMS AND METHODS

2.1 General

The overall goals of the survey were to:

- provide an estimate of the abundance and distribution of pearl oyster species present at Kiritimati;
- estimate the degree of pearl oyster exploitation by local residents;
- provide guide-lines for proper management of the resource in future;
- identify potential sites for spat collector deployment;
- deploy spat collectors in appropriate areas to enable long-term monitoring of spatfalls;
- assist counterpart Fisheries Officers from Kiribati and from the Marshall Islands to gain the expertise required to carry out similar surveys at other atolls in their respective countries.
- produce a comprehensive report describing the status of the existing stock and indicating possible scenarios for future development, with specific reference to the potential for establishment of pearl culture operations.

Background information was obtained through literature searches, discussions with local people, bathymetric surveys, and examination of harvested shells held in stock at the Kiritimati Marine Exports Division (MED) of the Ministry of the Line and Phoenix Islands. Free-diving and SCUBA diving surveys were employed for the stock assessment work. All field work was carried out from Fisheries Divisions vessel *Olympia*, an 8.5 m open fibreglass skiff powered by a 40 hp outboard engine. Fisheries Division provided the services of a boatman, and an additional crew member to assist with deck duties. Land transport of personnel and equipment was by pick-up truck made available by the Fisheries Division. SCUBA tanks were kindly filled by Mr Philip Wilder, private owner of the only diving compressor on Kiritimati, in exchange for compressor fuel supplied by Fisheries Division.

Field survey equipment included:

- SCUBA tanks and associated diving gear,
- a JMC 1205 echo-sounder, with both a paper-chart recorder and a digital depth indicator;
- underwater and land cameras;
- flux-gate, hand-bearing and diving compasses;
- an optical range-finder,
- a 100 m weighted transect rope;
- rulers, callipers, and waterproof notepaper.

2.2 Bathymetry and bottom type

Echo-sounder transects were conducted along four transects through the lagoon and passages. Reference points on the trace paper were marked at two-minute intervals, with elapsed time and water depth noted. Bearings were taken at periodic intervals, along with underwater observations of bottom type, made by quick free-diving search.

The locations of the echo-sounder transects are shown in Figure 2. Observations on bottom type and other benthos are also noted. These results were used in conjunction with the Admiralty chart of Port London (1964) to determine likely extent of pearl oyster habitat, and suitable spat-collector sites.

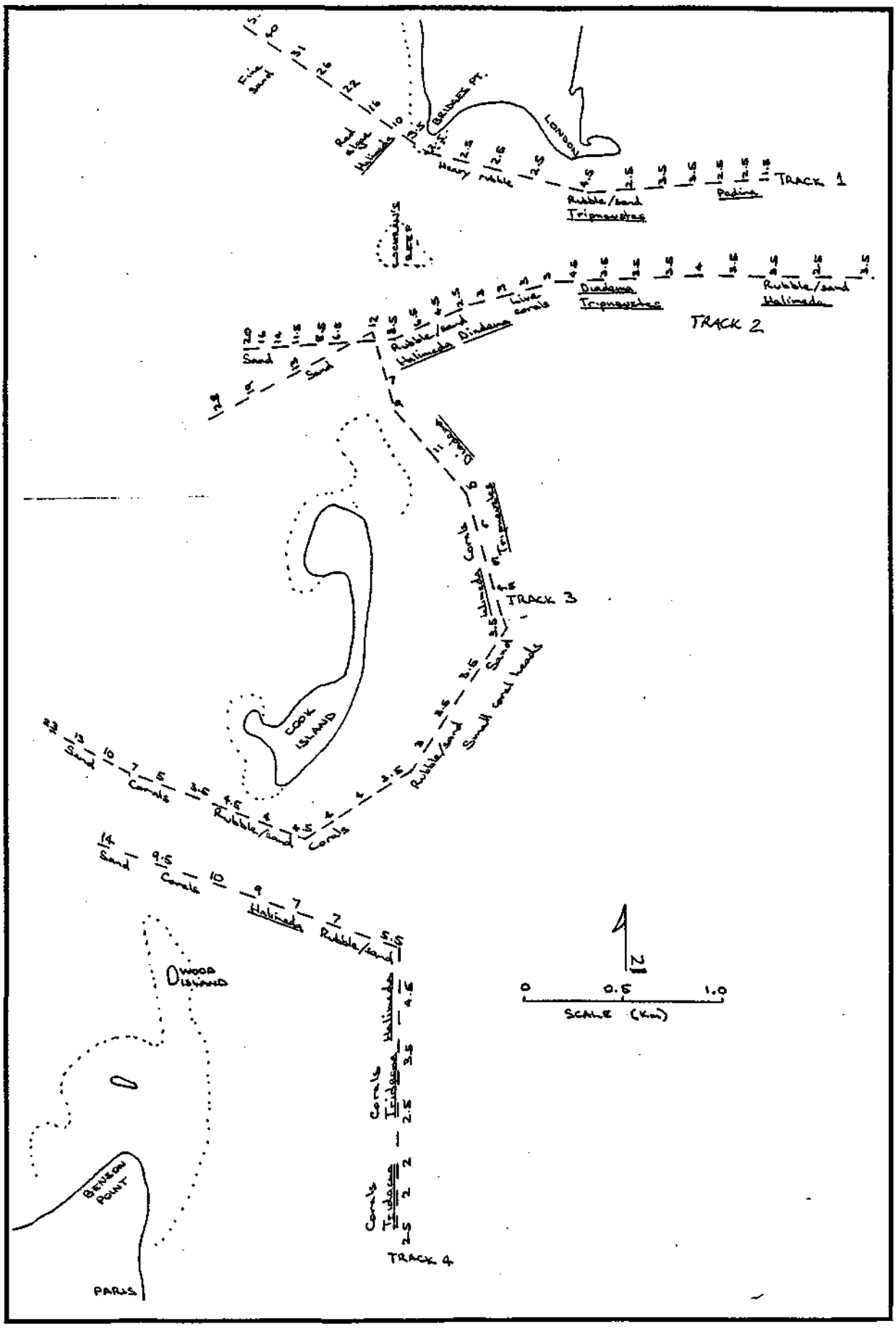

Figure 2: Echo-sounder transects

2.3 Pearl oyster survey

Pearl oyster survey work consisted of three types of search: free-swimming snorkel and SCUBA dives were used initially to investigate the areas of reported greatest abundance; snorkel transects were swum over distances estimated using a range-finder, to assess the range of pearl oysters across the lagoon, and swims along rope transects were used where greater accuracy was desired. Sampling site locations are shown in Figure 3.

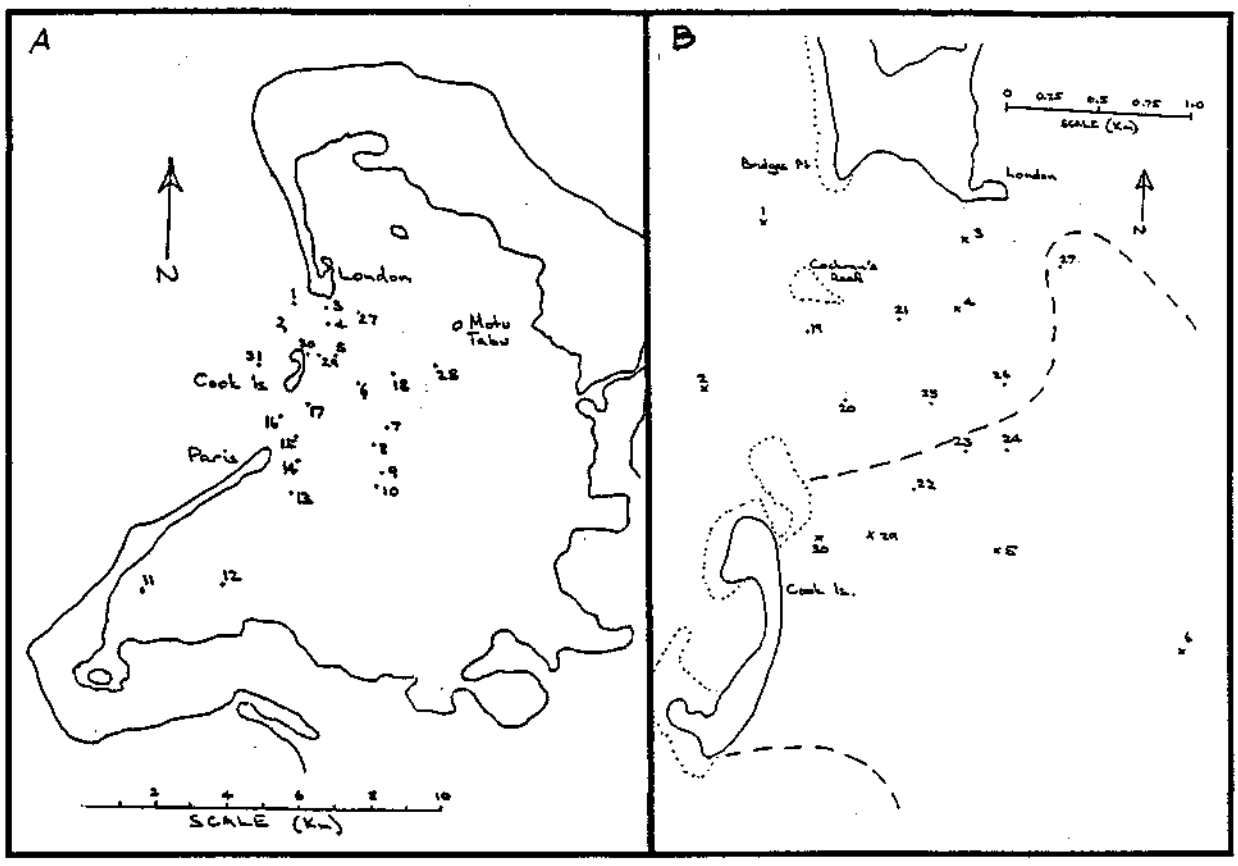

Figure 3. Sampling station locations: a) Throughout lagoon; b) Within Cook Island Passage area.

Three preparatory free-swim snorkel searches were conducted on the first day of the survey in the passage areas before sampling proper began. Three free-swim SCUBA searches were conducted on the outer reef slope in the mouth of Cook Island Passage and along adjacent reef areas (Stations 1, 2, and 31). Free-swim searches were also used at Stations 11 and 12, in the upper reaches of the lagoon.

Eleven stations were searched by approximate-area techniques (Stations 3 -10, and 28). A range-finder was used to estimate approximate length of the transect (either 100 m or 200 m), with widths estimated by arm-span from the line-of-swim (2 m). Most approximate-area searches were conducted by free-diving, but SCUBA was used in greater depths, or where the water was more turbid. Approximate-area searches were selectively sited to give a synoptic picture of pearl oyster distribution across the lagoon.

Nine sites were selected randomly from a grid laid over a map of the Cook Island Passage area, to give an unbiased estimate of maximum density in the zone of reported greatest abundance. A 100 m weighted transect rope, and standardised arm-spans were used for accurate-area searches at these, and eight other stations (Stations 13 - 27, and Stations 29 - 30). Both SCUBA and snorkel dives were used, depending on depth, current, and visibility.

Transects were either 2 m or 4 m wide, depending on water clarity and amount of bottom cover. Search area covered at each site varied from 400 m^2 to 800 m^2. All pearl oysters found within the area were measured to the nearest half-centimetre, using dorso-ventral measurement (DVM) from the umbo to the furthermost continuous border of the outer lip. Where shells were inaccessibly wedged into crevices, sizes were estimated.

Observations were made on bottom type at each station, including descriptions of sediment particle size, corals and seaweeds. Notes were also kept on the presence or absence, and relative abundance, of *Pinetada maculata* (the small pipi pearl oyster), *Pteria* sp (the winged pearl oyster), and other benthos at each site.

2.4 Sampling of sizes and growth rates

Together with the measurement of pearl oysters in the wild, a representative catch sample was obtained from the stocks in store at the Marine Exports Division warehouse. Sixty two shells were measured for DVM and heel depth.

It had been the intention at the outset of the survey to establish some culture trials in the lagoon, to provide indications of growth rates under culture conditions. Larger pearl oysters demonstrate minimal increases in DVM and are unreliable as indicators of growth conditions. All younger pearl oysters which were encountered during the survey were therefore collected and held on a buoy close to London. Unfortunately, only four pearl oysters of suitable size were obtained. Growth trials were thus not set up, and will need to be conducted at a later date as part of the out-growing programme for spat.

2.5 Spat-collector trials

Spat-collector lines were constructed by the survey team and deployed in the lagoon, in order to test their success and durability under prevailing conditions, permit future growth monitoring trials, and serve as an initial step towards stock re-establishment. Design and materials for the lines are described in Appendix 3, and detailed in Figure 4.

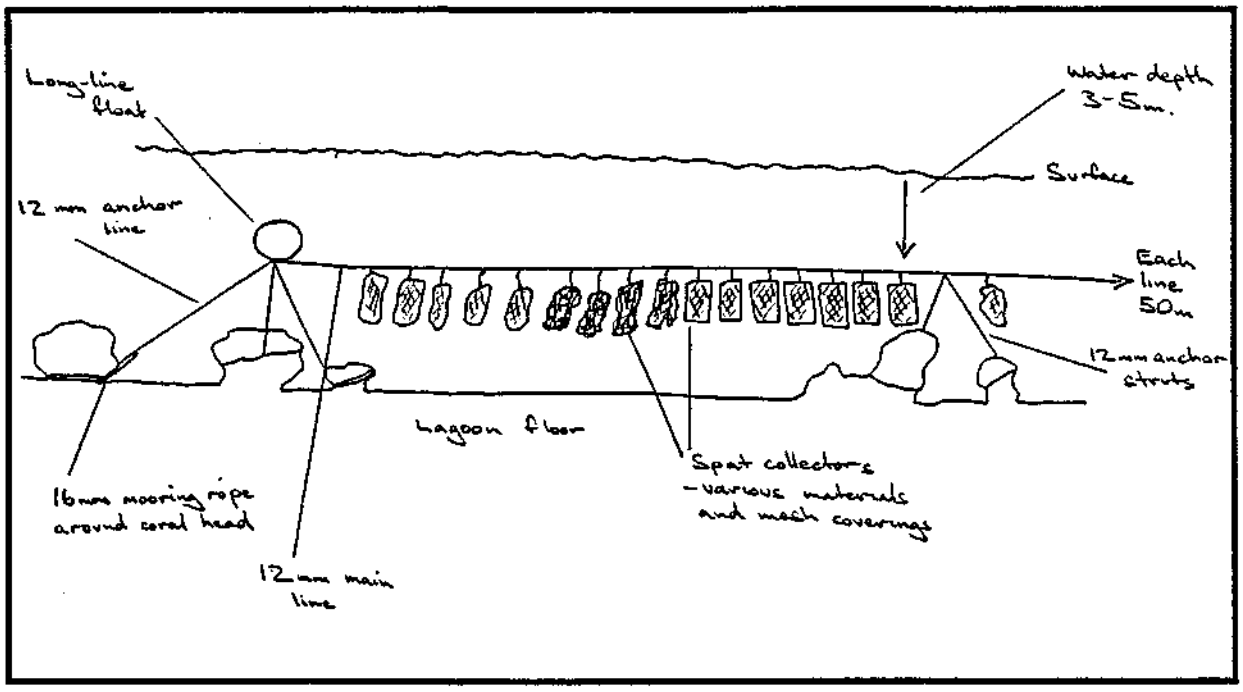

Figure 4: Typical configuration of spat-collector lines deployed during the survey

Five lines, each carrying fifty spat-collectors, were deployed during the survey, and should remain in place, with regular checking, for the next twelve months. The location of each line is indicated in Figure 5. The lines were set in water of depth between 3 m (lines 3,4, and 5) and 5 m (lines 1 and 2).

The relative scarcity of large coral leads in the lagoon caused some difficulties in securing the spat-lines, and will limit the number of possible sites for spat-collectors of this type.Currents and potential storm wave impacts also limit the possible area for deployment of spat-collectors. The potential for storm wave damage in the lagoon was established by discussions with local fisheries officers. Four of the spat-lines were set near to the passages, but in relatively protected locations behind Cook Island and the fringing reef of Wood Island.

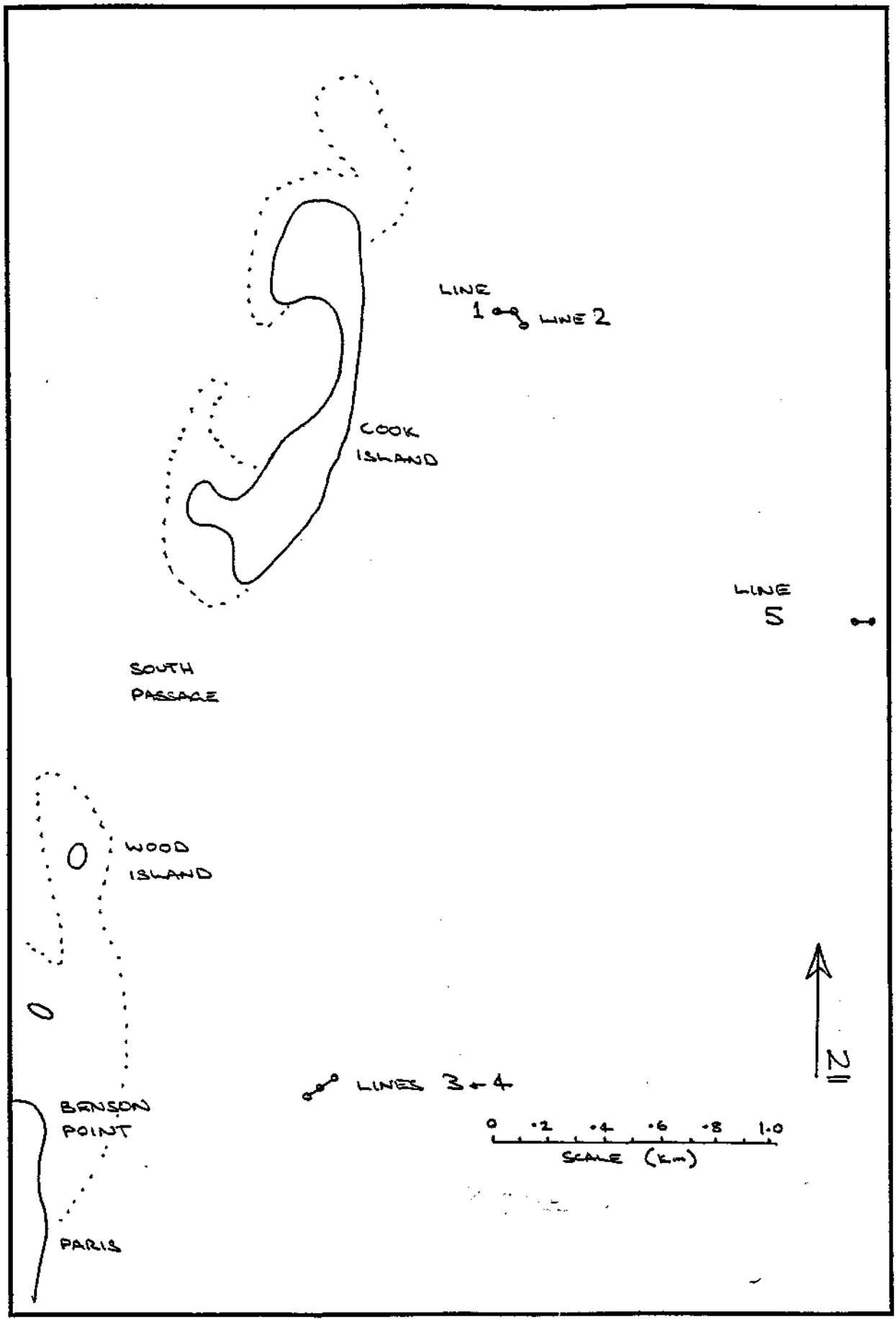

Figure 5: Location of spat collector lines deployed during the survey

4. RESULTS AND DISCUSSION

3.1 Present pearl oyster harvesting activities

Pearl shell lures are important to the artisanal pole-and-line tuna fishery in other parts of Kiribati. Kiritimati continues to be a source of supply of shell for lure manufacture. Shell are collected by Kiritimati Islanders and given or sold to the inhabitants of other islands, usually in small quantities (sacks or cartons). Occasionally local entrepreneurs organise somewhat larger shipments, of several hundred kg, to buyers in Tarawa or elsewhere. The quantities of shell taken by small-scale harvesting of this type are not known.

The MED commenced purchasing pearl shell in 1988 as part of a fisheries development and technical assistance programme, carried out in conjunction with the Japanese Overseas Fishery Cooperation Foundation (OFCF). The high prices offered by MED (reported to be AS2.00 per half-shell) undoubtedly led to a short period of fairly intense harvesting by local residents, during which time an already meagre stock was further depleted. Because of difficulties in finding a buyer for the shell, which is thick and of poor quality for button manufacture, the MED has been unable to sell its existing stock and no longer purchases pearl shell.

3.2 Pearl oyster densities and distribution

Survey results for each sampling site, including transect size, number and sizes of pearl oysters, and density (number of pearl oysters per 100 m^2) are given in Table **1.**

Table 1 : Pearl oyster density by station (see Figure 3 for station locations)

STN NO.	TRANSECT AREA (m^2)	SIZES (mm)	PEARL OYSTERS No.	DENSITY (No/ 100 m^2)
1	- - -	- - -	0	-.- - -
2	—	- - -	0	-.- - -
3	800	—	0	0.000
4	800	- - -	0	0.000
5	800	230,260,190,240	4	0.500
6	800	195,185,180,190,160,110,115	7	0.875
7	400	- - -	0	0.000
8	400	210,190	2	0.500
9	400	—	0	0.000
10	400	- - -	0	0.000
11	—	- - -	0	-.- - -
12	—	—	0	-.- - -
13	400	—	0	0.000
14	400	210	1	0.250
15	400	- - -	0	0.000
16	400	- - -	0	0.000
17	400	- - -	0	0.000
18	400	140,210,200,160	4	1.000
19	800	—	0	0.000
20	800	—	0	0.000
21	800	- - -	0	0.000
22	800	165,220,170	3	0.375
23	800	230	1	0.125
24	800	- - -	0	0.000
25	800	- - -	0	0.000
26	400	. . .	0	0.000
27	400	190,255	2	0.500
28	400	—	0	0.000
29	800	200,220,140,140,170,195,200,210	8	1.000
30	800	195,135	2	0.250
31	—	—	0	-.- - -
TOTAL/ AVERAGE	**15,600**	188 (s=36)	34	0.22* (s= 0.31)

* = Excludes stations 1, 2, 11, 1 2, and 31.

A total of only 34 pearl oysters (all *Pinctada margaritifera)* were found within station transects. Pearl oysters were absent from 21 of the 31 sites (68% of stations). The average density for all stations surveyed (excluding stations 1,2,11, 12, and 31, where surface areas were not measured) was 0.22 / 100 m^2.

Pearl oyster distribution was limited to the deeper areas of the lagoon, where there is greater water interchange through the passage, and lower sedimentation. The estimated extent of pearl oyster distribution within the lagoon is shown in Figure 6.

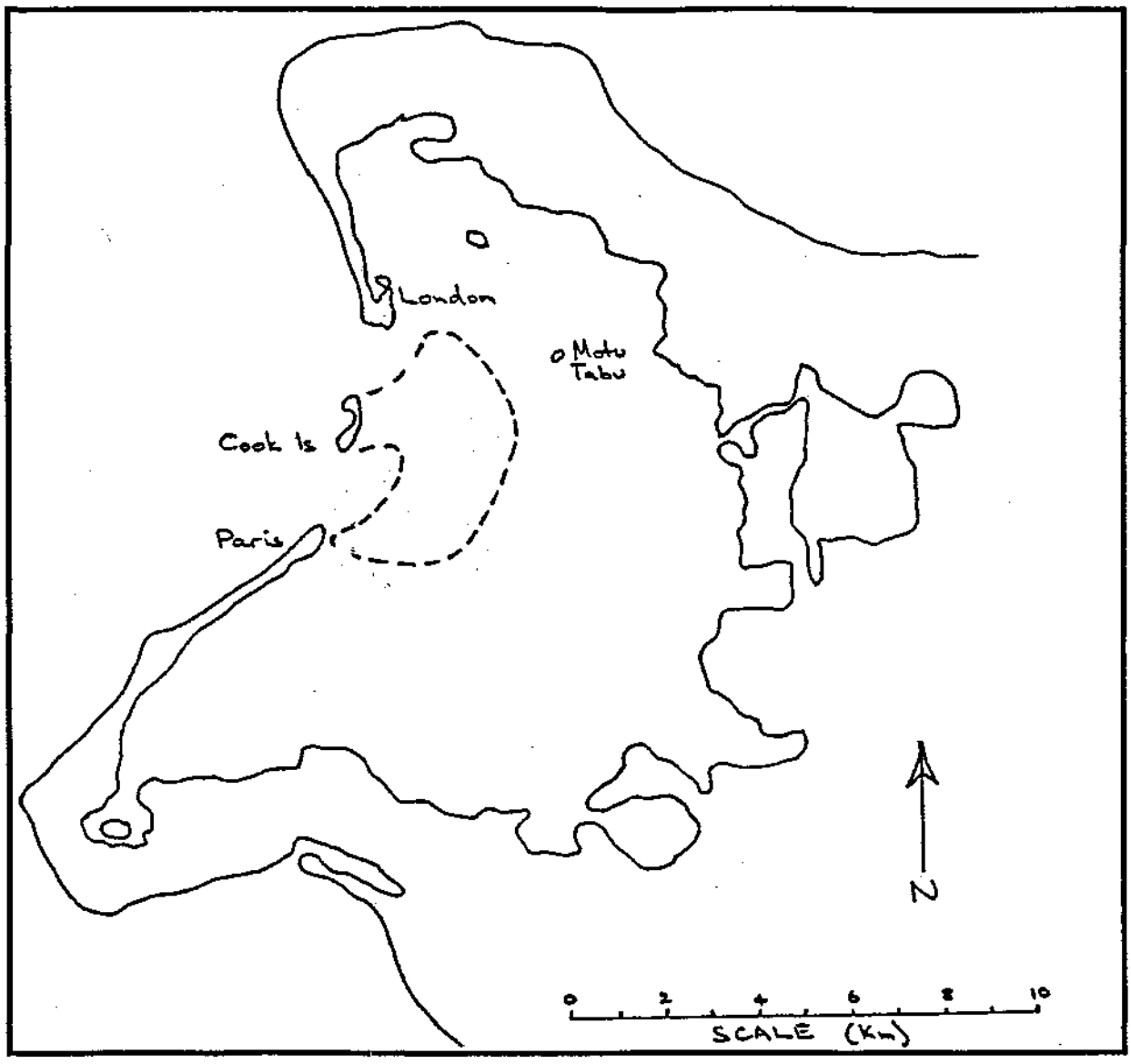

Figure 6: Estimated txtent of pearl oyster distribution in Kiritimati lagoon

Pearl oysters were absent from the deeper areas of the passages, possibly because of strong tidal currents, which might hinder settlement, or to heavier predation in these areas, which are within the feeding range of larger fishes from the outer reef slope. They were also absent from the inner reaches of the lagoon where colonies of branching *Acropora* sp were found (Stations 9, 10, 12, 13, and 28: the species belongs to the *horrida* group of Veron and Wallace, 1984).

3.3 Standing stock

Within the range of pearl oyster distribution, a maximum density of only 1.0 / 100 m^2 was recorded, at Stations 18 and 29. Average density at stations where pearl oysters were found was 0.54 / 100 m^2. The surface area of pearl oyster habitat was estimated at 11 km^2, giving a standing stock of around 60,000 ± 23,000 (95% confidence limits) as detailed in table 2.

Table 2 : Estimation of standing stocks of pearl oysters within pearl oyster range

Number of stations = 10
Area surveyed = 6,400 m^2
Mean density = 0.54 / 100 m2 (s= 0.30)
Confidence limits (95%) = ± 0.21 / 100 m^2
Estimated total area = 11 km^2
Standing stock = 11,000,000 m^2 * 0.0054 / m^2 = 59,400 ± 23,100

At present, therefore, black lip pearl oyster stocks are in low abundance in Kiritimati lagoon. The reports of good tonnages taken from the lagoon last century, however, indicate that pearl oysters were once plentiful. Based on reported harvest levels of at least 200 tons, and an assumed average weight of, say, 200 g shell per animal (probably an underestimate), an estimate of original standing wild pearl shell stock in Kiritimati would be some 1,000,000 pearl oysters.

There is no evidence of any recovery from the overfishing of last century, and the stock appears to be only marginally self-sustaining. At present, stocks are estimated at some 60,000 pearl oysters (±23,000), i.e less than 10% of the previous figure.

The low abundance is probably also maintained by heavy predation on pearl oysters in the wild, especially on smaller pearl oysters which have thinner shells, rendering them more vulnerable to predators. Being virtually unexploited by the local fishery, octopii and molluscivorous fishes, including large wrasses, emperors and puffer fishes, are common in the lagoon. All smaller pearl oysters, and many of the larger ones were found in protective crevices or beneath overhangs. Many showed notable scarring of the shell from previous attacks by predators (Figure 7).

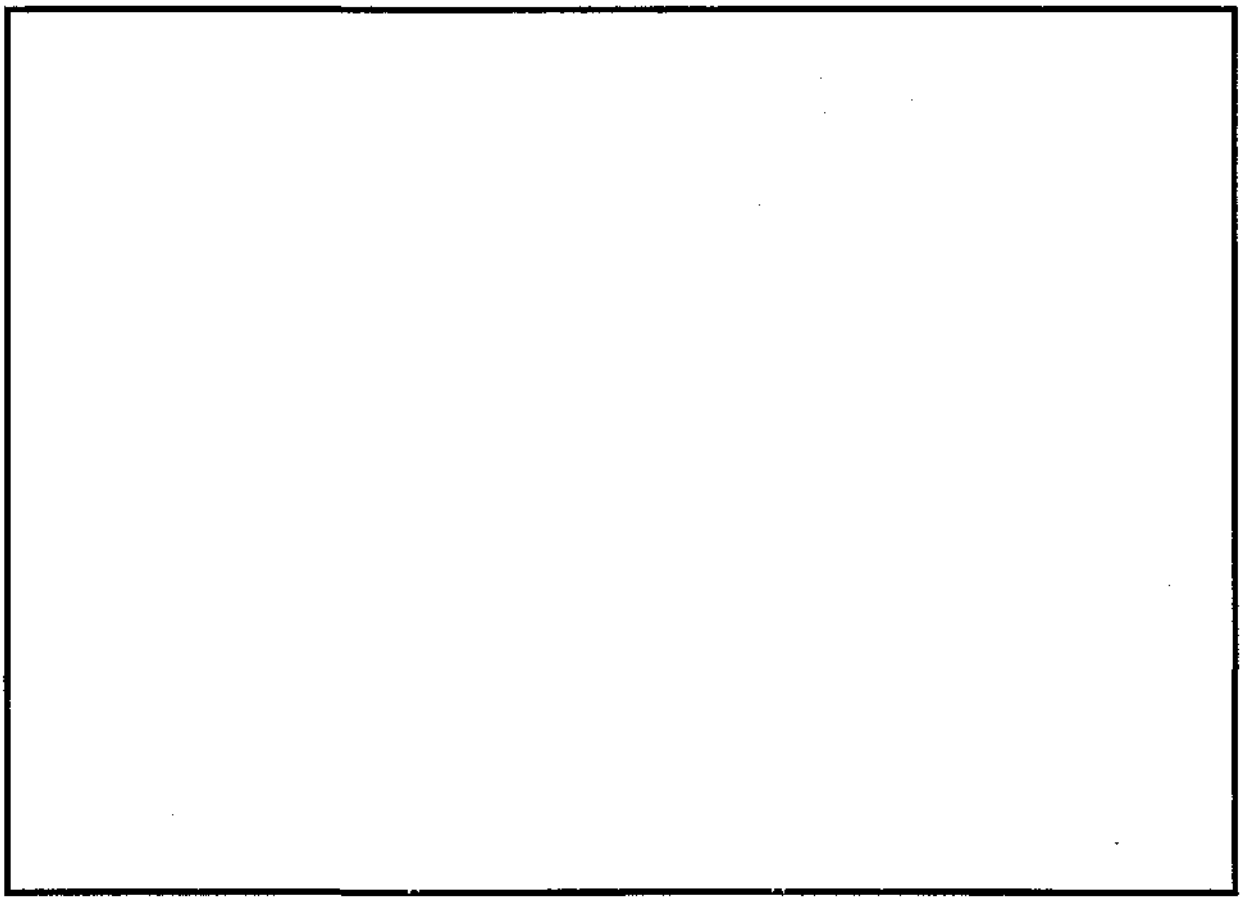

Figure 7: Pearl oysters from Kiritimati lagoon : a) Two pearl oysters showing stunting and scarring from previous predator attacks. The smaller, younger specimen still exhibits large growth processes, indicative of good growth. A year of older shell hangs like a damaged thumbnail. The larger, older shell was found firmly wedged into a protective crevice between massive coral colonies; b) Two pearl oysters showing good growth. Scars from predator attacks are still visible.

3.4 Size frequency distribution

The size frequency distribution of the stock in the wild (Figure 8a) suggests a situation of low recruitment and heavy predation. No juvenile pearl oysters were encountered inside the survey transects, the smallest found having a DVM of 110 mm. One 50 mm juvenile was found incidentally near the South Passage, around spat-collector line 4.

The harvested shells held at the Marine Exports Division store show similar size frequencies to those of the wild stocks (Figure 8b). There was no significant difference between the two size distributions (p = 0.17: Appendix 2a), suggesting that the size of the wild stock has not been greatly altered by recent fishing activity.

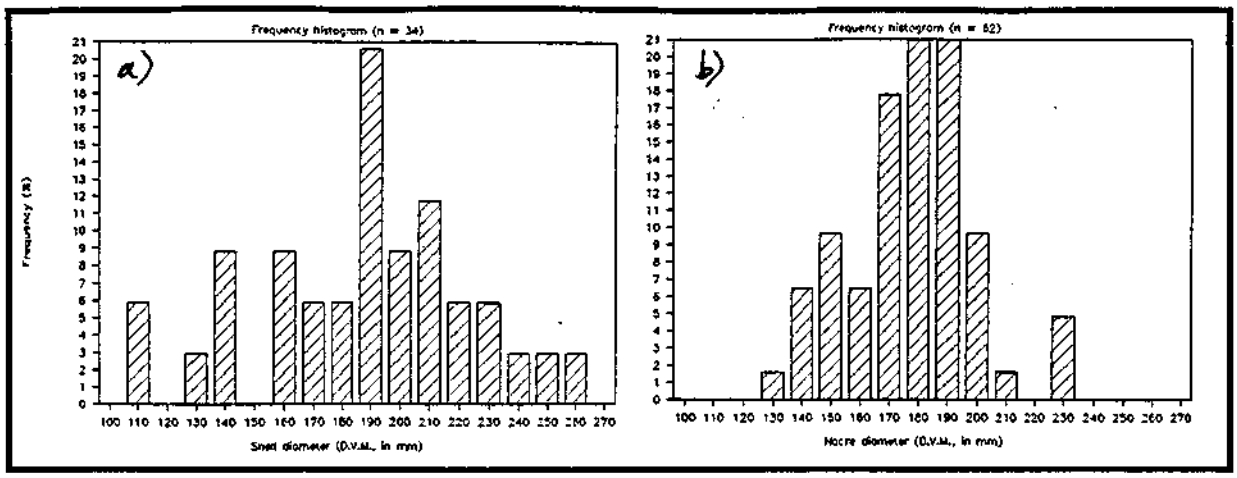

Figure 8: Size frequency distribution of pearl oyster shells from Kiritimati lagoon: a) Pearl oysters found during the survey; b) Shell held in stock in the MED store

The size frequency distribution (based on DVM) of pearl oysters in Kiritimati is similar to that of Suwarrow lagoon, in the Cook Islands (p = 0.96; Appendix 2b). Both Kiritimati and Suwarrow stocks have an average size of 188 mm DVM. However, stocks from a heavily exploited lagoon such as Manihiki, Cook Islands, are significantly smaller than in Kiritimati (mean DVM = 146 mm: p = 0.000; Appendix 2c).

The paucity of juvenile pearl oysters indicates irregular recruitment. Reproductive success is probably limited by the low densities (with resulting poor spawning synchronisation, and low fertilisation rates), and by the rapid turnover of lagoon water, with heavy larval loss through the passages.

3.5 Growth rates

Although no growth monitoring trials were initiated, the data on shell sizes (DVM and heel depth) obtained from the MED sample permits an examination of shell morphology of Kiritimati stocks. The ratio of DVM to heel depth can be considered an indicator of the rate of radial growth over the life of the pearl oyster. A high DVM: heel depth ratio implies rapid growth in the diameter of the shell (or, conversely, slow growth in shell thickness).

Shells from Suwarrow and Manihiki are much thinner than Kiritimati shells (p = 0.0000; Appendix 2d). The shape of Kiritimati shells suggests slower growth in diameter than in Cook Island lagoons. This may be due to a physiologically slower rate of dorso-ventral growth in Kiritimati, or a more rapid rate of nacre deposition, and faster thickening. It is possible that the thicker Kiritimati shells result from stunting caused by repeated attacks by predators. The noticeable scars (Figure 8) provide clear examples of the impact that predators can have on shell shape.

The spat-collectors set during this survey may allow acquisition of spat on which to carry out growth monitoring trials next year.

3.6 Other pearl oyster species, and incidental observations

Observations on other benthic organisms of potential significance were made, and are detailed in Appendix 1. *Pteria* sp appears to be more tolerant of fine sediments than *P. margaritifera,* and was found in the more turbid inner reaches of the lagoon. *P. maculata* occurred in shallow areas nearer to the passages, often in association with large heads of *Porites* (?) *lobata.*

4. MANAGEMENT AND DEVELOPMENT **OPTIONS**

4.1 Fishery management

The fragile status of stocks and shallow lagoon at Kiritimati mean that any further harvesting of pearl oysters would quickly lead to the exhaustion of the remaining population. In order to protect the remaining stocks in Kiritimati, it is recommended that pearl oysters be totally protected from all fishing. This is the preferred option if the Kiribati Government chooses to pursue the development of a pearl culture industry in Kiritimati.

Given the importance of the supply of pearl shell for lure manufacture in other parts of Kiribati, consideration might be given to permitting small-scale harvesting of shell by local residents. If this is authorised, then quantities should be limited to 5 kg per person, and export should be subject to the issue of a licence by the Fisheries Department. This option may be considered if the Kiribati Government chooses not to become involved in pearl culture activities in Kiritimati. It provides a compromise by permitting limited harvesting while still giving the wild stock a chance to recover.

Under no circumstances should the commercial export or other sale of pearl shell from Kiritimati be permitted for the foreseeable future.

4.2 Stock re-establishment

Development of economic activities based on the pearl oyster resource in Kiritimati hinges on re-establishment of the stocks. This would best be achieved by artificial collection and outgrowing of spat, together with establishment of protected breeding reserves of aggregated wild stocks (and, ultimately, pearl oysters under culture).

The main aim of a stock re-establishment programme would be to collect pearl oyster spat by the deployment of large numbers of spat collectors, and grow them through to maturity under protected conditions. This would eventually provide a core of cultured broodstock, with subsequent increases in spatfalls on collectors, and enhancement of natural recruitment.

The spat-collection programme was initiated during this survey and should be gradually expanded in size. Natural recruitment is often erratic, and good spatfalls may only occur infrequently. The stock re-establishment programme should continue until the abundance of wild stock and protected broodstocks are adequate to ensure satisfactory returns from spat collectors. A long-term perspective is required, with at least a five year initial period needed to assess the effectiveness of artificial collection of spat, and the reproductive capacity of the current stocks Appendix 4 proposes a long-term schedule which plans on a minimum of 2,750 spat collectors to be set over the next 5 years, giving a total of 6,250 spat-collector years. If funds and manpower are available to accelerate these projections, then the chances of significant successes in early years will be increased.

A further option to accelerate the re-establishment would be to aggregate some of the remaining wild stocks into a breeding reserve, in a more protected area of the lagoon. The higher densities and relocation would result in improved spawning synchronicity, higher fertilisation rates, and better retention of larvae within the lagoon. In this case, however, the potential for decimation of broodstock by predators or disease means that protective culture methods would be required, with greater initial capital costs, and on-going caretaking of the cultured broodstock. Depending on the level of commitment of the Kiribati Government to the programme, this step may be taken immediately, or at some later date, perhaps in conjunction with out-growing of collected spat.

Optimum conditions for settlement and growth of pearl oysters would probably be in the deeper waters close to either passage. The workable area of the lagoon is, however, limited by normal tidal currents and storm waves through the passages. Indications of the extent of storm wave encroachment in the lagoon could be best obtained by examining records and reports of earlier *Eucheuma* seaweed culture trials. Local reports and the survey observations suggested that the band of lagoon area indicated in Figure 9 might be suitable for spat collection and pearl culture.

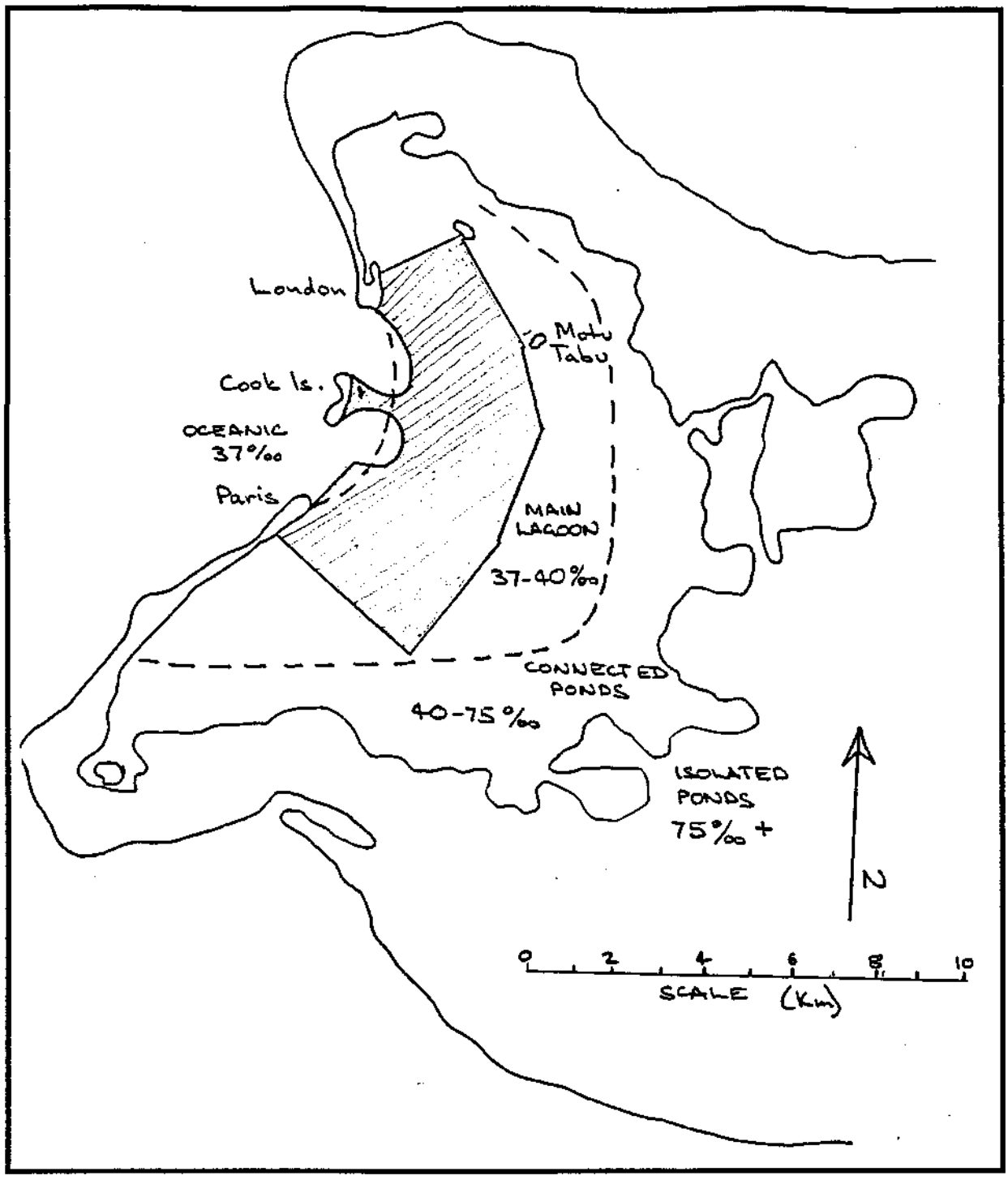

Figure 9: Potential area for pearl farming in Kiritimati lagoon (shaded area). The salinity profile of the lagoon is also shown (after Helfrich et al, 1973).

The abundant predators, and shallow, exposed aspect of Kiritimati lagoon will require sturdily constructed spat-collectors and culture platforms. Platforms must be designed differently to those used in deep water culture areas such as the Cook Islands and French Polynesia. A suggested platform design for Kiritimati lagoon is illustrated in Figure 10. The on-going capital requirements for the stock re-establishment programme are itemised in Appendix 3. The Fisheries Division should maintain detailed records of materials, mooring methods, deployment sites and depths, and results (both average sizes and numbers of spat for each collector) from spat-collectors over the life of the programme. Establishment and operation of the initial stages of the spat-collection programme should be co-ordinated through the Research Unit of the Fisheries Division, with the Kiritimati Fisheries staff undertaking weekly maintenance checks of the lines.

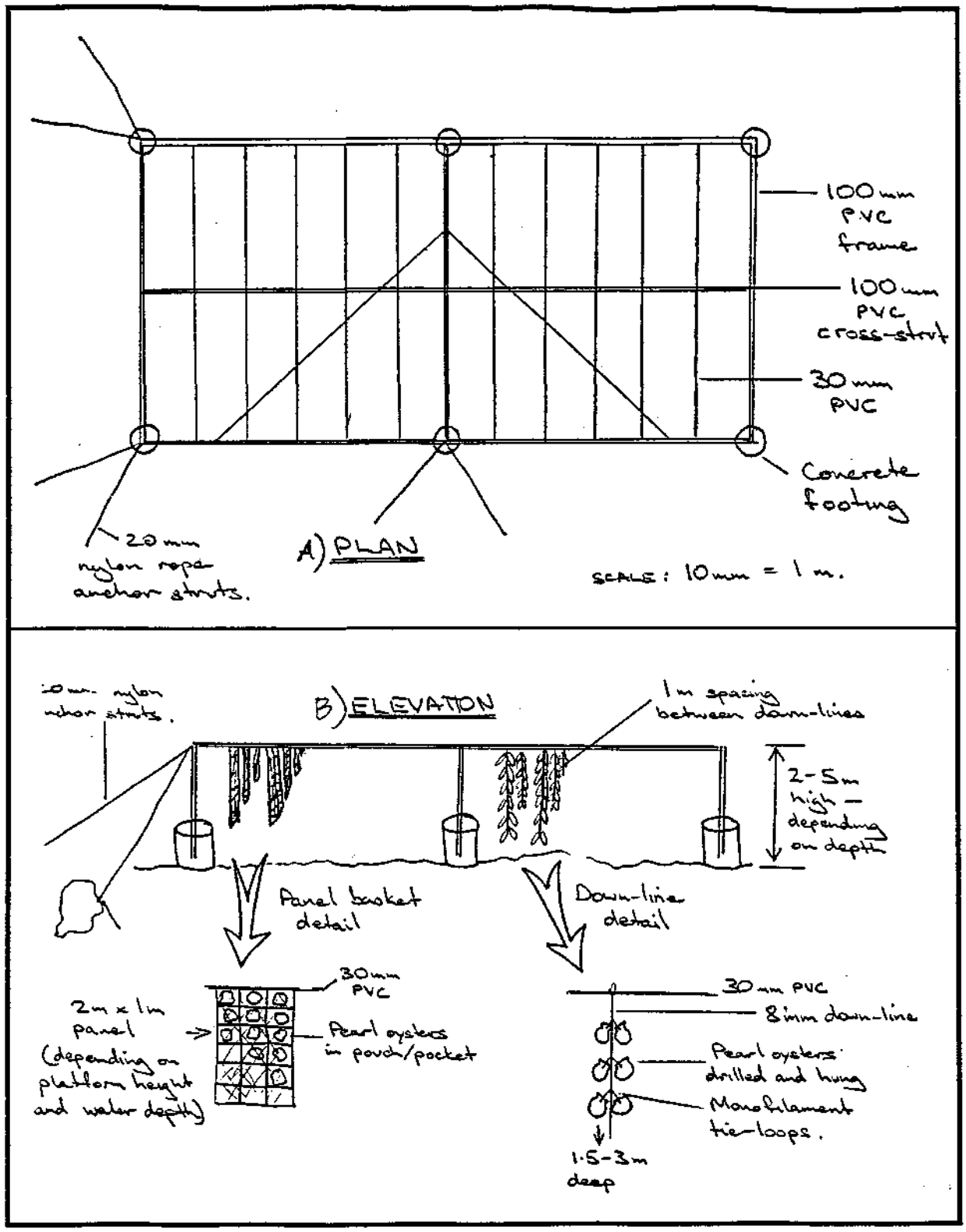

Figure 10: Suggested design for pearl oyster culture platform in Kiritimati lagoon: a) Plan; b) Elevation.

As more out-growing platforms need to be built and maintained for spat or broodstock, a greater commitment of time will be required. A fisheries officer on Kiritimati should be designated responsible, on a full-time basis, for the stock re-establishment programme. This officer, together with the supervising biologist from the Research Unit, should be given an opportunity for attachment training in a fully functional pearl culture industry. The Cook Islands should be approached with a request for attachment of these trainees to local pearl farming operations in Manihiki, for a period of around four weeks. This training should be undertaken as soon as practical.

4.3 Pilot pearl culture activities

Over a period of time, a continued programme of spat-collection and ongrowing, coupled with broodstock aggregation, will lead to spatfalls that are high enough to provide adequate numbers of juvenile pearl oysters for farming purposes. At this time a pilot pearl oyster culture project could be established. This would involve large-scale collection and out-growing of spat, establishment of a series of culture platforms in various locations across the lagoon, conduct of growth trials, and determination of the extent of viable farming area. These platforms would be separate from the broodstocks, and would use only juveniles taken from the spat collectors (not wild stock). Approximate costs of spat collectors and culture platforms are outlined in Appendix 3. The pilot programme would involve expansion of these costs on a scale commensurate with subsequent spatfalls, and the government's desired level of involvement.

After two years of on-growing, technicians would be engaged to carry out experimental seedings of cultured pearl nucleii, with the first pearls being harvested some two years later. The timing of these developments will be entirely dependent on the rate of re-establishment of wild stocks, and subsequent spatfalls (see Appendix 4).

Although commercial pearl culture could theoretically begin more rapidly if pearl oysters were to be introduced from other islands in French Polynesia or the Cook Islands, this option is not recommended. Considerable problems with disease transferral have been linked to pearl oyster transshipments between collection and culture areas in both the French Polynesian and Australian pearl culture industries. Introduction of stocks from outside would also dilute the genetic pool of the Kiritimati population. It is therefore recommended that introduction of pearl oysters from outside Kiritimati be prohibited pending the results of the spat-collector trials over the five year period.

4.4 Long-term development

In the event that the viability of spat-collection and pearl oyster culture in Kiritimati are proven by the pilot project, a review of management, investment, and marketing options should be conducted. The size, structure and operation of the pearl culture industry in Kiritimati should be carefully planned, with identification of areas for possible involvement of government, private local interests, and foreign capital and expertise. It should be emphasised, however, that small, locally owned and operated pearl farms require only minimal capital investment. Foreign involvement in pearl culture is only required for the provision of experienced Japanese pearl culture technicians to perform the seeding operation.

Development options and approaches for a pearl culture industry in Kiribati should involve close consultation with fisheries management authorities in other Pacific Island pearl culture industries. Consultation or collaboration in marketing arrangements could also be of mutual benefit. Some marketing controls may be needed to ensure consistent quality and grading. Small local farms and co-operatives may also require appraisal and brokerage services, which may be best provided through government. Given the current and projected levels of tourist traffic through Kiritimati, there appears to be potential for local marketing of both pearl jewelry and pearl shell handicrafts.

Decreased pearl quality and disease problems are associated with crowding of pearl oysters on culture platforms, or with over-farming of a lagoon. Development and management regulations for the pearl culture industry should therefore recognise a specified maximum standing stock of cultured pearl oysters in the lagoon. Based on the best estimate of original standing wild stock of around 1,000,000 pearl oysters, an overall ceiling of 200,000 pearl oysters under culture should be imposed.

4.5 Other areas

Although there is potential for development of pearl culture activities in Kiritimati, conditions are far from ideal. A depauperate broodstock, shallow exposed lagoon, high water exchange, and abundant predators will all combine to hinder the development of pearl farming. Other locations with more favourable conditions probably exist in Kiribati. If the Kiribati Government wishes to pursue the development of a pearl culture industry, it should consider the best areas and strategies for achieving this development.

There is a thus a need for assessment of the culture potential of pearl oyster stocks in other Kiribati lagoons. Those lagoons already reported to have pearl oysters (Butaritari, Abaiang, Onotoa, Fanning, Canton and Caroline) are obvious starting points, and there may be other islands where pearl oysters may thrive if they were introduced. Stock assessment surveys should be conducted by the Research Unit in these locations over the next few years. The reports of pearl oysters being present in the deeper lagoon of Fanning Atoll (e.g. Mees, 1986, and various uncorroborated verbal reports) require particular attention, given the Kiribati Governments commitment to repopulating this island, and the consequent need to develop small-scale income-earning opportunities there.

5. REFERENCES

Anon (1935 a). Untitled. The Pacific Islands Monthly. September, 1935. p 11.

Anon (1935 b). Suwarrow Island. Lever's experimental introduction of gold-lip pearl oysters. November, 1935. p34.

Bailey, E. (1977). The Kiritimati Story. Stacey International.

Helfrich, P. (1973). The feasibility of brine shrimp production on Kiritimati. Sea Grant Technical Report: UNIHI-SEAGRANT-TR-73-02. 173 p.

Kent, W.S. (1905). Torres Strait Pearlshell Fisheries. Report to both Houses of Parliament. Queensland Parliamentary papers : Session 2 of 1905. Vol 2. pp 1075 -1078.

Mees, C.C. (1986). A summary report of the fisheries resource survey of the Northern Line Group of Kiribati. Fisheries Division, Ministry of Natural Resource Development, Kiribati. 17 p.

Sims, N.A. (in prep). The biology, distribution and exploitation of the black-lip pearl oyster, P. margaritifera, in the Cook Islands. M.Sc. thesis.

Schoonmaker, J., G.W. Tribble, S.V. Smith, and F.T. Mackenzie (1985). Geochemistry of saline ponds, Kiritimati (Republic of Kiribati). Proc. 5th Int. Coral Reef Cong. Vol 3. pp 439 - 444.

Smith, S.V., et al. (1984). Chemical stoichiometry of lagoonal metabolism: Preliminary report of an environmental chemistry survey of Kiritimati, Kiribati. Sea Grant Co-operative Report UNIHI-SEAGRANT-CR-84-02. 30 p.

Uwate, K., P. Kunatuba, B. Raobati, and C. Tenakanai (1984). A review of aquaculture activities in the Pacific Islands region. Pacific Islands Development Programme, East-West Center, Honolulu, Hawaii. 585 p.

Veron, J.E.N. and C.C. Wallace (1984). Scleractinia of Eastern Australia. Part V : Family Acroporidae. Australian Institute of Marine Science Monograph Series, Volume 6. Aust. Nat. Uni. Press. Canberra. 485 p.

APPENDIX 1: DISTRIBUTION AND ABUNDANCE OF OTHER BIVALVES AND INCIDENTAL BENTHIC ORGANISMS

a) Notes on important species or groups

P. maculata

The small pipi pearl oyster was found in crevices in coral heads (primarily *Porites* (?) *lobata),* close to South Passage. Although some local patches of relatively high density were found, the species was generally not abundant

P. maculata frequently produces small, baroque (mis-shapen) pearls. Fisheries are only viable, however, in lagoons were the species occurs prolifically, and large catches can be readily taken (e.g.. Penrhyn Atoll, Cook Islands). Stocks are insufficient in Kiritimati lagoon to support a fishery. The low value of pearls produced from P. maculata means that the species has no potential for commercial pearl culture.

Pteria sp

The large, winged pearl oyster, Pteria sp, is relatively common throughout Kiritimati lagoon. The shell of this species is largely of non-nacreous material, with only a small, thin, nacreous sector near to the hinge. There is no commercial potential from either harvesting of wild stock for shell, or for culture.

Sea cucumbers (beche-de-mer)

Two species of medium commercial value were seen occasionally. The pineapple fish *(Thelenota ananas)* and the black teatfish *(Holothuria [Microthele] nobilis)* do not, however, represent any significant commercial potential, given the limited extent of suitable habitat near the passages, and the low densities observed.

Several non-commercial species were present in greater densities.These consisted primarily of *Holothuria atra* and *Bohadschia argus.* Both of these species were present in densities of more than 1 / m^2., at some stations. *Stichopus chloronotus* was also common, and *Actinopyga palauensis, A. miliaris,* and *Bohadschia marmorata* were all present, but uncommon.

None of these species are of any commercial significance at present.

Giant clams

Only the smaller giant clam, *Tridacna maxima,* was observed during the survey. The pattern of *T. maxima* distribution within the lagoon was similar to that reported for P. margaritifera; in the deeper areas of the lagoon, and extending into the shallower reaches, where substrate and water quality are suitable. Localised concentrations observed in some areas, where densities reached approximately 3 - 4 / m^2. *T. maxima* was also observed on the outer reef slope off the northwest side of the island.

A predominance of large animals reflected the current low level of exploitation, and high predation levels. Existing stocks could probably support increased harvests, but commercial exploitation should not be encouraged.

Te **Bun** *(Anadara maculosa)*

The presence of *Anadara* below the substrate was indicated by shells found in sand and gravel deposits. Te **bun** is a valued seafood in Tarawa, and is also consumed in the other islands of the Gilberts group where it occurs. Harvesting was reported to be minimal on Kiritimati.

Crown-of-thorns starfish

One large *Acanthaster planci,* was seen during the survey, on the reef flat north of Benson Point (Station 3). Some signs of damage to corals (especially large table-top formations of *Acropora)* were noted on the outer reef slope on the north-west and western outer reef shelf. Small coral colonies established on these older plates suggested that the plate corals had died perhaps fifteen or more years ago.

APPENDIX 1: DISTRIBUTION AND ABUNDANCE OF OTHER BIVALVES AND INCIDENTAL BENTHIC ORGANISMS (CONTINUED)

b) Survey observations by station

Stn No	Depth (m)	*P.maculata*	*Pteria*	Substrate	Other
1	21			2,5	A1
2	34			5	A1
3	3			1,2,4	A1,A2,c2, E1,E2,E3,h1,h6
4	3			2,3,4	e1,e2,e3,h1
5	3			2,4	B1,e1,e4,H1,H3,H5,
6	4	common		1,2,3,5	B1,C5
7	3	common		1,5	B1
8	2.5	present	present	1,2,5	B1,C3,C5
9	2	rare		5,6	b3,C1,c5,o2
10	3 - 1.5			6	C1
11	3			6	
12	3 - 0.5			2,6	c3,h5,
13	1.5	common		2,4	B1,C3,h5,C4
14	2	uncommon	common	2,4	B1,C3,H1
15	2.5	rare		2,3,4	B1,b2,b4,e1,h1
16	7			2,3,4	a1,A3,h4,H2
17	3	rare		3,5	B1,H1,O1
18	3	uncommon		4,5	c5,h1,h2,H5,h7
19	10			1,4	A1,A3,E2,h2,h4,H6
20	8			1,2,3,4	a1,A3,h1,h2,H5
21	4			5	c5,H1
22	3			2,3,4	a3,B1,c5
23	5			2,4,5	a3,C5,H1,H3,H5
24	5			2,4	a3,b1,h1,h3,H5
25	5			2,5	A1,A3,H1,c5
26	4			3,4,5	c5,H1,h2,h3,H5
27	3			2,3,4	E1,E2,H1,H6
28	3	abundant		4,5	b1,C1
29	4	present		2,3,4	b1,C5,E3,H1
30	3			2,3,4	b1,C5,E3,h1
31	25			2,4	A1,a2,a3,C5,e1,E4

Key to substrate :, 1 = Pavement, 2 = Rubble, 3 = Gravel, 4 = Coarse sand, 5 = Fine sand, 6 = Silt

Key to other species : (Capital letters = common, Lower case = rare, or uncommon)

Algae:
- Al = Red filamentous algae
- *A2* = *Padina*
- A3 = *Halimeda*

Bivalvia:
- B1 = *Tridacna maxima*
- B2 = *Spondylus* sp
- B3 =*Anadara* sp (dead)
- B4 = *Area* sp

Corals:
- *Cl* = *Acropora spp*
- C2 = *Pocillopora* spp
- C3 = *Porites* spp
- C4 = *Montipora* sp
- C5 = Diverse species

Echinoidea:
- El = *Diadema setosum*
- E2 = *Echinothrix* sp
- E3 = *Tripneustes* (?) *gradlla*
- E4 = *Echinometra* (?) *mathaei*

Holothuroidea:
- HI = *Bohadschia argus*
- H2 = *Thelenota ananas*
- H3 = *Stichopus chloronotus*
- H4 = *Holothuria nobilis*
- *R5=H.atra*
- H6 =(?) *Synapta maculata*
- H7 = *B. vitiensis*

Others:
- 01 = *Culcita novaeguineae* (Asteroidea)
- 02 = *Strombus luhuanus* (Gastropoda)

APPENDIX 2 : STATISTICAL ANALYSES

a) Comparison of sizes of Kiritimati pearl oysters in the wild with recently harvested pearl shells.

Method : Comparison of shell diameters (DVM) from survey samples with shell nacre diameters (D.V.Nacre) from Marine Exports Division (MED) stocks, using one-way analysis of variance (ANOVA).

Ho : There is no difference in shell diameter between the wild stock and harvested shells.

		SAMPLE	GROUP						
VARIABLE	MEAN	SIZE	VARIANCE	SOURCE	DF	SS	MS	F	P
DVNacre (wild stock)	188.5	34	1,346.0	BETWEEN	1	1,450	14502.0	1.86	0.1723
DVM (MED stock)	180.4	62	473.2	WITHIN	94	73,290	779.7	-.--	-.---
TOTAL	**183.3**	**96**	---.-	**TOTAL**	**95**	**74,740**	--.-	-.-	-.--

Therefore, accept the null hypothesis: Shell diameters are the same between the wild stocks and the recently harvested stocks.

---

b) Comparison of pearl oyster sizes between Kiritimati stocks, and an unexploited atoll (Suwarrow, Cook Islands).

Method : Comparison with shell diameters (DVM) from stocks in Suwarrow, Cook Islands, using one-way analysis of variance (ANOVA).

Ho: There is no difference in shell diameter between the two stocks.

		SAMPLE	GROUP						
VARIABLE	**MEAN**	**SIZE**	**VARIANCE**	**SOURCE**	**DF**	**SS**	**MS**	**F**	**P**
DVM Kiritimati	188.5	34	1,346.0	BETWEEN	1	1.682	1.682	0.00	0.9677
DVM Suwarrow	188.2	19	407.8	WITHIN	51	51,770	1,015	-.- -	-.- - -
TOTAL	**188.4**	**53**	---.-	**TOTAL**	**51**	**51,770**	--.-	-.-	-.--

Therefore, accept the null hypothesis : Shell diameters are the same in Suwarrow and Kiritimati.

---

c) Comparison of pearl oyster sizes between Kiritimati stocks, and a heavily exploited atoll (Manihiki, Cook Islands).

Method : Comparison with shell diameters (DVM) from shallow water stocks in Manihiki, Cook Islands, using one-way analysis of variance (ANOVA).

Ho : There is no difference in shell diameter between the two stocks.

		SAMPLE	GROUP						
VARIABLE	**MEAN**	**SIZE**	**VARIANCE**	**SOURCE**	**DF**	**SS**	**MS**	**F**	**P**
DVM Kiritimati	188.5	34	1,346.0	BETWEEN	1	3,642	3,642	47.48	0.0000
DVM Manihiki	146.3	51	385.0	WITHIN	83	6,368	767.2	-.--	-.- - -
TOTAL	**163.2**	**85**	---.-	**TOTAL**	**84**	**10,010**	--.-	-.-	-.--

Therefore, reject the null hypothesis : Shell diameters are in Kiritimati are much greater than in Manihiki.

APPENDIX 2 : STATISTICAL ANALYSES (CONTINUED)

d) Comparison of pearl oyster shell shape between stocks from Kiritimati Is., and Suwarrow and Manihiki Atolls, Cook Islands.

Method : Comparison of the ratio of shell diameters (D.Y.Nacre) to thickness (as indicated by heel depth) between samples taken from shallow water and deep water in Manihiki, and from Suwarrow lagoon, in the Cook Islands, with shell samples from Kiritimati. A one-way analysis of variance (ANOVA) was again used.

Ho : There is no difference in shell shape, as indicated by the ratio of shell diameter to heel depth, between the three samples.

VARIABLE	MEAN	SAMPLE SIZE	GROUP VARIANCE
Kiritimati	9.93	62	4.54
Manihiki (Deep)	16.38	26	26.54
Manihiki (Shallow)	19.05	26	37.27
Suwarrow*	20.19	32	74.68
TOTAL	14.95	146	-.-

SOURCE	DF	SS	MS	F	P
BETWEEN	3	2,933	977.5	33.15	0.0000
WITHIN	142	4,187	29.5	-.- -	-.- - - -
TOTAL	145	7,120	- -.-	-.- -	-.- - - -

* Suwarrow data is for DVM (not DVNacre) on heel depth.

Therefore, reject the null hypothesis : Shell shape is very different between the four samples. The most significant difference is between the Kiritimati Is pearl oysters, and those from the Cook Islands. The lower ratio of D.V.Nacre over heel depth indicates a thicker shell for its length in Kiritimati, compared with Cook Is. shells. Suwarrow shell was most thin, with the shallow shell from Manihiki thinner than the deep shell specimens.

APPENDIX 3: SPAT-COLLECTOR AND PLATFORM DESIGN, MATERIALS, AND DEPLOYMENT

a) Spat collectors (Typical spat-collector configuration is shown in Figure 4).

(i) Itemised costs of materials used during the survey (5 x 5 lines @ 50 spat-bags)

ITEM	COST (AS$)
Ropes	
- 3 x 220 m coils of 10 mm diameter polypropylene main line	160
- 1 x 220 m coil of 16 mm diameter polypropylene anchor line	80
- 4 x 220 m coils 5 mm lashing rope	25
Floats	
- 12 x plastic long-line floats	180
- 5 x inflatable white marker buoys	170
Collector materials	
- 2 x rolls (5 m x 17 m) "Film-grad" black polyethylene sheet (200 collectors)	55
- Coconut husks (72 collectors)	0
Bags	
- 3 x rolls (910 mm x 30 m) "Cyclone" nylon mosquito mesh (156 bags)	70
- 2 x rolls (2 m x 30 m) 40 mm black plastic screen	160
Other	
- Transportation/ freight	50
TOTAL AS$	**950**

(ii) Future deployments. For the stock re-establishment programme, the Fisheries Division on Kiritimati should construct and deploy at least five hundred spat collectors each year.

Materials: Recommended material specifications and quantities are:

5 x rolls black polyethylene sheet
5 x rolls blue polyethylene sheet
500 x spat bags (pre-made drawstring nylon)[2]
5 x coils 20 mm polypropylene anchor rope
5 x coils 12 mm polypropylene mainline rope

Schedule: Over five years of the programme, the following manpower and budgetary commitments would be required:

Year	Collectors pulled, checked, and reset	New collectors set No.	Cost (AS$)[3]	Labour (man-days)
1989		270	950	**16**
1990	270	500	2,090	**40**
1991	770	500	2,300	**80**
1991	1,270	500	2,530	120
1991	1,770	500	2,780	**160**
1991	2,270	500	3,060	200
TOTAL	6,250 spat bag years	2,750	13,710	**616**

2 available from EVAAM, Tahiti: Ministry of Marine Resources, Cook Islands; or direct from Japan
3 assumes 10% inflation per year

APPENDIX 3: SPAT-COLLECTOR AND PLATFORM DESIGN, MATERIALS, AND DEPLOYMENT (CONTINUED)

b) Out-growing platforms:

Materials for culture platform for up to 1,500 pearl oysters, as shown in Figure 10, include:

Frame and footing

12 x 6 m lengths 100 mm dia. high grade pvc pipe		3 x 25 kg bags concrete
12 x 6 m lengths 30 mm dia. pvc pipe (or similar)		6 x old 240 1 drums
5 mm lashing rope		100 m x 20 mm nylon anchor line

Culture system

80 x 1 m x 2 m net panel baskets,	**or**	200 m x 8 mm down-line, with 200 m x 50 kg breaking-strain monofilament nylon

APPENDIX 4 : TEN YEAR PROGRAMME FOR STOCK RE-ESTABLISHMENT, OUT-GROWING TRIALS, AND PILOT CULTURE PROJECT.

YEAR	Spat-collectors	Out-growing	Pilot culture
1	Initiate		
2	Continue: Modify designs	Construct platforms Use broodstock or spats Initiate growth trials: Sites and culture methods	
3	"	Increase broodstock Modify platform designs	
4	"	"	
5	Consistent? If not, consider introduction. If consistent spats	——	Pilot culture Use collected spat in lantern baskets
6	Extension work for spat collectors	Maintain broodstock	Out-grow pilot spat in optimum site
7	"	"	First pearl culture seeding: trial sites
8	"	"	"
9	"	"	Harvest first seeding
10	"	"	Extension of platform culture methods

NB : Projections based on good spat-fall