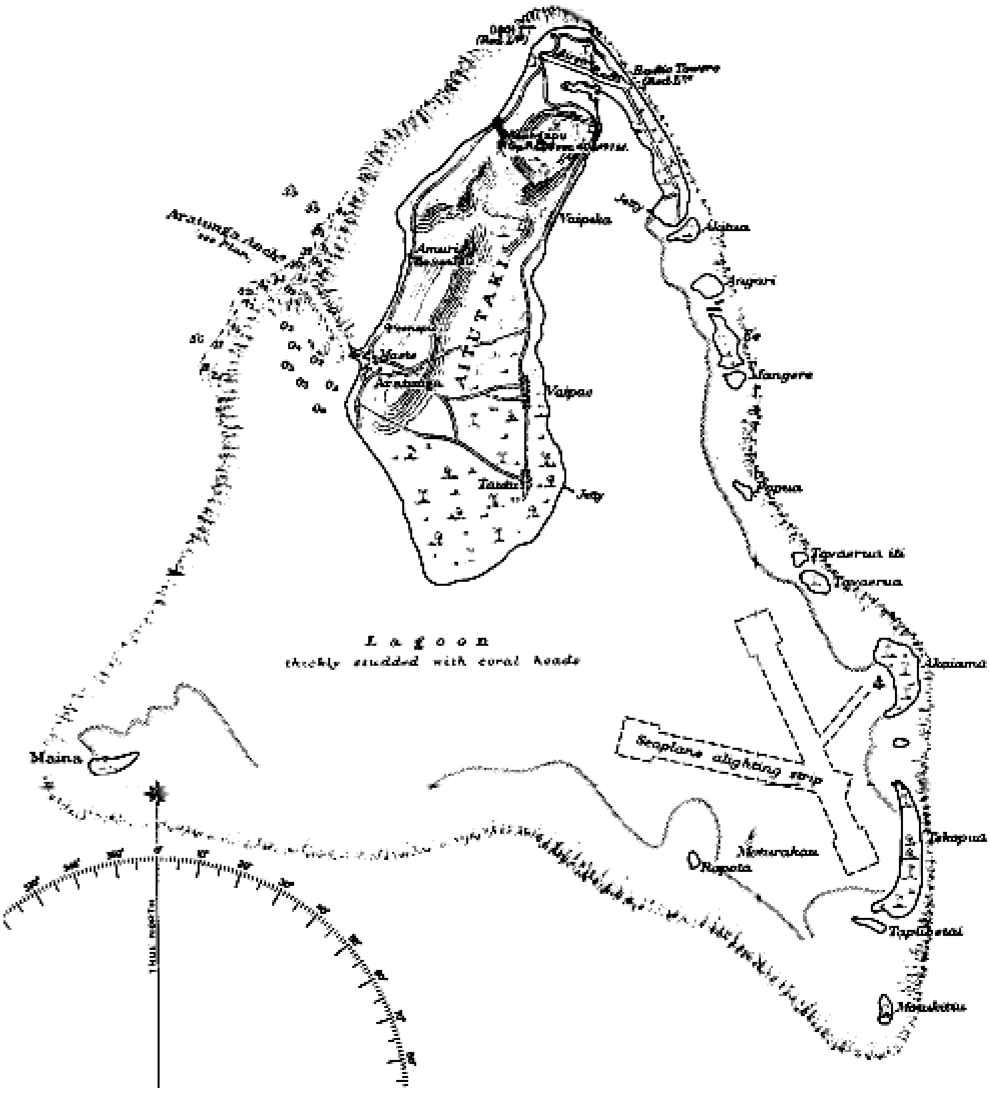
THE AITUTAKI LAGOON FISHERY

Consolidated report of field surveys and recommendations by the Ministry of Marine Resources in conjunction with the UK/South Pacific Commission Integrated Coastal Fisheries Management Project (ICFMaP),

by

T.J.H. Adams[1], I. Bertram[2],
P. Dalzell[1], J. Dashwood[1], M. Koroa[2], E. Ledua[1]
W. Marsters[2], S. Matoto[1], J. Ngu[2],
O. Terekia[2] & P. Tuara[1]



[1] South Pacific Commission, BP D5, Noumea, New Caledonia
[2] Ministry of Marine Resources, PO BOX 85 Rarotonga Cook Islands

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Introduction

The island of Aitutaki is part of the southern Cook Islands and lies about 225 km to the northwest of Rarotonga, the capital of the Cook Islands. Aitutaki is the second most populous island in the Cooks, with a population of about 2,300 people, and is becoming increasingly important as the main tourist destination after Rarotonga. One of the undoubted attractions of Aitutaki is the large shallow lagoon with many areas of sheltered water for swimming and snorkeling. The lagoon is also is also an important source of fish and invertebrates for food for the island inhabitants and in recent years Aitutaki's population has supplemented incomes from harvests of the introduced marine gastropod, *Trochus niloticus*, which is collected for its lustrous mother-of-pearl. Aitutaki has been notable for the production of giant clams, bonefish and milkfish, however, all of these have shown signs of decline in recent years.

Under legislation passed by the Cook Islands Government in 1989 (see Appendix V), the entire lagoon at Aitutaki was proposed as a designated fishery requiring a management plan to regulate fisheries activities and ensure sustainable production from the lagoon (Lodge, 1994). The Cook Islands Ministry of Marine Resources requested the assistance of the South Pacific Commission's Coastal Fisheries Programme in preparing recommendations for the Aitutaki lagoon fishery would help in preparing a management plan. The staff of the Integrated Coastal Fisheries Management Project (ICFMaP) made several trips to the Cook Islands (in November 1995 for one month, in December 1996 for two weeks, and in January 1999 for one week) to collect data and make observations on which to base management strategies, in partnership with Ministry staff. This report contains an account of the various investigations conducted by the Ministry of Marine Resources and SPC, and contains management recommendations for consideration by the Cook Islands Government.

Previous Studies on Aitutaki Fisheries and Marine Environment

Lagoon Environment

A detailed description of the physical characteristics of Aitutaki is given in a special edition of the Atoll Research Bulletin (Stoddart & Gibbs 1975). Aitutaki is termed an almost-atoll, in that it has a lagoon enclosed by a peripheral reef and reef flat (typically 0.5 to 1.0 km wide), but it also has a relatively large volcanic island (Araura) of about 17 km^2 which emerges to a maximum elevation of about 86 metres. Apart from the main island there are 15 small islands or motus around the rim of the peripheral reef, two of which are also volcanic in origin, and which comprise an additional 2.4 km^2 of land area. The main island and peripheral reef enclose a triangular lagoon with sides ranging between 13 and 16 km in length and which extend over an area of 50 km^2. Depths in the lagoon range from between 1.5 to 11.0 m, but shallow waters (1-3 m) predominate, with only a few areas of water deeper than 5 m.

Aitutaki lies between latitudes 18°49' and 18°57' south and average temperatures range between a maximum of 27.2°C during January to March, and a minimum of 23.9°C in August. The annual rainfall is about 2000 mm, with a wet season extending between November and April and with the dry season associated with the cooler months in the middle of the year. Apart from the main barrier reef, which forms the perimeter of the lagoon, fringing reefs are found around the islands, particularly the main island, and coral bommies and ridges are found throughout the lagoon, interspersed with fine sand. Along the eastern coast there are a number of *Cladium* and *Paspalum* marsh areas and these is a small swampy estuarine area in the northern apex of the lagoon, between the Ootu Peninsula and the mainland, into which small streams and freshwater runoff drains. In the western Pacific such areas would likely be colonised by mangroves but these are absent from the Cooks and the vegetation in this area is predominantly pandanus (*Pandanus tectorius*), hibiscus (*Hibiscus tiliaceus*), Scaveola scrub (*Scaveola sericea*), coconut (*Cocos nucifera*) and marsh grass (*Paspalum vaginatum*) (Passfield 1993).

Apart from the descriptive work of Stoddart & Gibbs (1975) other studies of the physical environment on Aitutaki include Sims & Charpy (1992) on water quality and phytoplankton standing stock in Aitutaki Lagoon, Paulay (1994) on the status of coral reefs and Forbes (1995) on coastal stability and sand transport. Sims & Charpy (1992) found chlorophyll concentrations of between 0.5 and 1.0 mg/m^3 in the inner lagoon waters, while lower concentrations 0.1 to 0.5 mg/m^3 were found in the southern and eastern sectors of the lagoon where oceanic influences are greatest. a very high concentration of chlorophyll (3.13 mg/m^3) was found in the inner section of the estuarine area at Ootu. The objective of Sims & Charpy's study was to assess the potential of Aitutaki Lagoon for the potential of green mussel (*Perna viridis*) production. Based on their results Sims & Charpy suggested that the levels of plankton standing stock could support a production of 0.4 kg/m^2.

Don Forbes of SOPAC took a look at coastal stability and sand transport at Aitutaki in 1995 (Forbes, 1995), and his conclusions do not disagree with the general feeling expressed by everyone on the island that certain areas of the lagoon are becoming shallower. There is probably a net movement of sediment into the lagoon over the western and southern reef, especially in the southwest corner in the middle of the proposed Motukitiu reserve, and an outflow over the eastern side. There used to be two passages into the harbour at Arutanga at the turn of the century, but the southern channel silted up before 1960 and there are calls to widen the existing northern channel.

Other work by Gustav Paulay of the University of Guam, who visited Aitutaki in 1984, 1986 and 1994, confirm the reports that live coral cover in the lagoon has decreased over the past decade. Because of the pattern of mortality, with most occurring in the staghorn corals and fire coral, Paulay concluded that this was probably a result of several coral bleaching events in the early 1990s caused by elevated seawater temperatures connected with El Niño events. If the mortality in the lagoon had been caused by Crown of Thorns starfish (*Acanthaster planci*) the fire coral (*Millepora spp*) would probably have been little affected. Although Paulay suggested that overfishing in the lagoon might have also contributed to coral death, he did not say how these events might be linked. The harvesting of giant clams by physically damaging coral heads is not likely to be a major factor, since clams are mainly embedded in the more massive corals, and usually in dead areas anyway. The more massive corals do not appear to have suffered great mortality.

Lagoon from air looking east

If Aitutaki lagoon is becoming on average shallower, this would tend to exaggerate any problems caused by elevated seawater temperatures, through increased potential for solar heating. Giant clams are also affected by elevated temperatures and tend to lose their zooxanthellae in the same way as corals - mantle bleaching. Although the relative temperature thresholds and recovery capacity of coral and clams are little known, it is quite possible that coral bleaching events would be accompanied by giant clam deaths, or recruitment failures.

The more recent observations of new recruitment in the natural population of giant clams may be a result of the reduction in excessive temperatures in recent years. In January 1997 a resource was made available on the internet for predicting potential coral bleaching events, by comparing an infrared satellite image of the Pacific with a chart of historical average temperatures to pinpoint "hotspots". This does not show any hotspots in the tropical Pacific at the moment, and it may be useful to monitor this.

There have definitely been fundamental changes in Aitutaki lagoon over the past decade, but whether these are caused by long-term climatic cycles or by human influence is difficult to say. However, as noted in Phase I, natural events, particularly cyclones, have had a great influence on the geomorphology of Aitutaki. Human influence is however evident in more superficial changes, caused by overfishing, of giant clams in the 1980s, and of certain other highly valued lagoon species. These changes can probably be reversed, and the current measures that the island council is considering will go a long way towards accomplishing this rehabilitation.

Previous Fisheries Surveys

The Ministry of Agriculture and Fisheries (Anon 1979) made an initial estimate of production within and outside the lagoon on Aitutaki in 1978. A survey of landings was conducted during one week of each of the four quarters in the year. These were then extrapolated to quarterly and annual totals. A total annual catch of about 790 t of all species was estimated from this survey, with just over half the catch taken by net fishing and a quarter from handline fishing (Table 1). About 40 per cent of the catch were unspecified reef fish, with about 13 per cent of landings formed by groupers and jacks, a further 6 per cent from snapper landings. Other components of landings that formed one per cent of the catch included molluscs, flying fish, mullet, sea weed and octopus. The data suggest that most fisheries production on Aitutaki in the late 1970s was mainly from the lagoon, with little contribution from pelagic fishes.

Table 1. Artisanal fisheries landings in Aitutaki during 1978

Species group	Lines (kg)	Nets (kg)	Spears (kg)	Hands (kg)	Total (kg)
Groupers	93,246	5,273	2,037	0	100,556
Jacks	27,457	75,761	4,865	0	108,083
Snappers	31,564	13,381	1,919	0	46,864
Reef fish	15,224	243,797	66,877	0	325,898
Flying fish	1,159	21,865	0	0	23,024
Mullet	1,608	18,072	692	0	20,372
Other fish	4,129	6,638	2,463	0	13,230
Crabs/crayfish	0	346	67	0	413
Molluscs	24,957	31,803	41,020	12,729	110,509
Octopus	1,868	5,306	4,661	88	11,923
Sea urchins/sea cucumbers	724	3,838	0	0	4,562
Seaweed	101	3,996	1,503	15,825	21,425
Total	202,037	430,076	126,104	28,642	786,859

However, some caution needs to be attached to interpretation of these data. The total estimated annual landed volume for Aitutaki represents an annual per capita production of about 343.5 kg/person/yr, which though not impossible, is extremely high and is associated with more rural and less developed Pacific islands such as atolls and coral islands in Kiribati, where food sources are less varied. Further, there are some apparent inconsistencies with the catch composition by individual gears. Handlines are reported to take predominantly reef fish, jacks and groupers, but also include as major catch components molluscs (15.6%) and flyingfish (7.5 %). Similarly, spearfish landings are dominated predominantly by reef fish, but also by molluscs (32.5 %). The most plausible explanation is that fishing trips were a mix of activities, such that handline fishing trips also involved some diving or reef walking for molluscs and netting for flying fish, and similarly, trips where spearfishing predominated also involved collection of molluscs. However, no details of the data collection methods are given in Anon (1979) so this must remain supposition.

A number of profiles and studies of the various fisheries resources in the Cook Islands including Aitutaki have been published by the Ministry of Marine Resources and these are also summarized in a general review of Cook Islands fisheries resources by the Forum Fisheries

Agency (FFA 1993). Of particular relevance to Aitutaki are trochus (Sims 1988), bêche-de-mer (Zoutendyk 1989), giant clams (Bertram & Maruai 1993), mudcrab (Whitford 1993), bonefish (Whitford & Guinea 1993) and a survey of the fish and invertebrates of the Ootu fish reserve by Passfield (1993). Each of these reports presents some information on the basic biology, distribution and abundance of the different marine resources within Aitutaki lagoon.

The estuarine environment at Ootu is probably unique in the Cook Islands, being the only extensive area of brackish water in this group of islands. Dahl (1976) suggested that this shallow estuarine area was an important nursery for juvenile fishes, particularly mullet, groupers and snappers, and also an important source of allochthanous nutrient input into the lagoon as a whole. In 1991 the area of water contained within Ootu Peninsula (125 ha) was declared a marine reserve by the Aitutaki island council (Passfield 1993). a survey of the reserve area by Passfield (1993) recorded a total of 19 species of fish, most of which were reef associated but some like the threadfin (*Polydactylus sexfilis*) and anguilid eels were found mainly in estuarine or freshwater habitats, or like the mullet (*Crenimugil crenilabis*) and bonefish (*Albula neoguinica*) range between reef and soft bottom habitats. Mud crabs (*Scylla serrata*) are found only in abundance in the Cook Islands within this area[1]. Whitford (1993) has made an estimate of crab abundance in the intertidal region of Ootu from mark and recapture observations and suggested mean densities of 108 adults/km^2 and 294 juveniles/km^2, but noted the wide confidence limits around these estimates. Due to the limited estuarine habitat on Aitutaki it is clear that the population of mudcrabs can only support limited harvests for subsistence and to supply the local hotel and restaurant trade.

The bonefish (*Albula glossodonta* and *a. neoguinaica*) are commonly found in shallow sandy areas of lagoons of the Pacific where they feed on shrimps, small bivalve molluscs and small crabs. According to Whitford & Guinea (1993) reports that *a. neoguinica* was once abundant in Aitutaki lagoon but now the stock is now reported to be reduced significantly through overfishing with gillnets (see below). Whitford & Guinea (1993) conducted underwater visual census (UVC) transect counts of bonefish adjacent to Rapota and Tapuetai islets in the southeast corner of the lagoon and found densities of 88.9 and 30.0 fish/km^2 respectively. Whitford & Guinea also presented some limited information on the biology of Aitutaki bonefish, including the length-weight relationship ($Wt = 0.0014.L^{1.721}$, with length in cm and weight in kg) observations on sexual maturity and spawning.

The small giant clam, *Tridacna maxima*, is abundant on Aitutaki and has traditionally been an important subsistence food and have been harvested from time to time in large quantities during social accessions, particularly when dance troupes or church groups visited the island. There has also been a strong demand for giant clam in Rarotonga and the improvements in flights between the two islands has led to increased harvesting of the Aitutaki clam resource. Giant clam stock densities declined markedly from around 4.0 clams/m^2 in 1987 to about 0.5 clams/m^2 in 1993 (Bertram & Marurai 1993) and that the majority of clams in the lagoon were sexually immature. Due to these findings, a moratorium on export of clams to other islands was imposed in 1994.

Trochus niloticus were introduced from Fiji to Aitutaki in 1957 (Sims 1988) and harvesting the population began in 1980 , where approximately 200 t of shell were collected between

[1] Mudcrabs are also reported from Rarotonga, but are not common (Dashwood, pers comm)

1980 and 1981. Subsequent harvests occurred every one to years until the end of the decade, with production of between 18 and 45.7 t of shell or an average of 34 tonnes. During the 1990s, harvests were made in 1990, 1992 and 1995, with production volumes ranging from 12 to 26 tonnes. During the 1992 season, a stock assessment experiment was conducted jointly by the Ministry of Marine Resources and the South Pacific Commission (Nash et al 1995), which compared different methods of estimating abundance and setting the harvest quota for an open season on trochus harvesting: strip transects, mark and recapture and the change-in-ratio for different size classes. Nash et al (1995) concluded that the mark and recapture method was more accurate that the strip transect for this fishery and more useful and robust than the change-in-ratio method.

The most recent study of lagoon fisheries in Aitutaki was conducted by Baronie (1995) on behalf of the Cook Islands Conservation Service. The objectives of the study were to assess the the current impact of fishing on the reef fish populations, conduct a household survey to record the patterns of fishing activity in the lagoon and to survey the opinions of tourists who visit the lagoon. The stimulus to conduct the survey was the increasing number of tourists visiting Aitutaki and the possible need to develop a management plan which would ensure that fishing and tourist related activities did not come into conflict. Baronie (1995) concluded that western fore reef and lagoonal reefs of Aitutaki showed clear signs of heavy fishing pressure. Baronie recommended the establishment of reserves at patch reefs at Maina and between Tapuaetai and Motokitiu, and the restriction of gillnets within the lagoon.

SPC - MMR 1995 SURVEY

Socio-economic and fisheries household survey

Methods

101 fishing households in 7 villages were surveyed by interview, for fishing gear, frequency of fishing activity, fishing zone, occurrence of fish-poisoning, fish sales and fish consumption. There are 477 households on Aitutaki, according to the September 1993 Aitutaki Household Listing, thus this survey covered the activities of approximately 20% of the population.

Each household was approached by two interviewers, including at least one Cook Islands Maori speaker, on either 8th, 9th or 10th November 1995. The purpose of the survey was to fill in some of the gaps and to expand on certain aspects of two previous household fishing surveys (Munro, unpublished 1993; Baronie 1995). The latter report recommended an extension of the work on community fishing practices, and this present survey will go some way towards filling that need.

Results

Household sizes were large, sometimes with two surnames under the same roof. On average, there were over 7 people per household. Based on this average number of people reported per household and the official number of households on the island (477 in 1993), this gives a population size of around 3,350. This is somewhat higher than that estimated by the 1991 census (2,357), but it is likely that the official definition of "household" differs from the statements made by respondents. If the official figures class different families as separate households, even if they live under the same general roof, this would account for much of the error in our estimate of total population size. Most of the fishing was carried out by men, thus the number of adult males per household is significant. Unfortunately this question was not included in the initial stages of the survey, but of the 35 households where this question was later asked, only 15 had less than two adult males in the household. In the 1991 census, 41% of the Aitutaki population was less than 15 years old.

Fishing frequency

The survey as a whole showed that, like most rural Pacific Islanders, Aitutaki residents maintain a high level of fishing, spread throughout the population. On average, at least one member of a fishing household would go fishing 2.25 times per week. The January survey (Baronie, 1995) respondents said that the average frequency of fishing in 1994 was 1.4 trips per week per household, but most of the respondents on that survey (85%) were male (many of whom would be employed and thus fish one day a week, on Saturday), whilst a larger proportion of our respondents were female, who were aware both of their own fishing, and of their men's. The January survey also concentrated more effort on the villages on the eastern side, which have a lower incidence of fishing than those on the west.

There were very few households (<10% of the 111 households actually approached) which admitted that they didn't do any fishing at all, in contrast to the survey by Baronie (1995) where 20% of the households approached said that "no member of the family used any method for collecting any variety of marine life". This disparity between the two surveys may have been due to a difference in initial approach. We did not ask the respondent the question "do you (personally) fish?" but "how often does a member of your household go fishing?". Many of the respondents were in a mood to talk about fishing since many were cleaning trochus resulting from the November 1995 trochus harvest.

Fishing gear

The ubiquity of reported fishing activity was confirmed by the responses to questions about fishing gear and fishing methods (Table 2). Over all 101 fishing households, there was an average of 1.4 gillnets per household, 2.1 handlines, 2.6 casting rods, 1.4 spearguns and 0.5 trolling lines (although there was confusion between "handlines" and "trolling lines", and many "handlines" are probably used for trolling).

Table 2 Fishing gear ownership by household and frequency of use

Gear	No of households in sample of 101 owning that gear	Total no of gear in household sample	Average no of times gear used per week by those owning it
Gillnets	63	140	1.22
Handlines	75	212	1.31
Rods	62	167	1.07
Trolling	26	54	1.12
Spear	67	141	1.67

The January 1995 Conservation Service survey did not ask questions about fishing gear ownership, but about the frequency of usage of different fishing gear. Since many of the gears are used seasonally (e.g. trevally casting in January-February), the answers may be somewhat different from the ownership figures. However, both surveys point to the prevalence of hook/line and gillnet fishing, and the relatively sporadic nature of invertebrate hand-collection. One major difference between the January sample and this is that many more households during this survey said that they used spears. In fact, spears were the most frequently used gear. This again is possibly an artefact of the different sampling coverage between the two surveys, but it may have been because the present survey asked more detailed questions about the usage of gear. Spearfishing is often not done in isolation, but in combination with other gear.

Estimated fish catch from the Aitutaki lagoon

From the data contained in the survey about the frequency of gear deployment, it should be possible to estimate a rough estimate of the fisheries production for Aitutaki by combining these with average catch rates for specific gears. One of the follow-up activities by the MMR staff following the survey was to obtain information on average catch rates of the fishing gears commonly used at Aitutaki and a summary of these is given in Table 3.

Table 3 Summary of average catch rates from spearfishing, gillnetting and line fishing at Aitutaki

Gear	CPUE (kg/man-hr)		Notes
	Lagoon	Outer reef	
Spearfishing	2.5	5	Lagoon spearfishing estimated from catches of eight different fishermen. Outer reef spear fishing catch rates based on 5 fishing trips conducted by MMR staff
Gillnetting	6.5	na	Catch rates from gill netting based on catches of two fishermen setting a 75 m, 3" gillnet and using it as a drive-in -net rather than fishing passively. The catch rate includes search time
Line fishing	1.5	na	Line fishing is based on catches of 9 fishermen

To estimate the production from the lagoon we have made several assumptions based on the conversations with fishermen during the household surveys. The average trip length from the household surveys was 5.12 hrs, during which fishermen would normally conduct several different types of fishing, generally, spearfishing gillnetting and line fishing, either with handlines or rod-and-line. The island council has discouraged passive gillnetting by a ban on setting nets overnight due to excessive catches and wastage by fish going rotten so we have assumed that gillnet fishing refers predominantly to drive-in-net fishing. The differences between rod and line and handline fishing are likely to be marginal as these gears can both be targeted at demersal reef and lagoon species or used for trolling. As catch rates from trolling are not available our estimates refer here only to demersal fishing.

Fishermen may fish individually, in pairs or in small groups. Fishing activity in some households is a weekly affair and the whole family participates during the fishing trip, with males fishing for finfish and females collecting shellfish. Given that we have little or no information on the cooperative nature of fishing by fishermen in Aitutaki, we have assumed that on each fishing trip an equal amount of time is spent on each fishing activity or 1.28 hrs devoted to each method of fishing, with the deployment of one set of fishing gear. The weekly catch from each gear type is therefore the product of the number of households with that gear, the frequency of deployment, the catch rate and the time spent fishing. a summary of these figures and the weekly catches is given in Table 4.

Table 4. Summary of the inputs used to compute the weekly and annual catch by gillnet, speargun, handline and fishing rod at Aitutaki.

	% of	**No of**	**Deployment**	**Catch rate**	**Hours**	**Weekly**

Gear	household with gear	households with gear [1]	frequency (per week)	(kg/man-hr)	fished	catch (kg)
Gillnet	0.63	285	1.22	6.5	1.28	2,893
Handline	0.75	340	1.31	1.5	1.28	855
Rod-and-line	0.62	281	1.07	1.5	1.28	577
Speargun	0.67	304	1.67	2.5	1.28	1625
Total						5,950

[1.] Total number of fishing households is estimated to be 453 based on 5 per cent of respondents in household survey who engaged in no fishing activities

The total weekly fish production on Aitutaki is thus estimated to be about 5.95 t/week, or an annual figure of 309.4 t/year. From the household survey about 80 per cent of fishing activity is conducted in the lagoon so that the estimated annual production from the inner reefs and lagoon of Aitutaki is 247.5 t/year.

Fish consumption

As might be expected from this level of fishing, fish figures heavily in the diet of Aitutakeans, with an average of 4.7 fish meals per week in each household. Fish is not as omnipresent a part of the diet as it is in some of the more rural Cook Islands, particularly in the atolls of the Northern Group but, given an average portion size of 400 grams (very roughly based on one typical fish per adult, and half a fish per child), this would be equivalent to an average (gutted, boned, fresh) fish consumption of around 100 kg per head per annum. One additional point worth noting is that the question asked by many interviewers was "How many days a week do you eat fish?". The respondent's answer probably usually did not include invertebrates as well as finfish, but it is likely that invertebrates would normally form a part of a meal together with finfish, and thus the "seafood meal frequency" would not be much higher than the 4.7/week "fish meal" frequency described here.

100 kg per head per annum would be a realistic consumption figure for an island with a semi-rural social structure such as Aitutaki. The overall average for Fiji, with big urban centres, and a large non-Pacific Island population, is nearly 50 kg per head per year (taking into account canned fish consumption), whilst fish consumption figures of over 200 kg per head per year have been recorded on outer island atoll populations in Kiribati. The product of a population of Aitutaki of 2357 people and an annual fish per capita consumption of 100 kg gives a total annual volume of fish consumed of 235.7 t. Pacific Islanders consume far more of a fish than the fillets, with only about 20 per cent (skeleton, gills and guts) of the total fresh weight of the fish being discarded. Using this as a scaling factor the annual consumption represents a whole landed weight of fish of 295 t, which is remarkably close to the total landed volume of fish for Aitutaki estimated in the previous section. Note, however, that the figure for annual per capita fish consumption may include some invertebrates, mainly bivalve molluscs and octopus, although these are likely to be either seasonal or a condiment (see following section), with fish forming the greater part of the seafood diet.

Invertebrate fishing

Of the non-finfish fisheries asked about, landcrab (*tupa*), octopus (*eke*) and seaweed (sea-grapes, *rimu*) collections were seasonal, *tupa* in Oct-Dec, *eke* in Aug-Oct (along with the breadfruit) , *rimu* in May-Aug. The frequency of fishing for other invertebrates (mud-crab, spiny lobster, giant clam (*paua*), turban shell (*ariri*), asaphis (*ka'i*)) tended to be either adventitious, if they were observed during fin-fishing in a suitable area (mud crabs are mainly found in the north east lagoon), or driven by requests from Rarotonga or visiting parties for a particular delicacy, such as *paua*, *ariri* or *rimu*. The average fishing activity for non-seasonal invertebrates was less than 0.5 times per week. Many respondents, when asked how often they collected invertebrates, said "when we feel like it". At the same time, the demand for some of these invertebrates, particularly *paua* which is subject to occasional intense fishing episodes as well as normal subsistence use, is more than high enough to cause concern, and this concern has been one of the driving forces behind the work on this management plan.

Fishing vessels

68 households out of the 101 surveyed owned 1 boat, usually a paddle canoe, and 17 households had two boats, including a powered dinghy (usually aluminium) or skiff (usually plywood or fibreglass). Those households that did not own boats would go fishing from the shore, borrow a boat, or go fishing with friends. There was a total of 51 canoes, 50 dinghies and 8 skiffs reported in the sample, an average of just over one boat per fishing household overall. The 50 dinghies had an average outboard horsepower of 30 hp, and the 8 skiffs had an average outboard horsepower of 40 hp.

In the January Conservation survey, 53% of the 49 respondents owned canoes, equivalent to this survey, but only 21% had a powered boat, which is about half the incidence of this survey. Since the ownership or not of a boat should lead to a fairly unequivocal answer from respondents, this difference is almost certainly a result of the different sampling coverage between the two surveys on the different sides of the island, reflecting the greater incidence of powered vessel usage in the east.

Fishing area

In terms of areas fished, 77% of total household fishing time was spent in the lagoon, 10% on the outer reef slope, 11% fishing for oceanic pelagics like tuna, and 2% fishing for flying fish. It should be noted that this breakdown of average household fishing time by area will not necessarily be the same as the breakdown of total catch by area, because this sampling is weighted heavily towards subsistence fishing. Commercial fishing tends to concentrate its more on the outer reef slopes and the ocean, thus a substantially larger proportion of the total island landings is expected to come from outside the lagoon than the 23% indicated here. It was clear from the interviews that most reef fish are retained for subsistence use (with a consequent dearth on the market place), whilst most oceanic pelagics are commercially sold (with consequent occasional gluts). However, it is clear that the average Aitutakean spends much more time fishing in the lagoon than outside.

The January 1995 Conservation Service survey (Baronie 1995) did not partition the overall fishing activity into broad habitat zones, but asked questions about the respondents most recent fishing trip within 20 geographical areas inside or outside the lagoon or on the barrier reef. Depending on what was the most recent trip, the responses might or might not be typical of fishing overall, but the question would provide more detailed information on the areas where effort was currently concentrated. The January survey showed that 61% of respondents' latest fishing trips were within the lagoon, with the most commonly fished area being the area south of the main passage to the southern tip of the island. Even though the Baronie survey was biased towards sampling the three villages who would normally use this fishing area (17% of households were sampled in Arutanga, Nikaupara and Reureu, as opposed to 10% of households in other villages), it is known that this area is subject to a great deal of activity, being close to the main centre of population and with easily accessible, relatively sheltered water.

Sale vs subsistence

Many households sold part of their catch, usually to pay for the outboard fuel used (and usually the pelagic part of the catch as noted above), "particularly the good-looking tuna" as one respondent said. Overall, around 18% of the total catch was sold. However 61 of the 101 fishing households said that they never sold any catch, and of those households that did sell anything, on average, around 43% of their catch was sold. These figures are based purely on respondents remembered estimates and are thus approximate. In 72% of the households, any fish marketed was sold by the adult male(s) of the household, either at the market by the wharf or to restaurants and resorts.

In the January 1995 survey, Baronie reports that (for respondents talking about the previous year's fishing) 72% of the households surveyed retained all the catch for home consumption, which agrees well enough with the estimate obtained here (61%), given the large potential error inherent in this particular type of question.

Fish price

The price of fish ranges from NZ$4.50 to $5.50 per kg. Some fish, particularly bonefish, are sold by the string and many fishing families feel that they get a higher price per unit weight this way. Of the invertebrates, lobster was quoted by one respondent only, at $12 per kg and octopus at $5 per kg, whilst mud crab is sold by one fisherman from $5 to $12 per kg, depending on tourist hotel saturation. The other invertebrates are not normally marketed, apart from the occasional octopus, but retained for family consumption or sending to relatives. There is no bêche-de-mer fishery on Aitutaki, except for the seasonal stripping of roe from pre-spawning *Holothuria* spp by visiting Rarotongans.

Seventy five per cent of the respondents answered "yes" in response to the question "Is any seafood harder to catch nowadays?" They were asked which, from a list of 28 categories, and there was a definite response to giant clams (42%), milkfish (32%), bonefish (28%) and parrotfish (17%). For all other species, less than 10% of the respondents said they were harder to catch. There was a general feeling that, apart from the species mentioned above, that finfish stocks were in better shape than the sedentary invertebrates. There was also less of a definite "yes" response to this question from young respondents than from old.

We did not ask this question about seaweed, but many respondents volunteered that*rimu* (*Caulerpa* spp. or sea grapes seaweed) has been getting very scarce around the Arutanga area where it was commonly harvested. *Rimu* is commonly found in areas of high tidal flow and good terrestrial runoff, typically at the edges of platforms in shallow water. It would be interesting to see whether this current dearth is due to over-harvesting (there is commonly a demand from Rarotonga for *rimu*), to changed water circulation patterns in the lagoon, or to a lessening of eutrophication in this area.

On a more positive note, several respondents in the eastern villages volunteered that juvenile giant clams (*Tridacna maxima*) were starting to be seen in areas where they hadn't been seen for years, particularly the Amuri foreshore. One respondent said that there were few juvenile giant clams visible in the late 1980's and early 1990's, even though Aitutakeans only harvest the large specimens, and that this recent settlement was a very noticeable and definite change, confirmed also by MMR staff. This should be very encouraging for the Island Council, following the introduction of the restrictions on giant clam harvesting in 1992 (see Appendix 2).

Opinions on environmental changes

Seventy two per cent of respondents said that they have noticed changes on the reef. Of the remainder, 26% said they had not noticed any changes, and 2% said they spent all their time on fishing boats and didn't have the opportunity to form a judgement.

Unfortunately, the anecdotal responses to the question "What changes?" appear to be strongly coloured by the regular TV viewing habits of the average Aitutakean, most of whom seem to have watched recent broadcasts on the state of the reef, judging by the similarity of wording of the responses. Of those responses that seemed to be based on reliable personal observation, several of the older fishermen said that they used to be able to find particular fish at certain "fish holes" and that many of these had been filled in or changed after Cyclone Sally in 1987, and that fish migration patterns had changed due to the change in water movement across the reef as a result of the hurricane shifting around the rubble. According to the geomorphological work reported in Stoddart and Gibbs (1975), cyclones have probably had a great influence on the Aitutaki lagoon and barrier reef. The motus on the western reef face appear to have accreted as a result of cyclone action, and cyclone influence can be expected to continue to cause occasional significant perturbations.

Other responses that seemed fairly definite were the decline in *rimu* in the lagoon off Arutanga, an increased incidence of *ciguatera* fish-poisoning (see later), more dead coral observed in the eastern lagoon ("you used to be able to run and jump on it when I was young but now it breaks"), more seaweed growth near the airport, siltation in certain places and "gravel washed in from over the reef". All of these observations might be consistent with a change in water circulation patterns due to cyclone or storm-induced changes.

Several older people mentioned that they thought the water in the lagoon seemed a bit greener than in their youth, but that it was hard to judge. Certainly a great deal of fertiliser went into the banana crop during its heyday in the 1970's and early 80's, and both fertiliser and pesticides would be included in the run-off from the island. The effect on a shallow, closed lagoon such as Aitutaki is potentially significant (see Sims & Charpy (1992), but there does not appear to be a time-series of nitrate observations to gauge the potential effect of agricultural run-off on the lagoon. Although Aitutaki lagoon is shallow (10 m maximum depth) there is a definite temperature stratification with depth, as well as great differences in turbidity, and some opinion should be possible on the degree of mixing of lagoon waters and the fate of runoff.

Respondents were also asked if they knew why the changes they described were occurring.

Theories put forward included nuclear bomb testing at Mururoa, crown of thorns starfish, not going to church enough, the air bubbles from SCUBA tanks poisoning the fish, the leakage of poisons being injected into crown of thorns by the eradication programme (with interesting parallels with the cyanide fishery for grouper in the Philippines), coral bleaching, global warming, too many outboard engines disturbing the fish from their normal spawning or migration areas, cyclone damage, agricultural runoff, people using traditional fish poisons to catch fish, or overuse of monofilament gillnets. These theories had varying degrees of plausibility, but there was no consensus.

When asked about problems experienced in catching or selling fish, the most common complaint was that it was hard to sell fish because the market was often flooded. Fish often had to be taken home and re-marketed the next day. Upon closer questioning, it was clear that this market flooding is mainly for oceanic pelagic fish like tuna, which tend to be sold in preference to the more favoured reef fish, to pay for outboard fuel. However, the fact that there are regular perceived superabundances of fish for sale in Aitutaki has considerable significance for lagoon fishery management. Inshore fisheries studies often recommend that Government make efforts to shift fishing effort and production offshore, in cases where inshore waters are under excessive pressure from the fishing community, but if offshore fish are much less acceptable on the market place such a strategy would have little success. However, it is encouraging to note that there does not appear to be a shortage of fresh fish on the island, if available production can satisfy the existing population and tourism, and this is a pointer that the present fishery is probably sustainable, barring certain critical species. One respondent noted that demand was continually good for flying fish, as opposed to tuna, and that not so many people were fishing for themselves nowadays but preferred to buy fish.

Another problem noted occasionally was competition from other fishermen for particular fishing grounds. This has probably always been a problem, due to the fact that the most productive "fishing holes" are limited in extent, thus it is inevitable that different fishermen will want to fish the same spots occasionally. Some people complained about certain fishermen gillnetting in passages or about the over-use of gillnets in general, but complaints about commercial fishing *per se* were rare, as might be expected in a fishery where most participants sell a part of their catch.

Nowadays there is no real partition of fishing areas between the different villages. Although certain villages tend to fish in certain areas closest to hand there is considerable overlap, and traditional fishing rights tend to belong to the island as a whole than to sub-units. Partitioning the fishing grounds by village would tend to reduce the potential for competition between fishermen, but this did not seem to be a big enough problem to warrant such a radical re-structuring.

Visual census

Methods

Two series of underwater visual census counts of reef fish were made in Aitutaki Lagoon. At each of the two locations, three sets of transects were laid down at three different sites. The two locations in the lagoon chosen for these observations were near the clam nursery behind Maina, in the southwest, and in front of Moturakau, in the southeast corner of the lagoon. Both areas have been proposed as marine reserves under the new Marine Reserves Act where fishing will be prohibited.

At each transect site, three 50 m ropes were laid down in a random orientation across sand and coral heads, and a pair of observers swam along the rope connected at the wrists by a 5 m line. Fishes lying within this 5 m band were counted by the two observers. On the upward swim, snappers, emperors, parrotfish and groupers were counted, whilst surgeonfish, goatfish and butterfly fish were counted on the return swim. Three teams of two observers each swam the three transects giving a total of 18 separate counts for the fishes in each site. Not all fish were chosen for counting as not all observers are familiar with the variety of reef fish, while the seven families counted here are commonly recognised by most Pacific Islanders.

Results

The objectives of this study were to estimate the numerical abundance of the commoner reef fishes in the lagoon back reefs and to compare the relative frequencies of the different families between the two sites. A summary of the results is given in Table 5. For the purpose of making a comparison of the relative densities of the different fish families between the two locations, the transect data were simply pooled for the two sets of observations

Table 5. Summary of the average numbers of reef fish in a 250 m ^{2} transect at Maina and Moturakau

Location	Family						
	Snappers	**Groupers**	**Emperors**	**Surgeonfish**	**Parrotfish**	**Butterflyfish**	**Goatfish**
Maina	0.69	1.09	1.7	15.7	6.19	3.44	0.43
95 % confidence interval	0.41	0.37	1.16	2.66	1.62	0.85	0.26
Moturakau	0.52	1.02	3.56	17.33	11.24	3.78	1.85
95 % confidence interval	0.27	0.31	2.1	2.78	3.07	1.05	0.61

There were a total of 3 sites at both of these locations, and three transects were laid at each site. Each transect was replicated three times by different teams, thus there were a total of 54 counts for each species group, as each paired team made individual observations.

A χ^2 test on the data suggests that there is no significant difference between the overall relative frequency composition of the different fish families at each location (χ^2 = 6.269, p >= 0.1, 6 degrees of freedom)

This suggests that there is relatively little difference in the composition of reef fish populations on the shallow back reefs of the lagoon. However, the χ^2 test of the differences between two whole frequency ranges is not very sensitive. When the confidence limits around the mean of the 54 observations for each individual family are compared, there are significant differences between the abundances of parrotfish and goatfish in the two locations, with on average about three times as many parrotfish and goatfish observed at Moturakau.

The average numbers of fish in the 250 m^2 transects at each location could also be converted to biomass in g using average weights for each family obtained from the spearfishing experiment at Mainia (see below). The totals of the products of numbers and average weights gave biomass estimates of 13 and 14 t/km^2 for Maina and Moturakau, respectively. This is about 3 times lower than the estimate of standing stock made from the spearfishing experiment (see below) and may indicate a general tendency for UVC to underestimate fish population size. The UVC work was valuable, not so much for estimating total population numbers, as for investigating relative species composition between sites

In the Conservation (January 1995) survey, a similar but less replicated exercise at more sites was carried out, with the recommendation that this be followed up every six months for the next two years. No information was available from any follow-up surveys, but the data from this MMR survey can tentatively be compared directly to an aggregate of the January survey data, from three lagoon sites (Table 6). Note that the present survey's "Moturakau" location is midway between Baronie's sites 10 and 6.

Table 6. Summary of the average numbers of reef fish per 250 m2 transect along the southern reef and western outer reef (After Baronie 1995)

Site	Family						
	Snappers	Groupers	Emperors	Surgeonfish	Parrotfish	Butterflyfish	Goatfish
Maina (3)	0.00	0.25	1.00	79.25	7.00	5.75	1.00
Mid-south (10)	0.50	0.75	2.50	71.00	7.50	4.25	1.25
Motukitiu (6)	15.00	2.25	65.75	43.50	6.25	22.75	2.75
Western outer reef (4,5,15,16)	0	2	1.94	172.19	28	9.63	0.5

According to Baronie (1995), 4 transects were performed at each site (equivalent to "location", in our terminology, in the interest of avoiding confusion), and two divers each counted a subset of species within 2.5 metres to both sides of the transect rope. The figures in Table 6 are derived from Baronie's Table 4 (Total number of fish at each lagoon site), with the individual species aggregated into families and the total divided by 4, which presumably approximates the number of fish counted per 250 m^2 area. The total number of observations for each species group at each of these locations is 4, but no breakdown of variability between observations is possible using the data available in the published report. It is thus not possible to say if there is any statistically significant difference between the different sites, but the frequency of snappers and emperors at Motukitiu would probably be significantly higher than the other two sites. Baronie's Motukitiu location appears to be a tourist fish-feeding site.

Compared with the equivalent figures from this survey, in the previous table, the most striking thing is the consistently far higher count of surgeonfish in the January survey, from 3 to 5 times as many as were counted here, and the generally higher count of fish overall, including a large aggregation of emperors near Motukitiu. The difference between the two surveys is that the Baronie survey apparently laid its transect tapes along the coral patch, choosing patches that were big enough to accommodate the 50 m line. During the present survey the transect lines were laid randomly, encompassing both coral patches and lagoon floor, and since the vast majority of the fish counted are highly coral-associated, the absolute counts are lower. When raised by the rough proportion of coral patch cover (Table 7), the present visual census survey results are more comparable to the January 1995 survey

Table 7. Summary of the average numbers of reef fish in a 250 m^2 transect at Maina and Moturakau, raised by the approximate average proportion of coral heads to bare substrate over all the transect areas (17%)

Location	Family						
	Snappers	Groupers	Emperors	Surgeonfish	Parrotfish	Butterflyfish	Goatfish
Maina	4.1	6.4	10.0	92.3	36.4	20.2	2.5
Moturakau	3.1	6.0	21.0	101.94	66.11	22.2	10.9

With this "patch reef cover" raising factor applied, the counts from the present study are now overall higher than the January underwater visual census. It is possible that counting of fish by family, instead of species, enables more rapid and higher counts to be made. It also perhaps underlines the variability inherent in the visual census of reef-fishes, particularly if the methodology cannot be absolutely standardised and a large number of replicates made (at *exactly* the same sites, in the case of a time-series), and caution is warranted in the interpretation of all such studies for estimating absolute numbers of fish[2].

Taken at face value, a major difference between the two surveys, apart from the large number of emperors observed at Motukitiu in January, is the consistently larger proportion of small parrotfish observed overall in this study, and the existence of twice the number of parrotfish at the Moturakau over the Maina location. Parrotfish are grazers of encrusting algae on dead coral, and the Maina location had a noticeably larger proportion of live coral, including the branching corals absent at the higher-energy Moturakau location.

The survey conducted by Baronie in early 1995 also looked at reef fish abundance on the western outer reef slope by conducting transects at four sites. Two sites were close to the Araura Research Station in the north, while the others lay close to the clam sanctuary outside the lagoon at Maina. As with the lagoon transects, Baronie presents the data from UVC counts with which to make comparisons both with his counts of reef fish in the lagoon and the counts made in this survey. The counts from the four outer reef sites were pooled to obtain an average and divided by four so that they were directly comparable with the mean from this study. The dominant feature of the outer reef slope counts are the surgeonfish, in common with both sets of observations in the lagoon, followed by parrotfish and butterflyfish. This is broadly similar to the observations made overall in this study for the reefs in the lagoon, however, in the absence of confidence limits for the means in Baronie's report makes further comparisons superfluous.

The Baronie survey did not record transects from the eastern or southern outer reef slope, presumably since the weather did not permit detailed work so close to these windward reef

[2] In the interest of avoiding confusion, when we talk about "coral cover" here, we are talking about coral heads and reef structures, whether they encompass live or dead coral. The Baronie survey appears to use the term "coral cover" to estimate the percentage of **living** coral on a coral head or reef structure.

faces, but fish populations are known to be denser, and with larger individuals, in these little-fished areas.

On the current survey, counts were also made of the abundance of the giant clam *Tridacna maxima*, along the transects at both locations, after the fish observers had passed. There was a very significant difference between the two locations, with an average of 25 clams per transect (50 m by 2 m) at the Maina location (3 transect sites with a total of 19 observations) and 0.8 clams per transect at Moturakau (3 transect sites, 12 observations). Again, this is expected given the higher-energy environment at the Moturakau location, which had a rubble or scoured coral substrate, closer both to the reef-crest and the area of trochus abundance than the Maina location, with its sandy floor and the protection of the lagoonal line reefs. Giant clam larvae do not tend to settle successfully in areas with high wave action and current, although juveniles and adults may do well in areas of good water movement if transplanted manually. (The sheltered location lagoonward of Maina makes this a very good place to site the giant clam nursery, where survival is usually more important than growth, and is possibly one of the best locations near any giant clam hatchery in the world. It is not clear how hurricane-proof it is though, since winds and storm-surges will come from unpredictable directions.). There were also far fewer dead giant clam shells at Moturakau than Maina, indicating that the low abundance of giant clams in this particular location is not due to overfishing.

Other fishable invertebrates were not particularly common. The holothurians *Stichopus chloronotus* (greenfish) and *Holothuria atra* (lollyfish) are both low value sources of bêche-de-mer and are virtually ubiquitous in Aitutaki lagoon, greenfish tending to be more abundant towards the barrier reef and lollyfish more abundant inshore. In the shallow lagoon off Amuri, lollyfish can reach very high densities of several per square metre (up to 50,000 per hectare). At the Maina and Moturakau sites the density was much lower, ranging from 0.2 to 1.7 per 2 m x 50 m transect (20-170 per hectare), with greenfish at a similar density (60-200 per hectare). Several specimens of the larger and more valuable bêche-de-mer, the prickly redfish (*Thelenota ananas*, which favours the sand around lagoonal coral patches) were seen near Maina, but this species is never found at high density.

The surf redfish (*Actinopyga mauritiana*) is the only other abundant holothurian of commercial note in Aitutaki lagoon. This species produces bêche-de-mer of medium value or less, but it is fairly common on the barrier reef top. It favours a similar habitat to the trochus, and is present at densities of about 600 animals/ha. There is no fishery for bêche-de-mer at Aitutaki, so these are probably virgin stock densities.

Other invertebrates of note seen included one large blacklip pearl shell (*Pinctada margaritifera*), a species which has always been rare in the Southern Cook Islands. Over the space of 5 years, only 7 blacklip shells have been noted by MMR staff in the lagoon. There is no prospect of basing a pearl culture industry on such a low density of naturally-occurring pearl shell, and it would require the manual rearing of spat *in vitro* if indeed the shallow lagoon at Aitutaki were suitable for pearl shell growth. A sample of 20 shells transplanted from Suwarrow in August 1994 survived one year in the lagoon, until brought into tanks for spawning trials.

One crown of thorns starfish (*Acanthaster planci*) was seen during the course of the 2 days of transect work, although it was not in the path of any of the transects, and one was observed during the two day depletion experiment. There does not appear to be an unusual incidence of crown of thorns within the lagoon at the present time, and the two specimens seen were both very large. Active crown of thorns outbreaks are usually accompanied by a profusion of very small starfish, especially around reef passages. However, casual observation shows that there are definitely more crown of thorns on the outer reef slope than in the lagoon, as would be expected on the growing side of the reef where live coral is naturally more profuse, and this is where any further eradication work, if considered necessary, ought to be concentrated.

There was an exercise in October 1994 where government employees on Aitutaki were asked to collect Crown of Thorns in the lagoon. A total of 630 starfish were collected during one day from the lagoon around Aitutaki by an unknown number of people. 570 were collected from the outside edge of the western reef mainly south of the main passage to Maina motu. During a similar one-day exercise in 1995, 306 starfish were collected from the lagoon. No collecting occured over the reef.

If further eradication is planned it is important both to keep a count of the starfish, and over what area, and by how many people, to see if the incidence is increasing or decreasing, or indeed to see what the actual incidence is. A great deal of work was carried out on *A. planci* at many Pacific Island locations in the 1970's, and there are many examples of the numbers of starfish and feeding scars that would be expected in a debilitating outbreak. The most effective way of killing the starfish, as well as the most unequivocal way of getting information about numbers and densities, is to pick them all up onto the boat and put them on the beach in the sun to dry out. There even used to be a market for dried crown of thorns in Taiwan and China.

Controlled spear-fishing experiment

Methods

A controlled fishing experiment was conducted over a two day period near the Marine Resources clam nursery at Maina. The fished area was 1,500 m^2, consisting of a coral wall across two sides of a right angled triangle of dimensions 50 m x 60 m x 80 m, and encompassing a large area of sand at 3-5 m depth, with several small coral patches. Three spearfishermen caught as much fish as they could shoot during four 1.5-2 hour fishing periods (mornings and afternoons on two consecutive days). Following fishing, the catches were sorted to species, which were then individually weighed and measured to the nearest 0.1 gram and millimeter respectively.

The main objective of this fishing experiment was to estimate the biomass or standing stock of reef fish on the shallow reefs in then lagoon. Where fishing is conducted intensively in a small area over a short time period, it is assumed that the processes of natural mortality, recruitment and growth are negligible. Changes in the catch per unit effort (CPUE) with time (t) should therefore be proportional to the removals from the population by fishing as expressed by the accumulated catch (K). The relationship can be expressed as follows:

$$CPUE(t) = qN_o - K(t)$$

where N_o is the initial population size and q is the catchability coefficient or the fraction of the fishing mortality from one unit of effort (Ricker 1975). This is a simple linear equation where the slope (q) and abscissal intercept (N_o) can be solved by a regression of CPUE(t) on K(t).

This model can be fitted to catch data expressed either in numbers (N) or weight (W)

Results

a summary of the catch data generated by the spearfishing experiment is given in Table 8. Over the two day period a total of 396 fish weighing 34.4 kg were caught by the three spear fishermen. a plot of the catch rate versus the cumulative catch for both weight and numbers is shown in Figure Z. The catch rate declined from around 2 kg/man-hr at the beginning of the experiment to 1 kg/man-hr at the end. Similarly, catch rate by number declined from around 20 fish/man-hr to 14.3 fish/man-hr over the two days of the experiment. The regression of catch per unit effort versus cumulative catch takes the form for catches in weight (W) of:

$$CPUE_w(t) = 2.5882 - 0.0443W_o \ (r^2 = 0.961, p = <0.020)$$

and for numbers (N) of:

$$CPUE_n(t) = 22.62 - 0.0193N_o \ (r^2 = 0.909, p = 0.05)$$

Based on the regression equations given above, the total fishable biomass in the fished area of 1500 m^2 amounted to 58.47 kg or 1,171 fish. This figure does not represent the entire density of fish available on the reef, as small species such as anthiids and many pomacentrids, and unusually large fishes such as moray eels and sharks were not targeted. Neither does it include invertebrates, hence the use of the phrase “spear-fishable biomass”, but it is certainly a minimum estimate of the total fin-fish biomass density.

Table 8. Summary of the catch data from the spearfishing experiment on a reef near Maina

Date	Time	Fishermen no.	Fishing time (hrs)	Effort (man-hrs)	Catch (kg)	Cumm. catch (kg)	Catch rate (kg/man-hr)	Catch (nos of fish	Cumm. catch (nos of fish)	Catch rate (fish /man-hr)
16/11/95	10.00-11.30	3	1.5	4.5	9.965	9.965	2.21	91	91	20.2
16/11/95	14.00-16.00	3	2	6	9.853	19.818	1.64	113	204	18.8
17/11/95	09.00-11.00	3	2	6	7.675	27.494	1.28	106	310	17.7
17/11/95	13.30-15.30	3	2	6	6.945	34.438	1.16	86	39 6	14.3

The bulk of the catch was made up of surgeon fishes, mainly one species, the black surgeonfish *Ctenochaetus striatus*, which formed 45% of the catch, and which also dominated the visual census survey (see earlier). Surgeonfishes as a family comprised 53% of the catch. Other common families in the catch were butterflyfish (Chaetodontidae) (11%) and emperors (Lethrinidae) (6%). The declining trend in CPUE with catch rate was observed in most of the catch components with the exception of the butterflyfish which increased markedly by weight towards the end of the fishing and showed a steady rise in CPUE by numbers during the progress of the experiment.

The positive trend in the catch rates of butterflyfish, however, is not an impediment to estimating the biomass. Polovina (1986) showed that the standard Leslie equation could be modified to account for increasing CPUE of a subordinate species which replaced a more dominant species in the catch as fishing progressed. Polovina's modification was based on observations from handline fishing where it was thought that competition for baited hooks meant that dominant aggressive species would be removed first and demonstrate a declining trend in CPUE. Less aggressive subordinate species would become more successful at taking the baited hooks and hence demonstrate an increasing CPUE as the population of the dominant species was reduced. With continued fishing even the subordinate population would eventually become depleted and CPUEs would decline, but in a short term experiment like this is towards an increase in catch rates.

With the spear fishing experiment conducted here, the fishermen initially ignored the smaller species such as butterflyfish and concentrated on other larger fish such as emperors, surgeonfish and parrotfish. As the populations of these fish were depleted through fishing then the fishermen were forced to catch the butterflyfish. Although this is a different interaction from the one described by Polovina (1986) the rise in butterflyfish CPUE(b) is a direct result of the decline of the other families in the catch and thus Polovina's method can be used to estimate the initial biomass of butterfly fish and their catchability.

The modified Leslie equation incorporates a term for the cumulative decline of the other species and takes the form:

$$CPUE(b) = q(b)[K(a)/N_o(a)] x\ N_o(b) - K(b)$$

where q(b) is the catchability coefficient of butterflyfishes in the absence of other species, K(a) is the cumulative catch of other species groups, $N_o(a)$ is the initial biomass of the other species, $N_o(b)$ is the initial biomass of butterflyfish and K(b) the cumulative catch of butterflyfish during the experiment. This is a simple multiple linear regression that passes through the origin and solves the two unknowns, $N_o(b)$ and K(b). This formulation was used with the catches in numbers and the initial biomass and catchability of butterflyfish was obtained. These and a summary of the results for other families are summarised in Table 9.

Using the biomass figures from this experiment it should be possible to make a rough estimate of the reef fish standing stock in the lagoon, bearing in mind that this is likely to be an under-estimate. Observations conducted during the spearfishing experiment indicated that fish were concentrating beyond the boundaries of the designated fishing zone. Several specimens in proximity to the fishing zone showed wounds where they had escaped after being hit by a spear in the fishing zone and had later moved out of danger. Such a response to fishing has been noted in reef fishes in other locations where fishing is particularly heavy (Russ 1991), however, our observations suggest that these modifications may happen relatively quickly once fishing has begun.

Table 9. Summary of the initial biomass estimates in weight and numbers, and the catchability coefficients from the controlled fishing experiment at Maina.

Family	Initial biomass		Catchability coefficient	
	kg	n	q(kg)	q(n)
All species[1]	58.43	1173	0.0443	0.0193
Acanthuridae[1]	30.57	473	0.0455	0.0311
Scaridae[2]	1.40	63	0.1344	0.0119
Serranidae[2]	1.40	23	0.2837	0.0714
Lethrinidae[2]	2.57	22	0.3039	0.2024
Chaetodontidae[3]	na	71	na	0.0381

1. Leslie model fitted using four data points
2. Leslie model fitted with two points, catch and effort for morning and afternoon of each day combined
3. Modified Leslie model used only with catch in numbers

The estimated standing stock of fish in the fished area represent a total biomass of 38.98 t/km^2 or 780,666 fish/km^2. The reef area of the lagoon was roughly estimated from a chart, based on aerial photographs. The total reef area of the lagoon barrier reef is about 36 km^2, while a further 15 km^2 of reef surrounds the main island of Aitutaki and forms coral ridges inside the lagoon. The total area of coral is likely to be higher than this as the lagoon floor is for the most part studded with coral heads which are difficult to discern from the chart. If we assume, however, that 51 km^2 represents a reasonably accurate figure for coral in the lagoon, then the total standing stock of reef fish within the lagoon boundary is in the order of about 2,000 tonnes or around 39,814,000 fish.

This estimate of standing stock is based on only one limited fishing experiment. Our other estimates of standing stock are from UVC observations and refer only to counts of a limited number of families, making comparisons of the results between the two methods somewhat difficult. However, it should be possible to make a some comparison of the biomass estimates of the dominant species group, the surgeonfish, from both methods. Further, the surgeonfish are more strongly site attached and less prone to flight from either spearfishermen or from enumerators conducting UVC counts and the errors in both methods should be minimised. From the fishing experiment the total biomass of 457 surgeonfish was estimated for the fished area of 1500 m^2, which represents a total of about 305,000 surgeonfish/km^2. The unadjusted average density of surgeonfish from all the UVC data combined is 16.5 surgeonfish/250 m^2 or 66,000 surgeonfish/km^2 . However, we have noted that much of the UVC observations were over bare sand and to express the biomass data more correctly this needs to be raised by the ratio of the sand to coral. Using an average of 17 % for the two sites, then the raised value for the surgeonfish density is 388,235 surgeonfish/km^2. Given the differences in methods and assumptions employed the estimates shows reasonable correspondence.

This small fished-down area will be used as a site for the experimental planting of maricultured juvenile clams free on the reef. Small giant clams normally have to be kept in wire-mesh cages on the lagoon floor to protect them from predators, both fish and molluscs. This experiment will see if it is possible to grow clams to "escape" size in a predator-reduced environment and thus avoid the serious expense of producing, repairing and maintaining the transplant cages.

Reef fish tagging

Methods

Reef fish in the lagoon were tagged with small dart tags 12 cm in length (originally designed for use with juvenile tunas). To catch as wide a range of fish, fishing was conducted both with fish traps and hand lines. Ten oblong wire mesh fish traps of dimensions 1.0 m x 2.0 m x 0.5 m were constructed from steel reinforcing rods covered with 2.0 cm mesh chicken wire (fig). Two conical funnels were set in opposite sides of the traps, which were baited with canned mackerel and fish scraps.

Results

Traps did not prove effective for catching fish for tagging in the time available to this preliminary survey and caught only 5 fish, two*Ctenochaetus striatus*, two *Epinephelus merra* and one *Lutjanus fulvus*. The traps were constructed immediately prior to the survey and did not have time to "mature" and become attractive to fish, but may improve as they accumulate a coating of algae and sediment. By contrast, fishing with rod-and-line proved extremely effective for catching mainly predatory species along the inner barrier reef face of the southern lagoon, and 53 fish were tagged and returned to the water in 3.5 hours fishing by 2 rods on the last day of fieldwork. This tagging work will continue with the aim of placing tags on 1-2,000 fish over the course of the year.

Publicity will be important in warning fishermen that MMR should be notified in the event of a tagged fish being caught, and this would probably be most effectively put across by a short video illustrating the catching and tagging of fish, with an explanation of the reasons.

Tag-recapture, if it can be conducted on a large enough scale, is one of the most effective ways of measuring the absolute abundance of fish, as well as providing accurate information about growth rates if whole fish can be examined. However, one of the main purposes of the tagging exercise is to observe how fish move around the lagoon. Different species are site-associated to different extent, and movement patterns can change markedly during the spawning season. a knowledge of reef fish movement is very important in judging both where to site marine reserves, and for judging the potential effectiveness of marine reserves in enhancing the surrounding fishable biomass.

Table 10 Summary of numbers of fish tagged in Aitutaki Lagoon

Species	N	%
Cephalopholis argus	2	3.77
Cheleinus chlorourus	6	11.32
Ctenochaetus striatus	2	3.77
Epinephelus merra	38	71.70

Gnathodentex aurolineatus	1	1.89
Lethrinus xanthochilus	1	1.89
Lutjanus fulvus	1	1.89
Rhinecanthus aculeatus	2	3.77
Total	53	100.00

Although reserves are of proven value in conserving species *within* their borders, there is still no unequivocal evidence of a spill-over effect, yet many reserves are being promoted as definitely being able to enhance nearby fisheries. The tagging experiment will test which species are most mobile, and thus which fisheries would be most assisted by the declaration of reserves. For the species where a spill-over effect is unlikely, more effective fishery management strategies would have to be devised.

Decline of bonefish stocks

The popular bonefish (*A. neoguinica*) has declined appreciably on Aitutaki and is no longer as plentiful as in the past. An interview with a resident of the island suggests that the main population of this species used to school around the western area of Rapota and was fished by him during his years as a professional fisherman (1973-1987). He used to fish 2-3 times a week with 3 x 105 m, 3.5" gill nets and landed and average of 2 sacks of fish, about 80 fish weighing on average 3 lbs (1.5 kg). This would normally take 1-2 days to market, depending on how much other fish was being landed on Aitutaki.

Fishermen from Tautu village also fished this bonefish stock as it moved along the reef plateau ('kena'), using a 2.5 inch mesh, nylon beach seine. The Tautu fishermen obtained the beach seine net from New Zealand and in 1978 surrounded and caught all of this bonefish stock as it formed a spawning aggregation to the west of Rapota. It is estimated that a total of 3,600 fish weighing 6 t were caught in a single set. The fish could not all be disposed of on Aitutaki and a government boat took them for sale to Rarotonga. The fish were not well preserved, and ultimately most were dumped in the sea.

Following this the stock at the Rapota/Moturakau area has never recovered. The fisherman moved his fishing operations deeper into the lagoon and began setting nets of up to 630 m in length to capture bonefish and trevallies. Lengthy those these nets were, he insists that they were not a 'wall of death' being full of holes that whole schools could not be captured. He notes that earlier catches of all fish (bonefish, drummers, trevallies) in 1974 were on average 200 lbs per trip. Catches gradually dropped and by the early 80’s, 125 lbs was considered a good catch. He also suggested that the growth of gillnet fishing in the lagoon has promoted the decline of milkfish (ava).

Some information on fishing and spawning seasons of reef and lagoon fish was also provided by the same fishermen, based on his observations from fishing in the lagoon. The fishing season for bonefish extends between July to Oct and for milkfish from August to September. During this period, the milkfish have lots of belly fat and ripe gonads. Milkfish are usually caught on the reef plateau or ‘kena’ to the west of Moturaka and the pass south of Arutanga

Pass. The season for trevallies follows the bonefish and milkfish season and extends between October to January. Between December and February, there is a major recruitment of juvenile surgeonfish and rabbitfish along the western side of Aitutaki, followed by a major spawning migration of adult fishes.

Decline of giant clam stocks

Aitutaki has long been noted for the dense populations of the small giant clam *Tridancna maxima* found in the lagoon. During the 1980s, however, there was a massive decline in the population of giant clams. The decline in the clam population was blamed variously on over-fishing, recruitment failure or residual agricultural pollution from the period when bananas were grown on Araura, however, overfishing was certainly a major factor.

During the period of peak clam abundance in the early and mid-1980s, exceptionally large numbers of clams were occasionally harvested for visiting church groups and dance troupes from other islands. This was in addition to the usual subsistence harvest and export of clam meat to Rarotonga. It is estimated, for example, that in that one visiting dance troupe from Mangaia visited Aituaki in the early 1980s and left with the meat from about 140,000 clams, much of which was lost at sea.

During our observations it was clear that juvenile clams were present in the lagoon, especially in the western side, something which had not been particularly evident during a previous SPC field study in 1992. With restrictions on harvesting over the past few years, particularly for *tere* parties, it appears that the decline in giant clam stocks has at least been slowed, and that there is optimism for the future, particularly with the large number of new juveniles being produced by the hatchery, both of local and introduced species.

Giant clam introductions

One thousand juvenile (12 to 18 month old) Tridacna derasa (giant clam) were introduced to Aitutaki from the Micronesian Mariculture Demonstration Center in Palau in 1986. To date a total of 100 adult T. derasa have survived at an average length of 33 cm at nine years of age. The majority of mortalities were experienced during the first six months of the lagoon-nursery phase due to the poor monitoring precedes this resulted in very high mortalities which were mainly caused by infestations of the locally-present predatory snail, *Cymatium muricinum*. (O. Terekia. pers. comm).

T. derasa was first spawned at the Araura Marine Research Station in 1991. No records are available on the total numbers of *T. derasa* produced during the spawning, or which were placed at the lagoon-nursery. In January 1995 there were a total of 27 *T. derasa* remaining, at 3 years of age with an average length of 18 cm. The production of hatchery reared juvenile *T. derasa* is currently underway.

A total of 11,000 *Hippopus hippopus* were introduced from James Cook University, Australia in 1991. A high mortality rate was experienced during the hatchery grow-out stage, but no records are apparently available on the history, (survival, mortality, growth etc) of the introduction. There are now a total of 55 *H. hippopus* remaining, with an average length of 9 cm at 4 years of age.

In 1991 20,000 *Tridacna gigas* were introduced from JCU and, like the other introduced clams, no records are available. Approximately 50% (128) of the remaining *T. gigas* were measured recently. The average length was 18.5 cm (sd * 3.6 cm) at 4 years of age.

Ciguatera incidence & management

Following the recent high incidence of ciguatera fish poisoning cases from Tikioki in Rarotonga, there was also an increase in reports of a similar problem at Aitutaki. Ministry staff have received training in monitoring water samples for *Gambierdiscus toxicus* - probably the main causative organism in ciguatera fish poisoning - and are preparing to take samples in Aitutaki as a result of the concern expressed. The ciguatera "hot-spot" is said to be the lagoon and reef near Arutanga, south of the main passage on the western side of the island.

Mild ciguatera outbreaks are notoriously difficult to pinpoint, since many cases go unreported they are not considered to be enough of a problem to warrant special medical attention and, since no cure is possible (although mannitol treatment is promising, and undergoing clinical trials), many Pacific Islanders resort to traditional medicines rather than hospitals. Reporting tends to increase in line both with the severity of the outbreak and with publicity, as possibly followed the extensive newspaper coverage of the Rarotonga outbreak.

During the household questionnaire survey, several questions were included about ciguatera fish poisoning. Thirty one per cent of the respondents said that someone in the household had fish poisoning sometime in the past (Note: this does not mean that 31% of the total population of the island has suffered fish poisoning, and many respondents specified only one member of the family who had eaten that fish, or who was affected, nor was any time period specified). Most of them could state which species was responsible, and only 5 could not say where it was caught because it was a fish they had not caught themselves. The species identified as being responsible for poisoning were *maito* (*Ctenochaetus striatus*) 8 cases, trevally (usually big) 7 cases, *iroa* (*Lethrinus miniatus*) 5 cases, moray eel 5 cases, and grouper 3 cases. The other species cited at one case each were kauvaa (*Epinephelus* sp) , hapuku (*Epinephelus microdon*), "tunnel fish" (?), stonefish (this was poisoning after eating, not a sting, but may have been venom rather than ciguatera), maori wrasse, "kirieva" and *tupa* (*Cardisoma carnifex*, land crab - obviously not ciguatera). Although at least one of these cases is definitely not ciguatera fish poisoning, this is balanced by the fact that two of the respondents had eaten poison fish more than once (one twice and one three times).

Although more cases were reported from fish caught in the Reureu/Arutanga area (8), there were several cases from fish caught in the Amuri lagoon (5) and from the north-eastern reef around Mangere and Popua (5). There were a further 2 cases from fish caught on the north of the island and the rest were scattered around the lagoon.

Significantly, all of the black surgeonfish *(maito)* cases were from the lagoon immediately around the main port, either north or south, whilst the trevally cases were scattered around with no apparent pattern. *Maito* are very site-associated fish, whilst trevally are highly mobile, so this pattern is not inconsistent with a single "ciguatera hot-spot" around the port, if the trevally had previously been feeding in that area. All of the *iroa* (emperor) cases where respondents were able to identify the area fished were also from near the port or the main passage, and these fishes are also fairly site-associated (although not to the extent of *maito*). The moray cases were scattered around the lagoon, both from the lagoon close to the main passage and the motus. Although moray eels are fairly site-associated, they are also one of the most consistently ciguatoxic of fish and probably poisonous at a much higher rate all around the lagoon.

The survey did not ask when the poisoning occurred, but "have you or your family ever become sick after eating seafood"? Thus we cannot say whether these cases are recent or not. However, several people volunteered that the cases had occurred within the past year or two. The ease with which most people remembered the species and the place it was caught may suggest a recent history, but if cases of individual poisoning are fairly rare (and there were only two people who admitted to being poisoned more than once) they would tend stick in the memory for a long time.

Note that a low incidence of individual ciguatera poisoning cases does not necessarily mean there is a low incidence of ciguatoxic fish, since local people will tend to avoid these fish and places once known. There is a well-known problem when people have to eat fish that is unknown in origin or type or season, as occurs with non-subsistence fisheries (particularly when fish are shipped from one place to another for sale, or the tourist hotel catering), and thus have no chance of using local knowledge to avoid poisonings.

Species checklist and local names

A checklist of fish species on Aitutaki was compiled during this survey and from other sources such as Sims (1993) and Baronie (1995) (Appendix I). The species list is duplicated in Appendix I with the fish sorted first by Aitutaki name and then by scientific name to assist with translation from one nomenclature to another.

Recommendations arising from the first survey

Given the amount of pessimism commonly expressed about the state of the Aitutaki lagoon fishery, the fieldwork here, compared against similar work done in other Pacific Islands, did not give a picture of a heavily overfished resource. Based on the estimate of the reef area from planimetry (51 km^2) and the annual finfish harvest computed from catch data (250 t/yr) and fish consumption (300 t/yr), the reef fish yield from the Aituaki lagoon was thought to lie of 5-6 $t/km^2/yr$. By comparison with other locations in the Pacific this is only a moderate exploitation and much lower than the 15 to 20 $t/km^2/yr$ which is thought to be the sustainable finfish yield for Pacific reefs (Dalzell & Adams 1996). However, there are definitely problem fisheries, such as bonefish, milkfish and giant clam, and probably localised depletions by spearfishing along the outer edge of the east reef, and almost certainly changes in the quality of lagoon water and circulation patterns over the past 30 years, but the immediate judgment would be of a fishery that is, taken as a whole, fully sustainable under current patterns of usage. This opinion of course may be modified as work proceeds over the next 12-18 months, but there appears to be plenty of cause for optimism.

It is difficult, given the current state of the art of stock assessment and the limited operational resources available to the Ministry, to give absolute figures on the status of the fisheries, but it is easier, particularly for outsiders who have surveyed many similar fisheries in other islands, to make a judgment about the status of stocks relative to those other places. Much of the pessimism about the Aitutaki fishery stems from the definite facts that this is the second most heavily populated of the Cook Islands, that the lagoon is very shallow and thus likely to be particularly susceptible to disturbance, and that the fish catch has been assumed to be much higher than it probably actually is. This high level of estimated catch stems from the 1978 survey sponsored by FAO of selected landings by artisanal fishing in the islands of the Southern Cooks (see above), which estimated that the artisanal catch for Aitutaki in 1978 was nearly 800 tonnes, or 325 kg per head of population. This contrasted with estimated landings per head of 16 kg in Rarotonga, 56 kg in Mangaia, 17 kg in Atiu, 74 kg in Mitiaro and 52 kg in Mauke. Unfortunately the methodology of the survey was not described, so it is impossible to judge the reliability of this estimate[3]. However, it contrasts strongly with the household survey described here, and the previous surveys by Munro (unpublished) and Baronie (1995), the combination of which are consistent with a total catch around the more reasonable figure of 300 tonnes or 100 kg per head, with the additional proviso that household surveys often over-estimate catch.

Given the generally stable nature of the overall lagoon fishery, with the caveat that work will continue to provide more detail on this, it would be most productive to concentrate any management measures on specific fisheries in urgent need of attention, either for reasons of commercial interest or for reasons of overfishing, as follows:-

Trochus: The trochus fishery at Aitutaki is probably more rigorously managed than any other in the Pacific. As a result, Aitutaki has been able to maintain a good commercial fishery where many other countries are struggling under a burden of over-harvesting. The Aitutaki trochus fishery has been considered at length in previous work (see Nash et al, 1995) and little needs to be said here save that the linkage between the Ministry of Marine Resources and the Island Council may need to be formalised to avoid any misunderstandings about respective responsibilities. Too many issues seemed to “fall through the cracks” during the November 1995 harvest, particularly the enforcement of size limits and the reserve. A draft management plan was drawn up in 1992 and could be the basis for such a formalisation, but it may be more desirable to retain the present flexible relationship as long as understanding is good. The trochus management issue is considered at more length later, in the report of the second survey.

Giant clams (Paua): This is another fishery where some good management measures are in place, but more in response to past overfishing episodes than to the need to maintain a commercial fishery. The Aitutaki Fisheries Protection Bylaws came into force at the end of 1990 with bag limits and restrictions on taking clams out of Aitutaki. It is clear now that many more juvenile giant clams are to be seen in the lagoon than in the recent past, particularly in places like the Amuri foreshore where they have not been seen for years, but it would be some time before *Tridacna maxima* becomes so dense on coral heads that it is difficult to avoid cutting your feet, as it was said to be 25 years ago. Given the stories told about the large amounts of clams given to *tere*[4] parties from other islands, it is likely that a strong restriction on this type of export would be a major factor in rehabilitating *paua* stocks. There is not much information about the potential recovery rates of giant clam populations, but if the current Aitutaki recovery is a result of the Island Council restrictions (rather than the result of a

[3] As stated earlier, some interesting statistics in the report include the catching of 25 tonnes of shellfish by lines and 8 tons of sea-cucumber, urchins and seaweed in nets at Aitutaki.

[4] Visiting dance troupes, or other groups such as church parties, youth or women’s groups

chance successful recruitment episode after several years of recruitment failure) then it appears that giant clam populations can show signs of recovery in a relatively short space of time, rather than the 20-odd years often assumed.

Bonefish (Kiokio). The powers are in place to enable the Island Council to manage much of the *kiokio* fishery, if it ever becomes rehabilitated, through powers to restrict the use of gillnets. However, the most immediate problem is the apparently very low level of the stock, particularly the schools that used to migrate around known areas of the lagoon. The most effective and enforceable management measure to impose at the outset would be a total ban, or a traditional *raui*, on taking bonefish for a period of three years, and see what happens. Apart from being a particularly sought-after local food-fish, it is possible that tag-and-release bonefish fishing could be a significant tourist attraction if the stock recovered to a sufficient extent (see Whitford & Guinea, 1993). Although bonefish can be specifically targeted by hook and line tackle by local fishermen observing the sand stirred up by bonefish feeding in the lagoon (and thus avoided), a significant number are taken by gillnets, particularly those set across passages in the barrier reef, and would be unavoidably be taken as a bycatch of the subsistence fishery. If restrictions are to be effective without a lot of administrative machinery a total ban on landing bonefish would be the most effective mechanism, but the question remains would fishermen be willing to throw them back, if caught during normal gillnetting? It appears that much of the population, in contrast to the general acceptance of the *paua* restrictions, is not observing the gillnet restrictions brought in by the Aitutaki Fishery Protection Bylaws at the end of 1990, particularly the requirement for people to remain close to nets whilst they are set. The bonefish issue might be used to stimulate a more general awareness of the desirability of some of these restrictions, particularly if fishermen occasionally were forced to discard bonefish.

If a total ban is impracticable, then a ban on landing (or possessing, for the purposes of easier enforcement) bonefish in and around the spawning season, say from August to November, would probably be the next most effective step, since bonefish are most vulnerable to mass fishing during their spawning aggregations.

Milkfish (Ava). Milkfish are another species which are locally sought-after, but where some restrictions may be necessary to rehabilitate the *ava* stock. Both milkfish and bonefish juveniles are found within the Ootu lagoon, so the protection of this area from disturbance will be an important part of maintaining any recovery. Again, a general ban on taking milkfish for a two or three year period would probably be the most effective and enforceable way of giving the stock some breathing space, but again, this is a fish which can also be taken in gillnets. It is probably impracticable to ban gillnets given their importance in quickly putting food on the family table and, as experience has shown, the restrictions that are in place are not particularly well-respected.

As with bonefish, if a total ban on landings is impracticable, a restriction during the spawning season would be the second best alternative. Assuming that conditions are Aituaki are similar to Tahiti, the milkfish spawning season at Aitutaki is probably similar to bonefish (Miharo, 1991).

Parrotfish (Pakati). There was not as much concern voiced about parrotfish as there was about bonefish and milkfish during the household survey. There is no export of parrotfish from Aitutaki at the present time, and the commercial production is locally marketed but, given the predilection of Cook Islanders for this family of fishes, and the demand for parrotfish in Rarotonga, it would be wise to watch commercial development and to be prepared for the future. The survey work on Palmerston Island (Preston et al., 1988) led to management recommendations for the parrotfish fishery, and many of the same principles would be applicable to Aitutaki, should the need arise.

Outer reef-slope fishes. The stocks of large snappers and groupers on the outer reef slope are probably not a major concern, given the size and amount of the fish that are regularly landed. There can be a noticeable decline in observed abundance after a series of heavy spearfishing episodes, but outer reef-slope fishing tends to be concentrated on the eastern and northern faces of the reef, in the lee of the prevailing winds, and the extensive windward reefs form a potential reserve for eventual replenishment. Heavy commercial spearfishing, particularly at night, can take a large toll on the larger predators, like the groupers, but is the only reliable way (apart from using gillnets) for catching herbivores such as parrotfish. The main recommendation here would be for MMR to keep a close eye on this fishery and to monitor abundance of the larger predators along a known stretch of reef, and on trends in commercial sales, size frequencies and exports. If these fish show signs of a continued decline in abundance or average size, then future remedial action might include restrictions on fishing at night and the extension of reserve areas along the outer reef face, or rotating area restrictions.

SPC - MMR 1996 SURVEY

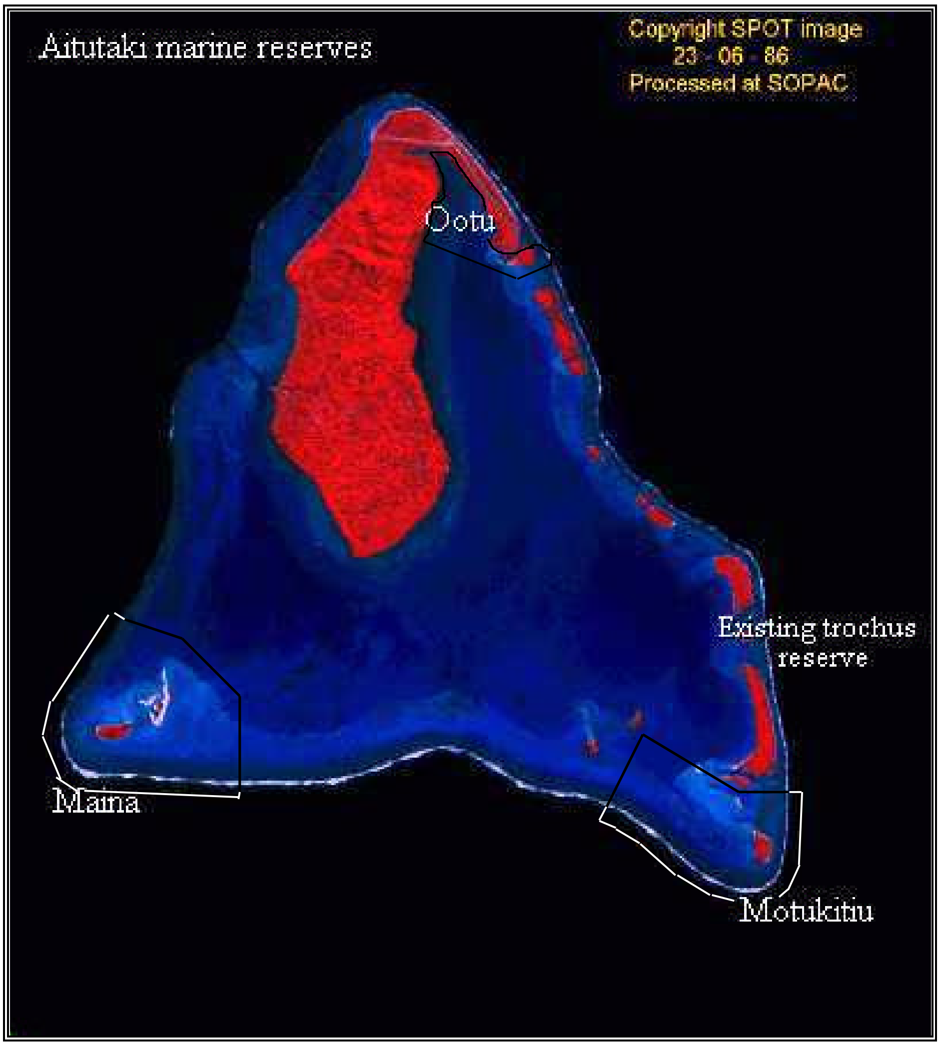
Introduction

The 1995 ICFMaP survey had concentrated on a broad-brush assessment of finfish resources and of fishing activity across the island. This was followed up in 1996 with some additional work on invertebrate resources, particularly trochus, and a meeting with the Island Council to discuss the implementation of some of the recommendations that had been suggested as a result of the first survey, and to support some of the existing local initiatives.

The ultimate intention at the start of the sub-project had been to produce a comprehensive management plan for the lagoon fishery, to be implemented jointly by the Island Council and the Ministry of Marine Resources. However it was becoming clear that the steady downsizing of the Ministry – the result of national economic restructuring - would severely limit the local technical capacity to implement the monitoring required by such a plan. There was general agreement that future management activities would be best concentrated on four key issues:- the introduction of several "no-take" marine reserve areas; more effective limitations on the use of gillnets; the integration of the Araura hatchery into the tourism development plan, and the identification of commercial alternatives.

In terms of development, apart from tourism and local food security, the main existing economic potential at Aitutaki is the trochus shell fishery, and there is possibly immediate potential in the export of bêche-de-mer. The fieldwork in this second survey was thus intended to look specifically at these resources.

In the time since the first survey the Island Council and the Ministry made considerable progress in addressing several issues. Draft bylaws defining the marine reserves had been drawn up and the Ministry had performed baseline assessments of the reef fish in the proposed reserve areas. A grant was obtained from New Zealand ODA to improve the hatchery for the benefit of visitors, and the giant clam seed production at the hatchery was greatly increased.



Trochus resource survey and harvest recommendations

The fieldwork in the first week concentrated on trochus, both to supplement the 1995 ICFMaP suvey, which had concentrated on fin-fish, and to provide an opinion to the Ministry and the Island Council about the status of the stock and the possibility of another harvest. The methodology followed the form of the standard trochus assessment described in detail in a report on the 1992 trochus harvest (Nash et al 1995). However, a “stripped-down” procedure has now been adopted, using 6 transects of 50m length at each site instead of the previous 100m transects, which enables two or three sites to be surveyed in a day, instead of the previous 1-2. The zonation of trochus across the reef crest and back-reef slope is well enough known by now that 50m transects can be placed across the zone of highest abundance. Accuracy is halved, since the survey area is only half that of the 100m transects, but accuracy is so low under the transect method anyway that this is of little import. The main idea was to provide an opinion on the state of the stock, and then use the mark-recapture method during the harvest to measure abundance extremely accurately, should that be required.

The most notable finding is that recovery of the stock from the last (October 1995) harvest has apparently been much faster than after the previous harvest (August 1992). The abundance actually seems to be higher than before the harvest (according to the transect survey of January 1995), and there appear to be several very highly-recruited year-classes (perhaps from spawning in 1992/3) moving through the population age-structure, following some years of poorer recruitment around 1989. The survey results will be compiled together with all available data from previous years to see if this hypothesis is provable. Trochus niloticus appears to be fairly dependent on shallow water for good juvenile survival - the best abundances are usually found on reefs which are almost dry at low tide and which have many rocks sticking up above the surface, or a very convoluted topography. It is possible that the slight average sea-level change during an El Nino event may be enough to affect recruitment, and many Pacific Island countries experienced poor trochus harvests in the early 1990's. It is possible that there was a common climatic cause for all this, and the data from Aitutaki is the only reasonably comprehensive time-series available to test this correlation. If we can predict good and bad trochus harvesting years based on climatic cycle predictions it will be useful for several countries.

Another notable aspect of the trochus data is the zonation of age-structure around the barrier reef at Aitutaki. Several surveys now have confirmed that the northern part of the northeast face of the reef (centred on E'e motu) has an unusual density of juvenile trochus. Some very small shells (down to 25 mm) were seen on this trip. It is known that there is a net seawater flow from the southeast to the northwest across the lagoon, and there is likely to be an eddy around the Ootu lagoon where the water cannot escape easily around the northern tip of the island. This may concentrate trochus settlement on the barrier reef at this spot.

The trochus abundance estimate (see Appendix V) suggested that the Island Council could call a harvest immediately, to take around 1 container (17 tonnes) of cleaned trochus shell, and still remain within the fairly conservative management plan guidelines. Politically, it was extremely useful both for the Ministry and the mayor to pass on this optimistic recommendation to the Council, to balance the more pessimistic measures (gillnet bans and reserves) that were to be promoted.

Although a trochus harvest was not called immediately in 1997, a harvest the following year, in 1998, yielded 32 tonnes of shell, resulting in around CI$200,000 in "windfall income" directly earned by every family on the island, whilst still falling well within the rule of thumb for sustainability of 1 container per year (presuming normal recruitment during the previous 2-3 years).

Bêche-de-mer (rori) fishery prospects for Aitutaki.

Four commercially-used species of bêche-de-mer were noted at Aitutaki during this series of surveys. Unfortunately, none of these are of the highest value, and the most plentiful, lollyfish (*Holthuria atra*, rori toto), is only of marginal value even in countries where large-scale bêche-de-mer processing is carried out. However, the surf redfish (*Actinopyga mauritiana,* rori puakatoro), is of medium value and present at Aitutaki in marketable quantities, whilst the greenfish (*Stichopus chloronotus*, rori matie), of low commercial value, is also present in reasonable numbers. The prickly redfish (*Thelenota ananas*, ngata), whilst of good value, was rarely seen.

So, whilst the Cook Islands are never likely to be a major bêche-de-mer exporting nation for geographical reasons (fewer and lower value species are found towards the Eastern Pacific, and densities are never high around small islands), it is possible that a small, intermittent commercial fishery would be financially viable, based primarily on surf redfish.

At Aitutaki, the harvesting and the management of surf redfish, with some greenfish and lollyfish to make up the balance of the shipment, are unlikely to be a problem, particularly if the harvesting and management are carried out in the same way as the methods currently applied to the trochus fishery. But the processing is likely to be the main constraint on viability. The processing of bêche-de-mer takes several days, and is a skill that takes some time to acquire. Experience in other countries has shown that the initial shipments from areas new to bêche-de-mer processing often receive low prices due to low quality and spoilage, yet Aitutaki does not have a large enough resource to afford too many mistakes. Bêche-de-mer buyers often have to put a considerable effort into teaching processing methods, and may be unwilling to give this proper attention if (as is the case) only a small and intermittent harvest is to be expected.

In short, the development of a commercial fishery is possible, but it may require considerable effort to set it up (as well as processing training, it is likely to require the production from several islands to make up one shipment), and the returns may not be worth it unless local labour is plentiful and the need for foreign exchange great.

Commercial-grade bêche-de-mer like surf redfish shrink to less than 10% of their fresh weight after processing. Marginal value species like greenfish and lollyfish shrink much more, due to their thinner body walls. According to experiments carried out in 1989 by the Ministry, the average rori puakatoro after processing would weigh around 50 grammes (down from 600 grammes wet weight). It thus takes around 20 surf redfish to make 1 kilogramme of exportable bêche-de-mer, and would take many more lollyfish or greenfish.

We have heard that areas which have plenty of freezers available may be able to market bêche-de-mer frozen, simply after boiling and gutting, but we have yet to see actual examples of this and do not know what sort of market is available. The price per kilogramme may be much lower than dried bêche-de-mer, and the overheads much higher (freezer container or airfreight rather than container), but since bêche-de-mer lose over 90% of their weight during drying, the undried frozen shipping method may give a better return per animal and involve less labour (as well as use less fuel-wood).

As a rule of thumb, surf redfish tend to be found in the same part of the reef as trochus (although more confined to the surf zone than trochus) and at approximately the same density as trochus. Greenfish are found more often on the back-reef, and lollyfish are at their greatest density close to shore, although they are also found all through the greenfish range as well. During the 1992 trochus survey counts were also kept of bêche-de-mer within trochus transects laid within the Amuri trochus fishing zone (bêche-de-mer counts were not continued in other areas once it was realised that surf redfish were present at approximately the same density as trochus, and because it slowed down the trochus survey). Surf redfish were present at an approximate density of 500-800 per hectare. Greenfish were present at less than 20% of the density of surf redfish, and lollyfish were found at over 3,000 per hectare. All these density estimates were from an area within a band 100m back from the surf zone into the lagoon, with surf redfish more prevalent on the surf side and the lower value species on the lagoon side. As with trochus, surf redfish do not appear to be found much seaward of the surf zone, unlike Rarotonga. Near the beach at Amuri the lollyfish density was in the region of 50,000 per hectare, but surf redfish and greenfish were not present.

Assuming that the area of available surf redfish habitat at Aitutaki is 400 hectares (slightly less than the figure of 463 hectares (4,627,200 square metres, including the reserve) of available trochus habitat used in calculating the trochus quota), we might very roughly expect there to be over 300,000 surf redfish present on the reef at Aitutaki. At 50 grammes each after processing, these surf redfish, if the entire stock was harvested at once, would produce around 18 tonnes of dried bêche-de-mer. For a sustainable fishery one might expect to take around a third of the standing stock per year, which would provide a sustainable harvest of 6 tonnes per year.

This is a conservative estimate, based on the 1992 data for the Amuri area. A more wide-ranging survey of surf redfish, covering more reef sites, was carried out in this present 1997 survey, and estimated an average of over 900 animals per hectare across the majority of the available habitat.

6 tonnes is nowhere near enough to fill a container, which is why several islands would have to group their harvests together to fill a container of surf redfish, or Aitutakeans would have to process large amounts of other low-grade species, with a much higher shrinkage factor (and the tendency to fall apart during boiling, in the case of greenfish), to make up a shipment. Luckily bêche-de-mer, if properly processed and stored, can keep for some months.

At the time of the survey, the latest export prices were not available to hand, but the selling price for surf redfish per kilogramme is likely to be more than the price of trochus. Unlike trochus, the largest sizes are preferred and receive a higher price per kilogramme than smaller grades. In Tonga, during the ICFMaP study at Ha'apai in May 1996, grade A surf redfish (dried, as bêche-de-mer) were being purchased by the local trading outlet for 9-10 pa'anga per kilogramme (the pa'anga is equivalent in value to the Australian dollar). Many bêche-de-mer dealers in Fiji and Tonga have now also started processing bêche-de-mer themselves at a central location, to ensure a consistent quality, and for this were buying good-sized surf redfish fresh, unprocessed, for 1 pa'anga (each if large, or per kilogramme if average). A container holds perhaps 16-17 tonnes of bêche-de-mer, so a container of processed surf redfish would thus be worth around A$160,000.

Given the newness of this fishery to the Cook Islands (although bêche-de-mer used to be processed in the last century) it would probably be best for the processing to be carried out at one central point in Aitutaki by the buyer, employing local people from several villages until the method is learnt. As mentioned, if production from Aitutaki is to be sustainable, each harvest of surf redfish would only fill around one third of a container.

If it is decided to start up a bêche-de-mer fishery, it is recommended that the fishery be managed in much the same way as trochus, with a short open season every 18-24 months. This could either be at the same time as the trochus season, or interspersed with trochus one year and bêche-de-mer the next. It is likely that the rori open season would have to be longer than the trochus season, because the animals take longer to process, in which case a fairly close eye would have to be kept on the number harvested to see that the quota was not exceeded. The quota could be assessed in much the same way as trochus, at the same transect sites, by MMR staff surveying the area for one week each year. It is impractical to impose size limits on live sea-cucumber because of their plastic morphology, but it might be wise to have some system to return obviously small animals to the reef, if only to maintain the value of the harvest. Small animals fetch much less on the marketplace.

Commercial or political pressure to increase the size of the harvest should be resisted until more is known about how these animals respond to fishing. The recent history of the bêche-de-mer trade in Melanesia is one of incessant overfishing, with large areas being wiped out in a short space of time, and exports only being maintained (for a short period), by shifting to areas further and further afield. Almost nothing is known about the biology of rori puakatoro, since scientific work has concentrated on higher value species. If it is found to have a short life-cycle then it may be possible to increase the harvest ratio, but this will only be evident after watching the fishery over several harvest cycles. Aitutaki has provided a good example to the rest of the Pacific with its comparatively finely-tuned management of the trochus fishery (see Nash et al, 1995 and Adams (in press)), and if the rori harvest can be managed along similar lines Aitutaki would be in a position to demonstrate the Pacific's first sustainable bêche-de-mer fishery.

Export restrictions

One fishery management measure that was considered by the Island Council and the Ministry during 1996 was the possibility of prohibiting the export of reef fish from Aitutaki, and this was discussed with the SPC team during the second field survey.

Per-trip individual export quotas already apply to Giant Clams, Asaphis, and Turban snails (maximum of 20 each, per person, under permit issues by the council), and this might be extended to fish as well, perhaps initially for non-Aitutakeans. However, it was suggested by the SPC team that, given the stringency of the other measures already proposed, this extra measure would be unnecessary. It would require a great deal of enforcement effort, and the "export" of reef fish for personal use does not threaten the resource very much compared to the large quantities of shellfish that used to be taken out of Aitutaki by tere parties during the 1980s, and for which an export restriction was definitely justified. It was felt that there might be a danger of jeopardising the whole management plan if too many restrictions were attempted at once, particularly a restriction like this that is likely to be strongly resisted.

Gillnet Restrictions

There was an initial discussion between the Mayor, the Ministry and SPC to explore the possibilities for addressing the perceived gillnet problem. There have been by-laws in place since 1990 to enable the Council to restrict the length, placement and soak-times of gillnets (see Appendix IV), but these have not been well-observed or easy to enforce. It is felt (and it is almost certainly true) that a complete ban on the use of gillnets within the lagoon would be easier to enforce than trying to continuously monitor mesh sizes and restricted zones. The anti-gillnet feeling has gradually been growing since the abrupt decline of the bonefish stock in the 1970s and 80s and now appears to be widespread enough to make compliance with a ban possible. There are several factors which suggest that any hardship caused by a ban on the use of gillnets on the island would be outweighed by the benefits:-

- The economy of the island is becoming more and more dependent on tourism and less on commercial fishing – and a good stock of fish in the water is likely to yield much more financial benefit than fish in the net. The existence of such a ban would also be of great, if intangible, publicity value in itself, since there are few such areas in the Pacific Islands.

- Although reef fish taste better according to many Aitutakean palates, there is a good supply of pelagic fish (even occasional oversupply) to local markets, taken from sustainable sources, so local nutrition is unlikely to suffer. Reef-fish would still be available using less wholesale fishing methods, and the handline fishery would almost certainly improve as a result.

- One of the Fiji ICFMaP subprojects dealt specifically with assessing the results of a locally-initiated ban on gillnet fishing on the Macuata coast (Ledua et al 1996). It concluded that there was a substantial benefit to the ban, both economically due to the restructured higher-quality fishery, and to subsistence fishing by more traditional methods.

If such a ban were approved by the Island council, it would preferably be phased in gradually over a period of about 18 months, starting with restricting the ownership of gillnets to one per household and preventing the importation of new gillnets to the island. It is hoped to find the funding to finance a buy-back scheme to initially retire this excess gear. At the end of 18 months a complete ban would be declared.

It was initially estimated that $20-30,000 would be needed to finance the buy-back scheme. However, the ICFMaP phase I household survey estimated that about 65% of the approximately 450 fishing households on Aitutaki owned gillnets, and that gillnetting households owned an average of 2.25 nets each - an estimated total of 630 or so gillnets. If a used gillnet is assumed to be worth around $50, and that 345 nets need to be bought back to restrict it to one per current gillnet-owning household (630 nets minus 285 gillnet-owning households), then a minimum of $17,250 would be needed for the buyback.

This is a very approximate estimate, based on a sample of only 20% of the households on the island. Some families may also decide to allow all of their gillnets to be bought back. To buy back all the gillnets on the island at a standard price of $50 would require approximately $31,500. These estimates agree well with the initial guesstimate of $20-30,000. Additional funds would also be needed to install extra fish-aggregation devices to assist displaced commercial fishermen.

This issue was discussed briefly during the Island Council meeting (see following section) and met with general approval. However, further action would depend on the availability of funds for the buy-back, which to date have not been found despite trying out a project funding proposal on several potential sources of assistance in 1997, including WWF. The general response from potential donors seemed to be that this should be a local expense, borne by those with most to gain from the ban. Ironically, those with most to gain would be the traditional fishing community, which does not generate income.

Island Council Meeting

A meeting of the Island Council was called to discuss both the ICFMaP advice and issues concerning the lagoon generally. The following discussion is presented according to the agenda.

Aitutaki Island Council Meeting
Special session on Aitutaki lagoon marine resources
Monday, 3rd February 1997

I. Background to South Pacific Commission's (SPC) Integrated Coastal Fisheries Management Project (ICFMaP) by SPC Fisheries Programme Manager

After an introduction by the Mayor, Julian Dashwood briefly ran through the philosophy behind the SPC/UK Integrated Coastal Fisheries Management Project, to assist SPC member countries to develop management measures to promote the sustainability of specific fisheries, and to work on economic alternatives where necessary. He stressed that SPC was only present in an advisory capacity to the Ministry, and that all decisions were the prerogative of the Island Council.

II. Summary of work done to date by Ministry of Marine Resources and ICFMaP on the status of Aitutaki lagoon fisheries

Tim Adams provided some general background to previous ICFMaP work at Aitutaki, and outlined the major findings and recommendations of the November 1995 fieldwork. He noted the general consensus on the decline of the lagoon fishery resources and, whilst the survey work indicated that the lagoon food fishery was probably sustainable in terms of overall fishable biomass (Aitutakeans consume around 100kg of fish per head per year, and take about 300 tonnes of fish overall from the reef and outside), that the more desirable species were definitely overexploited and in urgent need of effective maintenance. These included milkfish (*ava*), the larger parrotfish (*pakati*), bonefish (*kiokio*), giant clams (*pa'ua*), mud-crabs and others. He suggested that there was still the opportunity to rehabilitate these fisheries if effective action, along the lines that the Council already seemed to the thinking, were to be taken immediately. It was already proven that Aitutaki was capable of effective action, since the Aitutaki trochus fishery is considered to be the best-managed trochus fishery in the Pacific.

III. Issues for discussion:-

A. General marine management issues:

1. Aitutaki marine reserves

The Island Council was unanimous in its support for the reserve areas in principle, and it only remained to discuss and settle the exact boundaries in negotiation with the people. The Mayor was keen to "fast-track" this issue, and it appears likely that the three official reserves will be implemented before the end of the year.

The main problems are the question of whether or not to include the motu Maina within the southwest reserve area, or to allow a corridor for boats to approach it. Maina is a common landing spot, but people would not be able to land if they had been fishing elsewhere in the lagoon, because the proposed by-law prohibits gear aboard any boat within the reserve area. There was also some question about including the small passage within the reserve, since this might need to be used by fishing boats. On the Motukitiu side, the minimum boundary was agreed, but the Tautu people were interested in extend the reserve over an even larger area, from Rapota to Akaiami. At the Ootu lagoon site it was still being considered whether or not to include the resort motu Akitua within the area. Akitua is a sensitive subject at the moment following the Government sell-off of the resort.

ICFMaP agreed to provide some more information about the way in which fishing reserves are organised in other parts of the world, and to advise on the justification of by-laws and any papers to the Executive. It was mentioned that the fishing reserves at Apo in the Philippines are said to have resulted in a 50% increase in catch to surrounding areas following a 20% closure of fishing grounds, although this improvement was in a fishery that is far more heavily overfished than Aitutaki, and took 5-7 years for the full benefit to be felt. However, Aitutaki should see much sooner benefit in terms of tourism, since effective marine reserves were few and far between in the Pacific Islands. This would also be interesting to aid donors as well.

Dialogue New Zealand, the organisation which NZ ODA uses to implement the Cook Islands tourism masterplan, has arranged for a first draft of some additional by-laws under the Aitutaki Fisheries Protection by-laws, calling this new section "Fishing Development Reserves". The main instrument would be a new by-law 19, empowering "the Council from time to time to designate areas of the waters of Aitutaki, Manuae and Te Au O Tonga to be fishing development reserves." Implementing by-laws include a prohibition on the taking of any fish within these reserves, that the reserves override any permits issued by the Council for the taking of otherwise restricted species, and immediately defining the three reserves already discussed. The Council had added a suggestion for an additional regulation to make enforcement easier, which would prohibit boats entering the reserve with fishing gear aboard. ICFMaP suggested some alterations to this, making it an offence for a person to possess fishing gear or fish, or to have fishing gear or fish aboard a boat, within the reserve, in the interests of easier enforcement.

2. Gillnets

The mayor introduced this issue by pointing out that the existing gillnet by-laws were half-hearted, were difficult to enforce, and were thus almost universally ignored. There was agreement by the entire council that the use of gillnets within the lagoon should be phased out, starting with a ban on the import of nets. However, the ways in which this should be done were not yet clear.

The SPC Fisheries Programme Manager suggested that it would be almost impossible to prevent the import of gillnets to Aitutaki without a general ban on the import of nets to the Cook Islands by Customs, and that the scheme discussed previously with the Mayor, for an immediate buy-back of all nets excess to one per family, followed by a complete ban in 12-18 months, was likely to be the most effective. The estimate based on the ICFMaP fishing gear survey, that a buy-back scheme could be implemented for NZ$20-30,000 was mentioned, and that there was potential to obtain this funding from a donor source.

ICFMaP suggested wording for a short additional by-law that would make it an offence for gillnets to be used that were not tagged annually by the Council. This would enable a gradual restriction to be more easily enforced.

3. Export of lagoon fish

There was little discussion under this agenda item. Most councillors seemed to feel that this measure was unlikely to be immediately necessary on top of the gillnet restrictions and the reserves, and that it would be little complied with.

B. Specific marine resource issues

1. Trochus

The results of the latest MMR/SPC survey were presented, along with the opinion that the Council could call a harvest, with a total allowable catch of 17-18 tonnes, in the near future if it wished, in view of the strong year-classes that were appearing within the fishable size limit “window”. Unless another poor recruitment period occurred (for which it was necessary to continue the annual stock assessment), it should be possible to regularise harvesting to take one container full every 18 months.

The need to pick and choose the best shells (8-11 centimetres diameter, with no worm-scars) to maximise the value of the harvest was stressed, and it was agreed that the Individual Transferable Quota (ITQ) system should continue as it appeared to alleviate most of previous rush to get shells in before the TAC was reached (and the consequent high percentage of poor quality shells).

The Mayor said that the Council would handle the entire marketing operation next time, to avoid giving a cut to a middleman. A little time would be needed to explore markets before declaring the harvest.

2. Bêche-de-mer - rori

ICFMaP presented the results of the survey to the Council, that the only bêche-de-mer species with any good commercial prospect at Aitutaki is the surf redfish (*Actinopyga mauritiana, rori puakatoro*). There was plenty of lollyfish and greenfish in the lagoon, but this would not be worth the effort of processing, until perhaps the market price got a bit better. Based on this, and two previous reconnaissance surveys in 1988 and 1992 which agreed well, it was suggested that a sustainable annual harvest level would be in the region of 6 tonnes processed weight. Although the first harvest of the virgin stock could possibly take up to 10 tonnes it was felt that a maximum level ought to be instituted immediately to prevent undue expectation, and to provide some leeway for statistical uncertainty in assessment.

There was some discussion of the best way to handle the processing side, perhaps using one central processing point at the copra dryer for 3 months of the year, rather than trying to teach processing at every village. The mayor mentioned one recent approach by a potential buyer in Rarotonga who had apparently offered $1 per kg for prickly redfish, and wanted 200kg immediately. ICFMaP pointed out that the buying price for surf redfish in Tonga was 9-10 pa’anga (=A$) per kg, and prickly redfish was slightly more. And that 200kg of prickly redfish would probably come near wiping out the stock of this erratically-occurring species at

Aitutaki. Some background was given on the state of the world market and the extremely high demand and continually rising prices that make this a seller's market. Aitutaki can afford to wait for a good opportunity.

3. Giant clams - pa'ua, and future of hatchery

MMR outlined the current hatchery programme, involving reef-reseeding of giant clams in Aitutaki and other islands (including Pukapuka, Palmerston and Rakahanga), as well as a start to exploring the commercial prospects. A survey of shops and restaurants suggests that there is a demand for 200kg per week of clam meat in Rarotonga, and that there would be prospects for people in Aitutaki to set up grow-out farms for hatchery-reared clams to supply this market in future. Esaroma Ledua provided some background on the giant clam hatchery in Fiji, and suggested that Aitutaki should also explore the USA aquarium market, since this takes smaller clams for a much higher price, particularly if they are of certain colours. Julian Dashwood pointed out the advantages that Aitutaki would have in this market, which can only take certified hatchery-reared clams due to CITES (Convention on International Trade in Endangered Species) restrictions. The Mayor pointed out that foreign exchange was now a priority for the Cook Islands.

The hatchery had also received a grant from NZ ODA under the tourism master plan, to tidy up the hatchery and develop its suitability for taking parties of tourists on guided tours. Additional species were being spawned, particularly trochus, as a fall-back against years of poor recruitment in the natural stock, as natural algae-scrubbers for the clam tanks, and for stocking other places, such as Manuae.

The Mayor said that there were often misunderstandings about the hatchery (such as the recent complaints from Aitutakeans about clams being given to other islands but apparently requiring payment in Aitutaki), and that it would be good for the Ministry to regularly update the Council. Given some problems recently with potential farmers placing their clams in unsuitable habitats, he suggested that the hatchery should also provide some written guidelines for potential farmers, to avoid getting the blame for any failures.

Julian Dashwood provided some general background on the philosophy of the hatchery, which had been set up under his tenure as Secretary for Marine Resources, explaining that the fundamental aim was to repopulate natural stocks in the Cook Islands, rather than farming, but that the hatchery would naturally develop income-earning opportunities where it could.

Ian Bertram said that although there appeared to be some recent natural recruitment of *Tridacna maxima* within the lagoon, there were still not many large animals around of the type needed for broodstock, and that*T. squamosa* was rare. The Council agreed that some large clams could be obtained from Manuae for broodstock purposes.

C. Manuae

It was suggested that the Council consider making the entire reef a reserve, particularly as an example to Aitutakeans of what to aim for in the reserves on Aitutaki. Julian Dashwood said that although there was pressure to earn income, and that Manue might be considered by some to be an untapped source of resources, the Manuae lagoon was very small and easily devastated.

D. Ideas for education, public awareness and publicity about Aitutaki lagoon

The Mayor outlined his ideas for educational trips to Manuae, educational videos on the local TV station, and more attention to schoolchildren generally. SPC mentioned that one of the outputs of this ICFMaP subproject, as well as the technical reports and advice, would be a more easily digested booklet about Aitutaki lagoon fisheries and their management, in English and Aitutaki Maori. SPC also offered to explore the possibilities of getting educational resource materials from other organisations, and the prospects for including the Aitutaki reserves as one of the global weekly news-feed items under the 1997 International Year of the Reef campaign.

E. Compliance and enforcement of by-laws and Council decisions about Aitutaki marine resources

There was a brief discussion centering on the difficulties of the enforcing the existing gillnet regulations, compared with the good compliance experienced with the trochus harvest measures. The Mayor mentioned the reluctance of the Police to enforce the fisheries protection by-laws, and perhaps the need to have an independent enforcement unit. The Council agreed that there was little point in setting up regulations and not following-through, and that regulations needed to be as easy to comply with as possible (which in turn requires that all measures are fully discussed with the people and agreed to).

IV. Priorities for action - (what is possible now and what is more difficult?)

The Council agreed that the first priorities were to get the additional by-laws for reserves in place, and to eliminate gillnets from the lagoon, and that this needed to be supported and followed-up by educational programmes. The Mayor suggested that it would be a good idea to get a joint activity going between the Ministry of Marine Resources, Conservation and the Council, to provide support and advice during Councillor’s meetings in the village to discuss these issues.

V. How to implement priority decisions? (fishery management plans, by-laws, proposals for outside assistance, publicity etc.). Possibilities for help from SPC, MMR & other organisations.

By this time, the implementation of these decisions had become fairly obvious, so discussion was minimal under this agenda item. The action towards the reserve by-laws and some educational programmes was already being taken, and further actions required a little more discussion and agreement with the people, and the exploration of assistance from different specialised organisations.

The SPC Fisheries Programme Manager said that the report from the ICFMaP Aitutaki sub-project would be submitted to the Council through the Ministry as soon as it was finished (probably before the end of the month), and would be available to assist the Council in preparing any documentation or justification required to implement these meaures. SPC also offered to photocopy its library of technical documents about Aitutaki for the benefit of the Council, and to explore funding prospects for monitoring the reserves, and gillnet buyback/alternative fishery (FAD) schemes with other organisations.

VI. Other Issues

The issue of lagoon siltation was raised, to see if ICFMaP or the Ministry had any advice to give. Tim Adams said that this was outside the ambit of the South Pacific Commission, but that SOPAC had produced a recent report on coastal protection after a brief survey of Aitutaki. He said that all the evidence suggested that certain parts of the lagoon were indeed getting shallower, and that this would probably have some influence on fisheries and coral inside the lagoon. He pointed out though that it was not certain if this was a long-term trend, or a decadal-scale cyclic event. The morphology of Aitutaki barrier reef and the motus appears to be strongly influenced by cyclones, which push coral blocks and sediment over the reef, blocking some gullies and opening others. It was even possible that the next big cyclone might reverse the trend and start fears of coastal erosion. IFREMER in Tahiti made a study of the effects of Cyclone Betty on Aitutaki lagoon using satellite photos. It might be possible to compare a recent satellite photo with those from the late 1980's to measure the extent of any siltation.

At the winding-up of the session, the SPC Fisheries Programme Manager thanked the Mayor and the Council for a most productive meeting, and felt that the Council would be making its mark on the history books if it managed to implement even half of these far-sighted proposals.

The Mayor said that this had been one of the most interesting Council sessions that they had had in recent times, and was particularly pleased by the concrete alternatives that had been put forward by MMR and ICFMaP. He felt that with this advice they could realistically aim for the goal of maximum production with minimum damage.

Conclusion

The recommendations made as a result of this series of fieldwork and discussions are presented piecemeal above for the advice of those in charge of assessing and managing the marine resources of Aitutaki. Inevitably, since implementation depends so much on local political considerations and changing circumstances, it is difficult for a regional project to do more than advise and encourage.

The major finding of the survey component of this project is that, apart from some definite problems with individual species fisheries, overall the Aitutaki fishery is in good shape under the existing community management regime. Specific measures to address individual problems have been identified, discussed, and are in the process of implementation if not already in place.

It has not been possible for the Cook Islands Government to formally legislate a complete management plan covering every species in the lagoon, as was the initial aim of the project (a more ambitious aim that any of the other ICFMaP subprojects, which concentrated on specific fisheries), but drafting such a plan would not be difficult at this stage. However, the best management plans evolve through negotiation, testing, and re-negotiation and do not necessarily spring forth fully-fledged within the time-limit imposed by a project cycle. The current strategy of implementing individual components of management within the current operational constraints appears to be working well, certainly by comparison with other Pacific Island fisheries. It may be preferable to leave the legislation of a comprehensive plan, drawing together all the workable measures, several years down the track. The SPC Marine Resources Division would be ready to assist with this whenever called upon.

Indeed, the progress made at Aitutaki under its forward-thinking Mayor, with the dynamic assistance of several young fisheries officers, has been remarkable. Hopefully, the political will to consolidate these gains will continue, and Aitutaki will continue to be an example of positive action to other Pacific Islands facing similar problems.

Encouragingly the Mayor of Aitutaki feels that the best long-term protection for the marine resources of Aitutaki lagoon is in public education, particularly for the younger generation. This might include organising parties of schoolchildren (and even adults) to visit Manuae and see what Aitutaki lagoon was like 30 years ago, whilst encouraging them to restore it to that state. He feels that the education system is gravely lacking in marine awareness in the junior curriculum, and hoped to screen videos regularly on the local TV network. The South Pacific Regional Environment Programme (SPREP), with its public education programmes, may be of assistance here, particularly in the provision of videos and general awareness literature.

On a more specific level, as well as producing this technical report for the benefit of Cook Islands fishery managers, SPC will also produce more accessible and concise documents for the benefit of the fishing community and tourists at Aitutaki, to illustrate the marine resources, their importance, and the management measures that are in place.

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APPENDIX I. Scientific, local and common names for fishes observed at Aitutaki

Aituaki name	Scientific name	Common name	Aituaki name	Scientific name	Common name
A'uru	*Parupeneus barberinus*	Dash-and -dot goatfish	Maomao	*Abudefduf lorenzi*	Demoiselle
A'uru kiokio	*Parupeneus barberinus*	Dash-and -dot goatfish	Apiapi	*Acanthurus guttatus*	Whitespot surgeonfish
A'uru puaka	*Parupeneus bifasciatus*	Two barred goatfish	Ikutoto	*Acanthurus nigricans*	Whitecheek surgeonfish
A'uru puaka	*Parupeneus cyclostomus*	Yellow saddle goatfish	Rai	*Acanthurus sp*	Black surgeonfish
Aa'i	*Thunnus sp*	Tuna	Manini	*Acanthurus triostegus*	Convict tang
Angamea	*Lutjanus bohar*	Twinspot snapper	Manini	*Acanthurus triostegus*	Convict tang
Apiapi	*Acanthurus guttatus*	Whitespot surgeonfish	Ikutoto	*Acanturus achilles*	Achilles tang
Atea	*Epinephelus fasciatus*	Black-tipped grouper	Marmari	*Aethaloperca rogaa*	Redmouth grouper
Ature	*Selar crumneophthalmus*	Big-eye scad	Tamanu	*Aetobatis narinari*	Spotted eagle ray
Aumauri	*Scarus altipinnis*	Filament-finned parrotfish	Kiokio	*Albula neoguinica*	Bonefish
Aupa	*Coris aygula*	Clown coris	Patiki	*Bothus mancus*	Peacock flounder
Ava	*Chanos chanos*	Milkfish	U'u moemoe	*Calotomus carolinus*	Bucktooth parrotfish
Avarua	*Scarus microrhinos*	Steephead parroffish	Kokiri pae	*Cantherhines dumerilii*	Barred filefish
I'e	*Hemiramphus spp*	Halfbeak	Iputurau	*Caranx sp*	Jack
I'e	*Sphyraena acutipinnis*	Sharpfin barracuda	Paoa	*Caranx sp*	Jack
Ikutoto	*Acanthurus nigricans*	Whitecheek surgeonfish	Taupoko	*Caranx sp*	Jack
Ikutoto	*Acanturus achilles*	Achilles tang	Titiara	*Caranx sp*	Jack
Ikutoto	*Naso lituratus*	Orangespine unicornfish	Tuatao	*Caranx sp*	Jack
Iputurau	*Caranx sp*	Jack	Urua	*Caranx sp*	Jack
Iroa	*Lethrinus xanthochilus*	Yellowlip emperor	papera	*Carcharhinus amblyrhynchos*	Grey reef shark
Kanae	*Crenimugil crenilabis*	Fringelip mullet	Taraoa roi	*Cephalopholis argus*	Peacock grouper
Karakarae	*Saurida gracilus*	Graceful lizardfish	Ava	*Chanos chanos*	Milkfish
Karakaraea	*Synodus dermatogenys*	Sand lizardfish	Kopirpoiro	*Cheilinus chlorourus*	Floral wrasse
Karaoa	*Gymnothorax javanicus*	Giant moray	Maratea	*Cheilinus undulatus*	Napoleon wrasse
Karore	*Thalassoma spp*	Wrasse	Koiro	*Conger cinereus*	Moustache conger
Katoti	*Stegastes nigricans*	Dusky farmerfish	Aupa	*Coris aygula*	Clown coris
Kiokio	*Albula neoguinica*	Bonefish	Mai mai	*Coryphaena hippurus*	Dolphin
Kiriva	*Lutjanus semicinctus*	Half-barred snapper	Kanae	*Crenimugil crenilabis*	Fringelip mullet
Kivari	*Herklotsichthys quadrimaculatus*	Gold spot herring	Maito	*Ctenochaetus striatus*	Striped bristletooth
Koina	*Epinephelus caeruleopunctatus*	Snowy grouper	Totar pae	*Diodon hystrix*	Porcupinefish
Koiro	*Conger cinereus*	Moustache conger	Totara	*Diodon hystrix*	Porcupinefish
Kokiri	*Rhinecantus aculeatus*	Picassofish	Va'aroa	*Enchelynassa canina*	Viper moray
Kokiri pae	*Cantherhines dumerilii*	Barred filefish	Kopiropiro	*Epibulus insidiator*	Sling-jaw wrasse
Koma	*Mulloides flavolineatus*	Yellowstripe goatfish	Marari	*Epibulus insidiator*	Sling-jaw wrasse
Komuri	*Seriola spp*	Amberjack	Koina	*Epinephelus caeruleopunctatus*	Snowy grouper
Kopeti	*Gymnothorax meleagris*	Whitemouth moray	Atea	*Epinephelus fasciatus*	Black-tipped grouper
Kopiropiro	*Epibulus insidiator*	Sling-jaw wrasse	Patuki	*Epinephelus hexagonatus*	Hexagon grouper
Kopirpoiro	*Cheilinus chlorourus*	Floral wrasse	Taroa	*Epinephelus hexagonatus*	Hexagon grouper
Ku ku	*Sargocentron diadema*	Crown squirrelfish	Ngatara	*Epinephelus socialis*	Tidepool grouper
Ku ku	*Sargocentron ittodai*	Samurai squirrelfish	Papa	*Fistularia commersoni*	Cornetfish
Ku ku	*Sargocentron melanospilos*	Blackspot squirrelfish	Taraki	*Gnathodentex aurolineatus*	Yellowspot emperor
Ku ku	*Sargocentron microstoma*	Finelined squirrelfish	Tarakii	*Gnathodentex aurolineatus*	Yellowspot emperor
Kuta	*Sargocentron sp*	Squirrelfish	Varu	*Gymnosarda unicolor*	Wahoo
Kuta	*Sargocentron spiniferum*	Long-jawed squirrelfish	Karaoa	*Gymnothorax javanicus*	Giant moray
Lai rotea	*Hipposcarus longiceps*	Pacific longnose parrotfish	Kopeti	*Gymnothorax meleagris*	Whitemouth moray
Maemae	*Siganus sp*	Rabbitfish	I'e	*Hemiramphus spp*	Halfbeak
Maemae	*Siganus spinus*	cribbled rabbitfish	Kivari	*Herklotsichthys quadrimaculatus*	Gold spot herring
Mai mai	*Coryphaena hippurus*	Dolphin	Lai rotea	*Hipposcarus longiceps*	Pacific longnose parrotfish
Maito	*Ctenochaetus striatus*	Striped bristletooth	Rai mamarenga	*Hipposcarus longiceps*	Pacific longnose parrotfish
Mamaringa	*Scarus sp*	Parrotfish	O'opu	*Katsuwonus pelamis*	Skipjack
Manini	*Acanthurus triostegus*	Convict tang	Pipi	*Kyphosus bigibbus*	Insular rudderfish
Manini	*Acanthurus triostegus*	Convict tang	Pipi nanue	*Kyphosus cineracsens*	Highfin rudderfish
Maomao	*Abudefduf lorenzi*	Demoiselle	Mu	*Lethrinus obsoletus*	Yellowstripe emperor
Mapoto	*Myripristis sp*	Soldierfish	Iroa	*Lethrinus xanthochilus*	Yellowlip emperor
Marari	*Epibulus insidiator*	Sling-jaw wrasse	Angamea	*Lutjanus bohar*	Twinspot snapper
Maratea	*Cheilinus undulatus*	Napoleon wrasse	Tangau	*Lutjanus fulvus*	Flametail snapper
Marmari	*Aethaloperca rogaa*	Redmouth grouper	Tangua	*Lutjanus fulvus*	Flametail snapper
Maru	*Triaenodon obesus*	Reef whitetip shark	Kiriva	*Lutjanus semicinctus*	Half-barred snapper

Aituaki name	Scientific name	Common name	Aituaki name	Scientific name	Common name
Miro	*Platybelone platyura*	Keeled needlefish	Mu	*Monotaxis grandoculus*	Bigeye emperor
Moi	*Polydactylus sexfilis*	Sixfeeler threadfin	Mu tara	*Monotaxis grandoculus*	Bigeye emperor
Morava	*Siganus argentus*	Forktail rabbitfish	Rakoa	*Mullidae*	Goatfish
Mu	*Lethrinus obsoletus*	Yellowstripe emperor	Koma	*Mulloides flavolineatus*	Yellowstripe goatfish
Mu	*Monotaxis grandoculus*	Bigeye emperor	Vete	*Mulloides flavolineatus*	Yellowstripe goatfish
Mu tara	*Monotaxis grandoculus*	Bigeye emperor	Takua	*Mulloides vanicolensis*	Yellowfin goatfish
Nato	*Valamugil engeli*	Engel's mullet	Vete	*Mulloides vanicolensis*	Yellowfin goatfish
Ngatara	*Epinephelus socialis*	Tidepool grouper	Mapoto	*Myripristis sp*	Soldierfish
Nou poaki	*Syanceia verrucosa*	Stonefish	Ume	*Naso lituratus*	Orangespine unicornfish
Nou taraoa	*Scorpaenosis oxycephala*	Tassled scropionfish	Ikutoto	*Naso lituratus*	Orangespine unicornfish
O'opu	*Katsuwonus pelamis*	Skipjack	Ume	*Naso unicornis*	Bluespine unicornfish
Ono	*Sphyraena barracuda*	Great barracuda	Ume	*Naso unicornis*	Bluespine unicornfish
Ono	*Sphyraena genie*	Blackfin barracuda	A'uru	*Parupeneus barberinus*	Dash-and -dot goatfish
P'ao	*Scarus sp*	Parrotfish juv	A'uru kiokio	*Parupeneus barberinus*	Dash-and -dot goatfish
P'ao p'ao	*Scarus sp*	Parrotfish	A'uru puaka	*Parupeneus bifasciatus*	Two barred goatfish
Pakati	*Scarus bowersi*	Bower's parrotfish	A'uru puaka	*Parupeneus cyclostomus*	Yellow saddle goatfish
Pakati	*Scarus flavipectoralis*	Yellowfin parrotfish	Miro	*Platybelone platyura*	Keeled needlefish
Pakati	*Scarus forsteni*	Forsten's parrotfish	Moi	*Polydactylus sexfilis*	Sixfeeler threadfin
Pakati	*Scarus frenatus*	Vermiculate parrotfish	Tataraiau	*Pterois radiata*	Clearfin lionfish
Pakati	*Scarus globiceps*	Roundhead parrotfish	Tataraiau	*Pterois volitans*	Lionfish
Pakati	*Scarus psittacus*	Palenose parrotfish	Kokiri	*Rhinecantus aculeatus*	Picassofish
Pakati	*Scarus rubrioviolaceous*	Redlip parrotfish	Ku ku	*Sargocentron diadema*	Crown squirrelfish
Pakati	*Scarus sordidus*	Bulletfish parrotfish	Ku ku	*Sargocentron ittodai*	Samurai squirrelfish
Pakati	*Scarus sp*	Parrotfish school	Ku ku	*Sargocentron melanospilos*	Blackspot squirrelfish
Paoa	*Caranx sp*	Jack	Ku ku	*Sargocentron microstoma*	Finelined squirrelfish
Papa	*Fistularia commersoni*	Cornetfish	Kuta	*Sargocentron sp*	Squirrelfish
papera	*Carcharhinus amblyrhynchos*	Grey reef shark	Kuta	*Sargocentron spiniferum*	Long-jawed squirrelfish
Patiki	*Bothus mancus*	Peacock flounder	Karakarae	*Saurida gracilus*	Graceful lizardfish
Patuki	*Epinephelus hexagonatus*	Hexagon grouper	Aumauri	*Scarus altipinnis*	Filament-finned parrotfish
Pipi	*Kyphosus bigibbus*	Insular rudderfish	U'u koti	*Scarus bleekeri*	Bleeker's parrotfish
Pipi nanue	*Kyphosus cineracsens*	Highfin rudderfish	Pakati	*Scarus bowersi*	Bower's parrotfish
Rai	*Acanthurus sp*	Black surgeonfish	Pakati	*Scarus flavipectoralis*	Yellowfin parrotfish
Rai mamarenga	*Hipposcarus longiceps*	Pacific longnose parrotfish	Pakati	*Scarus forsteni*	Forsten's parrotfish
Rakoa	*Mullidae*	Goatfish	Pakati	*Scarus frenatus*	Vermiculate parrotfish
Rereau	*Zanclus cornutus*	Moorish idol	Uu	*Scarus frontalis*	Tan-faced parrotfish
Rereau	*Zebrasoma scopas*	Brown tang	Rotea	*Scarus ghobban*	Blue-barred parrotfish
Roro	*Scarus sp*	Parrotfish	Pakati	*Scarus globiceps*	Roundhead parrotfish
Rotea	*Scarus ghobban*	Blue-barred parrotfish	Avarua	*Scarus microrhinos*	Steephead parroffish
Rotea	*Scarus sp*	Parrotfish	U'u	*Scarus microrhinos*	Steephead parroffish
Takua	*Mulloides vanicolensis*	Yellowfin goatfish	Pakati	*Scarus psittacus*	Palenose parrotfish
Tamanu	*Aetobatis narinari*	Spotted eagle ray	Pakati	*Scarus rubrioviolaceous*	Redlip parrotfish
Tangau	*Lutjanus fulvus*	Flametail snapper	Pakati	*Scarus sordidus*	Bulletfish parrotfish
Tangua	*Lutjanus fulvus*	Flametail snapper	Mamaringa	*Scarus sp*	Parrotfish
Taraki	*Gnathodentex aurolineatus*	Yellowspot emperor	P'ao	*Scarus sp*	Parrotfish juv
Tarakii	*Gnathodentex aurolineatus*	Yellowspot emperor	P'ao p'ao	*Scarus sp*	Parrotfish
Taraoa roi	*Cephalopholis argus*	Peacock grouper	Pakati	*Scarus sp*	Parrotfish school
Taravano	*Tylosurus corcodilis*	Crocodile needlefish	Roro	*Scarus sp*	Parrotfish
Taroa	*Epinephelus hexagonatus*	Hexagon grouper	Rotea	*Scarus sp*	Parrotfish
Tataraiau	*Pterois radiata*	Clearfin lionfish	Vaia	*Scarus spp*	Parrotfish
Tataraiau	*Pterois volitans*	Lionfish	Nou taraoa	*Scorpaenosis oxycephala*	Tassled scropionfish
Taupoko	*Caranx sp*	Jack	Ature	*Selar crumneophthalmus*	Big-eye scad
Teatea	*Siderea picta*	Peppered moray	Komuri	*Seriola spp*	Amberjack
Tetu	*Sphyraena forsteri*	Blackspot barracuda	Teatea	*Siderea picta*	Peppered moray
Titiara	*Caranx sp*	Jack	Morava	*Siganus argentus*	Forktail rabbitfish
Totar pae	*Diodon hystrix*	Porcupinefish	Maemae	*Siganus sp*	Rabbitfish
Totara	*Diodon hystrix*	Porcupinefish	Maemae	*Siganus spinus*	cribbled rabbitfish
Tuatao	*Caranx sp*	Jack	I'e	*Sphyraena acutipinnis*	Sharpfin barracuda
U'u	*Scarus microrhinos*	Steephead parroffish	Ono	*Sphyraena barracuda*	Great barracuda
U'u koti	*Scarus bleekeri*	Bleeker's parrotfish	Tetu	*Sphyraena forsteri*	Blackspot barracuda
U'u moemoe	*Calotomus carolinus*	Bucktooth parrotfish	Ono	*Sphyraena genie*	Blackfin barracuda
Ume	*Naso lituratus*	Orangespine unicornfish	Katoti	*Stegastes nigricans*	Dusky farmerfish
Ume	*Naso unicornis*	Bluespine unicornfish	Nou poaki	*Syanceia verrucosa*	Stonefish
Ume	*Naso unicornis*	Bluespine unicornfish	Karakaraea	*Synodus dermatogenys*	Sand lizardfish

Aituaki name	Scientific name	Common name	Aituaki name	Scientific name	Common name
Urua	*Caranx sp*	Jack	Karore	*Thalassoma spp*	Wrasse
Uu	*Scarus frontalis*	Tan-faced parrotfish	Aa'i	*Thunnus sp*	Tuna
Va'aroa	*Enchelynassa canina*	Viper moray	Maru	*Triaenodon obesus*	Reef whitetip shark
Vaia	*Scarus spp*	Parrotfish	Taravano	*Tylosurus corcodilis*	Crocodile needlefish
Varu	*Gymnosarda unicolor*	Wahoo	Nato	*Valamugil engeli*	Engel's mullet
Vete	*Mulloides flavolineatus*	Yellowstripe goatfish	Rereau	*Zanclus cornutus*	Moorish idol
Vete	*Mulloides vanicolensis*	Yellowfin goatfish	Rereau	*Zebrasoma scopas*	Brown tang

APPENDIX II Continuous monitoring programmes for Aitutaki Lagoon Fishery

Introduction

During the first phase of the ICFMaP project in 1995, the Secretary of Marine Resources asked that a schedule for monitoring the status of resources, fisheries, and management to be drawn up. The SPC ICFMaP would maintain contact with Aitutaki MMR staff for the next 12-18 months, to assist in refining this schedule, and to provide advice on the analysis, interpretation and uses of the information collected, and this information would contribute towards the production of the fishery management plan, with the assistance of the Island Council in 1997.

Unfortunately it was not feasible for the Ministry to fully implement this continuous monitoring programme, because of the effects of government downsizing particularly on the outer islands technical staff complement, and it was possible only for certain aspects to be followed up (particularly the fish monitoring in the proposed reserve). However, the full recommendations are included here, as presented, for potential future reference and adaptation.

Aitutaki fishery monitoring

If it proves feasible and successful, this fishery monitoring and management programme would provide a case-study for extension to other Cook Islands in the future. The most important thing to bear in mind when considering the workload described in the following pages is that it should not take up a great proportion of MMR staff time and should fit in as well with normal activities as possible. In addition, there should be a clear, useful reason for doing the work, and that reason should be for the practical benefit of maintaining the long-term future of the Aitutaki lagoon fishery, not research for research's sake.

The following are items of information that will need to be gathered to describe and define fisheries, to identify fisheries in need of special management attention, to identify the most effective management strategies, and to monitor possible changes in fisheries.

Typical Catch Rates

> The catch rate of the average fisherman, using different types of gear or collection methods, is useful primarily as a "raising factor" against rapid appraisals of total fishing effort, such as counts of lagoonal fishing boats from the hilltop, to obtain an estimate of the total catch from the lagoon. Although it would be good to have as many different observations as possible to get a more meaningful average, this type of work does not have to be carried out continuously, but just long enough to get a representative sample.
>
> Catch rates (number and weight of fish per gear-use-hour (from boat) or per man-hour (in water)) are most effectively gained by accompanying fishermen on fishing trips, which can also provide a lot of incidental information to enable better interpretation of results, and local knowledge. Fisheries Officers should not feel guilty about going out fishing, as long as they are conscientious about writing down what they find out.

Failing this, people returning from fishing trips can be interviewed about the methods used and time spent fishing, and the catch weighed.

It is important to cover all fisheries, including reef-gleaning and any fisheries that are carried out specifically by women or children. The impression formed by the 1995 household survey was that women do not catch a great deal of fish or invertebrates, and often accompany their husband on trips rather than go out alone, but this is only an impression, and it is notable that women in some South Pacific subsistence fisheries have been proved to land more seafood than men when their work is actually quantified.

If trial spearfishing is done, to estimate biomass, this includes the implicit estimation of catch rates. However, it would also be useful for MMR staff to estimate the catch rates from ordinary spearfishing (where the catch is more typical). A data form pinned over the office freezer, where numbers, species and weights of fish, together with the time spent fishing and the number of spears, would encourage good reporting habits. Catch rate information would also emerge from any line-fishing tagging done.

One statistic that this survey did not attempt, since this management exercise is primarily for the lagoon subsistence fishery, is catch rates from fishing outside the reef. However, it would be very helpful to have such information, since much of the fish commercially sold would come from outside the reef.

Total Fishing Effort & Seasonal Trends

Some quick and easy method of estimating overall fishing activity from week to week would be useful to obtain an estimate of total catch and seasonality to check the result of the household surveys. Since 50% of the households on Aitutaki own a boat or canoe, a survey of boats out on the lagoon would cover a good percentage of the total fishing effort. A lot of the subsistence fishing takes place on Saturday, so it is important to spread observations over different days of the week. A quick bi-weekly binocular count from the top of Black Rock (at the same time of day each time) would provide information about fishing effort, overall trends in fishing effort with time, and the distribution of fishing across the lagoon. If it is possible to spot lights and underwater torches in use at night, then it would also be useful to check night fishing from the hilltop occasionally, if feasible.

It is already known that the largest number of people fish on a Saturday, especially those individuals with jobs in the Public Service or private enterprise. Observations should therefore aim to include Saturday and one day of the working week, probably Wednesday. Initially it would be useful to conduct counts for all days of the working week to see if indeed Wednesday is representative of the average day in the week.

The time of day counts are carried out will also be important as fishermen's decision to go fishing will be dependent on other factors such as tide and moon phase. If at all possible, it is suggested that counts be conducted in the morning an hour or two after dawn and in the evening an hour or two before dusk. This will catch most of the daily fishing activity during the working week and also the longer fishing trips made by people on the Saturday. The only drawback to this method is that the type of fishing activity being conducted from the canoe or dinghy will not always be obvious. Where possible observers should note down the type of fishing activity being conducted from the fishing vessel (ie spearfishing, netting, handline fishing). Naturally this will not be possible with boats at the limits of the lagoon but should be readily observable for vessels (or individuals on foot) nearer the main island.

It is not possible to observe the nearshore waters immediately south of the main island. Counts of these areas may have to be conducted from shoreline sites at other locations, such as the Tautu jetty in the east and from hr beach at Nikaupara in the west. Counts at these locations could follow the initial observations from the Black Rock but should not be too onerous a task and divert MMR staff from other station activities. The staff should be encouraged to develop their own system of observations based on their local knowledge of the geography of the islands and fishermen movements.

Certain types of fishing are not amenable to this sort of "remote sensing", and it would be necessary for MMR staff to use their local knowledge to estimate how many major fishermen there are in certain fisheries (such as mud-crab netting) and how often they go out. Further, experience on this trip has shown the value of conducting interviews with commercial or semi-commercial fishermen, who through long term association with a fish stock(s) can provide useful narrative accounts of changes in the absence of quantifiable data. Other individuals on the island who are long time regular fishermen should be contacted to record their impressions of change in the fishing conditions of the lagoon and immediate surrounding waters.

As the lagoon is being used increasingly for tourist related activities, the recreational aspect of the lagoon needs to be more fully described. The topics required include; the number of full time and part time operators who take tourists snorkeling in the lagoon, how many trips per week they make, the average number of tourists on each trips, departure point and places visited, fish feeding, conflicts with fishermen. Although some operators may take people fishing beyond the lagoon, do any of them currently take tourists fishing in the lagoon for bonefish and reef fish?

Fish Demand & Trade

The actual usage of fish and seafood will have a large bearing on the management plan, and is very useful in predicting what is likely to happen to certain fisheries. For example, as mentioned earlier, there is no point in promoting offshore fishing if there is already a glut of offshore fish on the market because people prefer lagoon fish.

The household surveys already carried out have given a good picture of household fish consumption, fish prices, and subsistence usage versus sale. However, circumstances change, and fish sales and export patterns can yield a great deal of information about the status of, or potential problems in, a fishery.

In this respect it would be useful to check market prices regularly, making a note if there is any changing trend for different species that is not obviously due to inflation. The species composition of the marketed catch is important, given the different mix of species used in commercial and subsistence consumption, and occasional descriptions should be made. It is not envisaged that Aitutaki MMR staff would be in a position to mount a regular full-scale market monitoring programme, but occasional documented samples would be useful.

The amount of fish and invertebrates leaving the island is an important, but currently unknown statistic (apart from trochus). Hand baggage is undocumented, but the "chilly bin" is a ubiquitous feature of Air Rarotonga flights out of the island, and fish freight records are not compiled. Possibly in conjunction with the people who normally act for the Island Council checking outgoing flights for illegal exports of giant clam, it should be possible to make an occasional questionnaire survey of passengers about any fish or seafood they are carrying, and to get records of any fish carried as air-cargo. Particular note should be taken of the type of gifts taken away by *tere* parties, and the incidence of such parties estimated. This again would not need to be a continuous exercise, but carried out enough times to get a representative sample, and to put together a realistic rough estimate of exports.

Effectiveness of Reserves in Enhancing Nearby Fishing

One of the objectives of this survey was to conduct a preliminary study of he effectiveness of tagging reef fish. Several areas of the lagoon have been proposed as fish sanctuaries, however, there is little information available on the movements of reef fish and effectiveness of marine reserves. Fish traps and line fishing were used to catch as wide a range of fish as possible. The trap catch rates were disappointing, with only 5 fish captured in the 10 days the traps were deployed. Experience has shown that traps set near shallow reefs in the Pacific will catch between 1-2 kg of fish in 4-5 days after being left to initially mature for about a month. This maturation process effectively means allowing alagal growth build up on the traps so that they obscure fish within the trap and thus act as a refuge for small herbivores such as parrotfish and surgeonfish.

Catches of mainly predatory fishes (serranids and wrasses) were readily made with fishing rods and even trigger fish, which normally eat coral would take a baited hook. Herbivorous fishes such as rabbitfish and surgeon fish might also be captured occasionally by this method. A total of 48 fish were captured by line fishing and tagged. The location of the tagging was recorded along with the species name and length to the nearest millimeter. Apart from information on movements of fish, the tagging exercise may also generate biological statistics on growth, mortality and abundance. The table below suggests that species such as *E. merra* can be readily caught and marked, and would be a useful subject to determine tag loss (through double tagging) and tag mortality, by catching 50-100 specimens, marking them and keeping them in the tanks at the Araure facility for observation.

For the tagging study to succeed, the project will need to be widely publicised on the island. This can be achieved by an article in the Cook Islands News, through posters and perhaps most importantly, through a MMR video to be broadcast on local television. A simple reward will be required to encourage fishermen to return tags or inform fisheries that they have caught tagged fish so that MMR staff can recover the tag and record the relevant information. MMR will have to reassure fishermen that all tag returns will be kept confidential in the event of reserves being legally established and illegal fishing taking place.

If the present research officer at MMR Araure facility takes up a masters scholarship at James Cook University of North Queensland in early 1996, then this will offer additional opportunities for further management-orientated research. Once a tagging study has been established, fish might also be additionally marked with tetracycline to estimate the rate of growth rings in the otoliths. This in turn will assist in validating age and growth estimation of reef fishes from the lagoon (and possibly outside the lagoon). Tetracycline is readily absorbed into the bones of fish and will fluoresce when viewed under ultraviolet light. Fish marked in this fashion thus have a convenient time marker from which to count subsequent growth increments on the otoliths.

Ciguatera Cases & Dinoflagellate Monitoring

The household study conducted in this survey revealed that at least one individual about one third of the households had been afflicted with ciguatera at some time in their lives. The results further suggest a ciguatera hotspot close to the main wharf. Given the recent training in ciguatera monitoring conducted by the James Cook University, it might be appropriate to carry out a survey of the densities of the causative organism, *Gambierdiscus toxicus*, both at the wharf and elsewhere.

We say "might" be appropriate, because there does not appear to yet be any good link proven between ciguatera outbreaks and the occurrence of this dinoflagellate. As with other places in the Pacific, local people are usually well aware of the sites where ciguatoxic fish occur, and local knowledge is probably more valuable than dinoflagellate surveys. However, the *G. toxicus* survey would confirm if the outbreaks are in fact associated with high concentrations of the dinoflagellate, and thus be of benefit not only to the Cook Islands but to the rest of the tropical Pacific. This is basic research and further resources should not be devoted to it if a link does not appear after a few trials.

APPENDIX III: PROFILE OF SURGEONFISH RESOURCES ON AITUTAKI

Introduction

A number of resources profiles have already been published by the Ministry of Marine Resources on the commonly exploited fisheries resources in the Cook Islands. One of the main features of shallow water fish stocks in Aitutaki were the surgeonfish. Observations on surgeonfish conducted during this study were combined with information from elsewhere in the Cook Islands and the Pacific to produce a profile of surgeonfish biology germane to their management in the Aitutaki lagoon.

The surgeonfish family includes the tangs, unicornfish and the sawtails. Surgeonfishes are characterised by a deep, oval or elliptical body, small terminal mouths and the presence of one or more pair of caudal (tail) spines. In the tangs there are only a single pair of retractable spines either side of the tail, while the unicorn fish have one or two pairs of fixed caudal plates. Further, many of the unicornfish develop a distinctive rostral (forehead) horn, convex foreheads, or a humped back, and many develop filamentous caudal lobes). The sawtails, which have up to six caudal plates are sub-tropical species and not found in the Cook Islands.

Surgeonfish range in size from species that rarely exceed 15 cm to those with maximum sizes approaching 100 cm. They are normally abundant in shallow lagoon waters close to coral reefs, in pools on the reef flat, in the surge zone on the reef crest and down to about 100 m on the outer reef slope. They are one of the more abundant of the reef fishes in the Pacific Islands both in terms of species diversity and in biomass on the reef. They are readily caught by spearing, in nets and traps, and can be induced to take a baited hook although they are not a common feature of hook-and-line catches. In most locations in the Pacific, surgeonfish form a major component of reef fish landings in both commercial and subsistence fisheries.

Surgeonfish species at Aitutaki

Sims (1993) lists 22 species of surgeonfish from either Aitutaki or the southern Cook Islands and these are summarised in Table 1.

Table 1. Summary of species of Surgeonfishes reported from Sims (1993) to occur on Aitutaki or in the islands of the southern Cook Islands

Scientific name	**Common name**	**Maori name**[1]	*Habitat*
Acanthurus achilles	Achilles tang	Maito tuitui	Lagoon, reef flats and outer reef slope
A. guttatus	Spotted surgeonfish	Maito	Surf zone
A. leucopareius	White-bar surgeonfish	Maito	Lagoon, reef flats and outer reef slope
A. lineatus	Blue-line surgeonfish		Shallow water on outer reef slope
A. mata	Elongate surgeonfish	Maito	>20 m on outer reef slope
A. nigricans	White-cheeked surgeonfish	Maito	Reef flats and outer reef slope
A. nigrofuscsus	Brown surgeonfish		Shallow lagoon back reefs

Scientific name	Common name	Maori name[1]	Habitat
A. nigroris	Blue lined surgeonfish		Shallow lagoon back reefs
A. olivaceus	Orange-epaulette surgeonfish	Maito	Lagoon, reef flats and outer reef slope
A. thompsoni	Thompson's surgeonfish		>20 m on outer reef slope
A. triostegus	Convict tang	Manini	Reef crest and outer reef slope
A. xanthopterus	Yellowfin surgeonfish		Lagoon, reef flats and outer reef slope
Ctenochaetus striatus	Bristle-toothed tang	Maito	Lagoon, reef flats and outer reef slope
Ctenochaetus strigosus	Goldring surgeonfish		Outer reef slope
Naso brevirostris	Short-snouted unicornfish	Ume	> 10 m depth on outer reef slope
N. hexacanthus	Grey unicornfish	Ume	>20 m on outer reef slope
N. lituratus	Painted unicornfish	Ume	Lagoon, reef flats and outer reef slope
N. unicornis	Green unicornfish	Ume	> 10 m depth on outer reef slope
N. vlamigii	Purple lined unicornfish	Ume	> 10 m depth on outer reef slope
Zebrasoma scopas	Brown tang		Lagoon, reef flats and outer reef slope
Zebrasoma veliferum	Sailfin tang		Lagoon, reef flats and outer reef slope

1. Where no explicit Aitutaki name is cited by Sims (1993) then the Rarotongan name is given

Biology

General

Surgeonfishes have a small terminal mouth with a single row of close set teeth. All have a long intestine characteristic of herbivorous fishes and the species of*Ctenochaetus* and several of the *Acanthurus* have a thick walled muscular gizzard-like stomach. Most of the tangs (*Acanthurus*, *Paracanthurus* and *Zebrasoma* spp) are herbivores feeding on micro and macro-algae growing on and around coral reefs, while many of the unicorn fish (*Naso*) feed mainly on zooplankton in the waters adjacent to coral reefs and on fleshy macro-algae.

Surgeonfish have been observed to form spawning aggregations at or around the full moon, usually on an ebb tide in areas such as reef passes where the current will wash the eggs out to sea (Thresher 1984). Surgeonfish have a long oceanic larval stage of between 2-3 months during which they grow to between 2.0 to 2.5 cm. and transform into a juvenile or acronurus stage. By this time the juveniles are ready to settle out on reefs. This may take the form of a sudden massive invasive settling of juveniles on to the reefs as has been observed with *Ctenochaetus* spp in India (Pillai et al 1983) and in American Samoa (R. Buckley, T, Buckley & D. Itano pers . comm.).

Pillai et al (1983) reported that in late September 1982 the reefs at Minicoy in the

Lakshadweep Archipelago, were overwhelmed with juvenile *Ctenochaetus strigosus* with an average size of about 6.5 cm total length. This massive invasive recruitment was preyed upon by reef predators such as groupers and even herbivorous species such as parrotfish were feeding on the juvenile surgeonfish. Two weeks after the initial invasive recruitment the numbers of *C. strigosus* had been reduced significantly and by early November the juveniles were observed intermittently in between dead corals in the lagoon.

In American Samoa during late February-early March 1985, sports divers encountered a large school of juvenile *Ctenochaetus striatus* moving in a large cylindrical formation heading towards reefs to the west of Pago Pago Harbour on American Samoa’s main island, Tutuila. At about the same time a large yellowfin tuna was caught from an fish aggregating device anchored about 5 km south west of Pago Pago Harbour with a stomach containing over 300 juvenile *C. striatus* with an average length of about 6.5 cm standard length. The juveniles settled out in a massive invasive recruitment on the reefs around Tuituila in early March and were observed for a three month period through regular transect counts. Densities declined from around 3.72 fish/m^2 in early March to 0.38 fish/m^2 in mid-June. These events happen periodically in the Samoas and are welcomed as ‘windfall’ of free food.

Recent work on ageing of surgeonfish from the Great Barrier Reef using annual marks on otoliths (Choat & Axe in press) has shown that they are relatively long lived fishes with life spans between 20 to 40 years where fishing mortality is minimal (Table 2). In areas where fishing mortality is significant, the same species may reach the same maximum sizes as in unfished areas but do not achieve the same longevities. Note in particular the differences in maximum lifespans between *Acanthurus lineatus* and *Ctencochaetus striatus* from the Samoas and the GBR. On the GBR, where fishing mortality for Surgeonfishes is zero both these species can achieve life spans in excess of three decades, while *A. lineatus* in American Samoa has a lifespan of 18 years and that of *C. striatus* from the same location is only 3 years. Both fishes are common in the inshore waters of both American and Western Samoa where fishing pressure from subsistence and commercial fishing is considerable.

Table 2. Recorded maximum size and estimated longevities for species of surgeonfish from the Pacific region which are also common to Aitutaki

Species	Location	Maximum size (cm)	Life span (yrs)	Fishing mortality	Reference
A. lineatus	Great Barrier Reef (GBR)	38	45	Zero	Choat & Axe (in press)
A. lineatus	American Samoa	24	18	Moderate to heavy	Craig et al (in press)
A. nigricauda	Papua New Guinea	25	5+	Moderate	Dalzell (1989)
A. nigrofuscsus	GBR	21	20	Zero	Hart & Russ (1996)
A. olivaceus	GBR	35	35	Zero	Choat & Axe (in press)
A. triostegus	Hawaii	18	5+	Moderate to heavy	Dalzell (1989) based on Randall (1961)
A. xanthopterus	Papua New Guinea	48	25	Moderate	Dalzell (1989)

Species	Location	Maximum size (cm)	Life span (yrs)	Fishing mortality	Reference
A. xanthopterus	Hawaii	50	25+	Aquarium specimens	Randall (1960)
Ctenochaetus striatus	GBR	26	35	Zero	Choat & Axe (in press)
C. striatus	American Samoa	21	2.5-3.0	Moderate to heavy	Ralston & Williams (1988)
Naso brevirostris	GBR	50	22	Zero	Choat & Axe (in press)
N. brevirostris	Fr. Polynesia	35	9-10	Moderate to heavy	Caillart (1988)
N. hexacanthus	GBR	75	42	Zero	Choat & Axe (in press)
N. unicornis	GBR	70	30	Zero	Choat & Axe (in press)
N. unicornis	Hawaii	65	20+	Aquarium specimens	Randall (1960)
N. vlamigii	GBR	55	42	Zero	Choat & Axe (in press)
Zebrasoma scopas	GBR	20	35	Zero	Choat & Axe (in press)

Biology of surgeonfishes at Aitutaki

Few observations have been recorded on the biology of surgeonfishes in the Cook Islands. Sims (1993) reports observations on a spawning aggregation of *Acanthurus guttatus* at Rarotonga, where a school gathered in Ngatanglia Passage two hours before sunset, two nights before full moon on the ebb tide. Individuals in the school exhibited typical spawning behaviour of circling, nudging and rubbing of abdomens, culminating in an paired upward rush where the gametes were released near the waters surface, intermingled and were dispersed on the tide. Sims also noted similar schooling behaviour in*A. triostegus* and *C. striatus* at the same location but did not observe actual spawning. Sims noted that during the breeding season (September-October) that *A. achilles* on Penrhyn is prized due to the accumulation of fat. Sims also mentions that *C. striatus* is implicated in fish poisonings on Atiu and Mitiaro as indeed is the case with this species in Aitutaki (see below). Massive recruitments of*C. striatus* and other juveniles such as rabbitfish (Siganidae) have been noted at Aitutaki in the summer months (January-March) and this season of juvenile abundance is known colloquially as *Tikomi*. Similar recruitment of surgeonfish in January and February has been noted in Penrhyn (Bertram, unpub. obs.)

From our observations conducted during the UVC counts and the experimental spearfishing it is clear that *C. striatus* is the dominant surgeonfish in the shallow lagoon back reefs of Aitutaki. About half of the fish in each of the UVC transects were surgeonfish, although only species belonging to seven families were enumerated. However, the amount of surgeon fish caught in the experimental spearfishing at Maina were surgeonfish both by weight (53.0 %) and numbers (54.5 %). A summary of the surgeonfish species composition from the spearfishing is given in Table 3. *C. striatus* accounts for about 95 per cent of all surgeonfish catches by number, but as this is one of the smaller species of acanthurids, it makes a smaller contribution to catch weight (85 %). Only two other surgeonfish species were caught, *A.*

triostegus and *N. lituratus*, accounting for between 2-3 per cent of catches by number, but the larger heavier *N. lituratus*, comprising proportionately more of the catch in weight (11.5 %).

The length frequency distribution of the 205 *C. striatus* is shown in Fig. 1. Few fish smaller than 130 mm were caught and the mean size and modal length of the distribution is around 150 mm. The length-weight equation for *C. striatus* at Aituaki is as follows:

$$Wt = 3.109 \times 10^{-6} (L^{3.404}) \quad (N = 204, r^2 = 0.88)$$

where Wt is total weight in grams and L is fork length (from snout tip to mid-point of lunate caudal tail) in millimeters. The length-weight scatter for *C. striatus* is shown in Figure 2.

Table 3. Species composition of surgeonfish catches from spearfishing in Aitutaki lagoon

	No	Wt (kg)	% No	% Wt
Ctenochaetus striatus	205	15.58	94.47	85.37
Acanthurus triostegus	5	0.57	2.30	3.12
Naso lituratus	7	2.10	3.23	11.51
Total	217	18.25	100.00	100.00

Resource

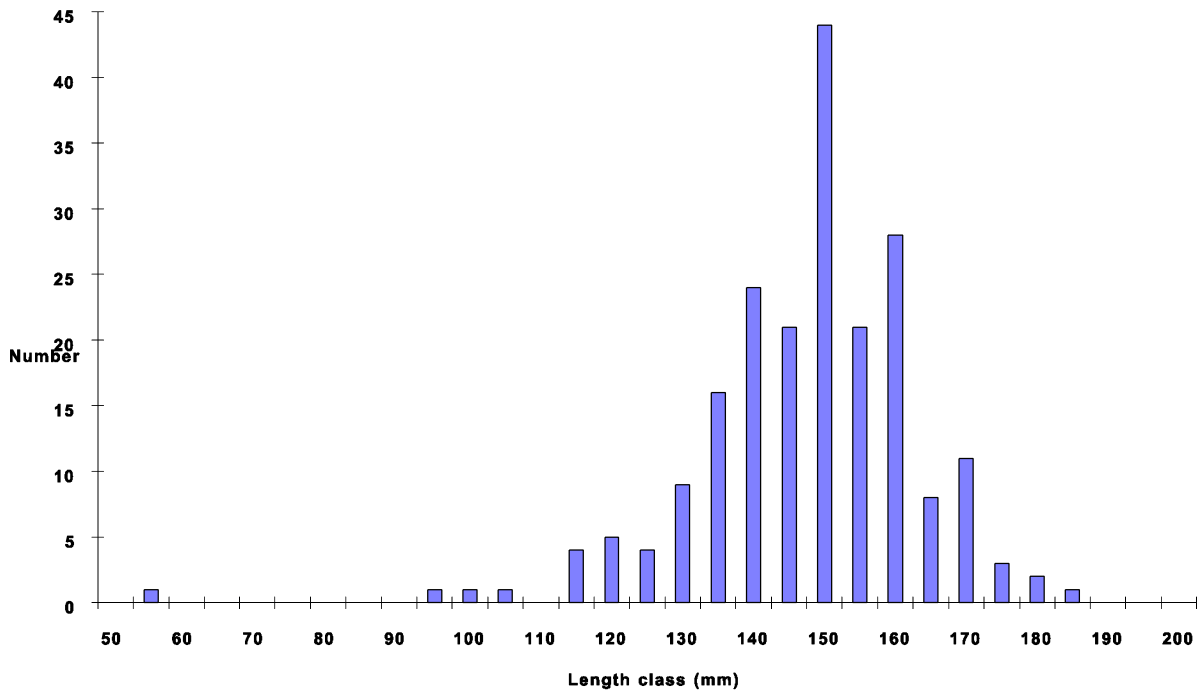

Figure 1. Length frequency distribution for *Ctenochaetus striatus* at Aitutaki

The surgeonfish density in numbers from UVC counts, raised to account for coral cover, showed reasonable agreement with density estimates of surgeonfish from the experimental spearfishing. This was not the case with the other six fish families enumerated during the UVC counts. A total of 305,000 surgeonfish/km^2 of reef were estimated from spearfishing at Maina and 388,235 surgeonfish/km^2 of reef from the adjusted UVC observations. Given an estimated 51km^2 of coral reef (both living and dead reef) inside the lagoon at Aitutaki then these figure suggest a population of 15.5 to 19.8 million surgeonfish on the lagoon reefs. From the spear fishing experiment the estimated total surgeonfish biomass in the fishing ground was 30.57 kg or 20.38 t/km^2 of reef. This translates to a total surgeonfish biomass of just a little over 1000 t, of which 85 per cent is likely to consist of *C. striatus*, assuming a similar mix of species as observed in the spearfishing for the whole lagoon.

Management

From our observations it is clear that surgeonfish are abundant in the lagoon and are caught mainly for subsistence use. Less than 10 per cent of the respondents in the household survey perceived a problem with catches of surgeonfishes from Aitutaki lagoon, suggesting that surgeonfish stocks are only subject to light to moderate fishing mortality. Baronie's (1995) study suggests that 15 per cent of landings from the lagoon are surgeonfish and given a total harvest of all fish from the lagoon of about 250 t/yr, this amounts to a total surgeonfish catch of about 37.5 t/yr. The only serious management problem that is posed by surgeonfish is the tendency for the most abundant species, *C. striatus*, to readily absorb ciguatoxins through its diet on calcareous algae, the preferred substrate for *Gambierdiscus toxicus*, the dinoflagellate believed to be responsible for this form ichthyosarcotoxism. Of the 33 cases of ciguatera that were reported during the survey, 8 of these (24 %) implicated *C. striatus* as the cause of

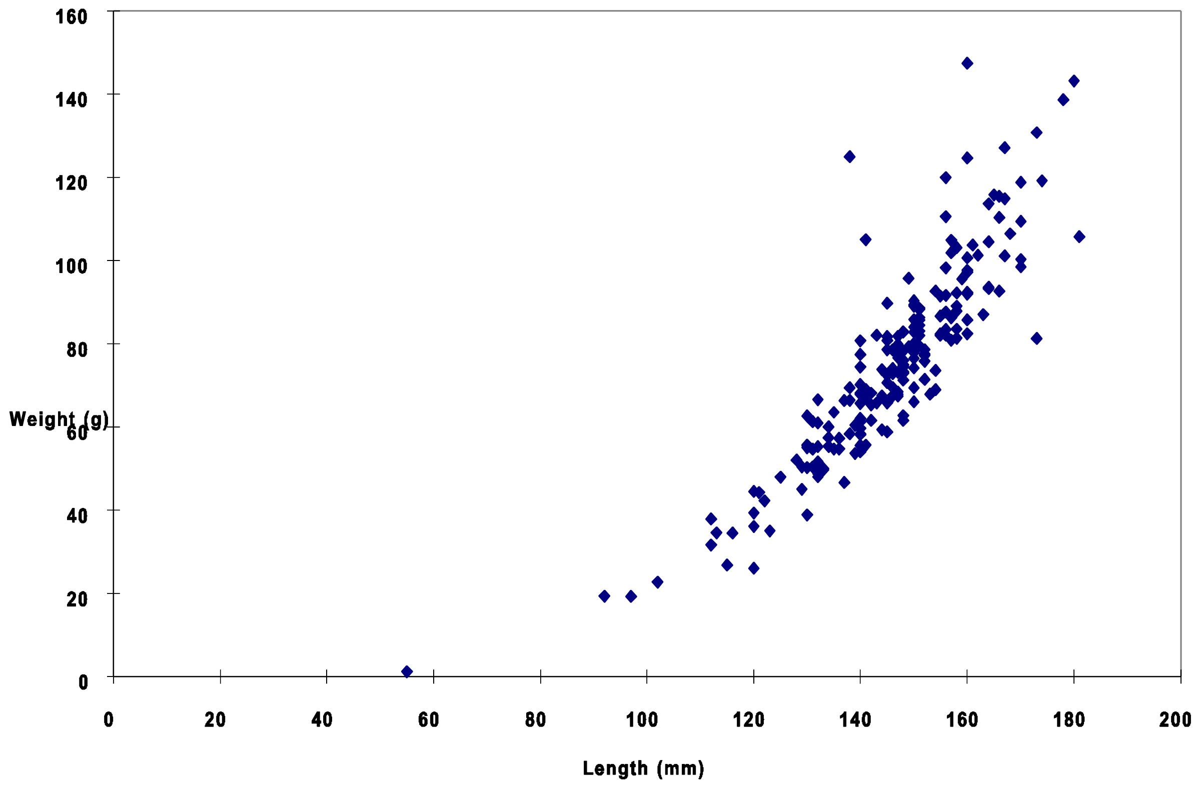

Figure 2. Scatter plot of length versus weight for *Ctenochaetus striatus* at Aitutaki

intoxication. Catches of susceptible species such as *C. striatus* should thus be discouraged in areas known to be ciguatera “hot-spots,” such as the lagoon and reef near Arutanga, south of the main passage on the western side of the island.

APPENDIX IV - RELEVANT LOCAL LEGISLATION

AITUTAKI FISHERIES PROTECTION BY-LAWS 1990

T.Tangaroa, Queen's Representative

ORDER IN EXECUTIVE COUNCIL

At Avarua, Rarotonga, the 16th day of November 1990
Present:
HIS EXCELLENCY THE QUEEN'S REPRESENTATIVE
IN EXECUTIVE COUNCIL

PURSUANT to Sections 15 and 16 of the Outer Islands Local Government Act 1987, the Queen's Representative acting by and with the advice and consent of the Executive Council, hereby makes the following by-laws.

BY-LAWS

1. *Title and commencement* - These By-laws may be cited as the Aitutaki Fisheries Protection By-laws 1990 and shall come into force on the first day of December 1990.

2. *Application of these By-laws* - These By-laws shall apply to the islands of Aitutaki, Manuae and Te-Au-O-Tonga and shall extend to the waters surrounding each island to a line measured seaward from the outer limits of the reef, every point of which is 200 metres (218 yards) distant from hte nearest point of the outer limit of the reef.

2. *Interpretation* - in these By-laws unless the context otherwise requires:

"Council" means the Island Council of Aitutaki elected in accordance with the Outer Islands Local Government Act 1987.

"Drag net" means any net or part thereof (including any warp rope chain material or device used in conjunction with or attached to the net) which has a buoyancy system on the top edge and which is weighted on the bottom edge and is operated by surrounding any fish and being drawn over the bed of any waters or through any waters to the shore.

"Enforcement Officer" means the person appointed as an Enforcement Officer pursuant to these By-laws.

"Fish" means any aquatic plant or animal, whether piscine or not; and includes any oyster or other mollusc, crustacean, coral, sponge, holothurian (bech -de-mer), or other echinoderm, turtle and marine mammal and includes their eggs, spawn, spat and juvenile stages referred to in the Schedule to these By-laws.

"Net" means any net or part thereof used or capable of being used to take fish and includes any drag net and any set net.

"Set net" includes a gill net, drift net, trammel net or any other sort of net which acts by enmeshing, entrapping or entangling any fish.

"Underwater breathing apparatus" means any apparatus capable of being used for providing breathable gases underwater, and includes self contained underwater breathing apparatus (commonly known as "scuba") but does not include any snorkel.

PART I - SHELLFISH

4. *Taking of fish prohibited* - no person shall -

(a) permanently take or attempt to take to any place beyond the areas to which these By-laws apply, any fish in the Schedule to these By-laws; or

(b) sell any fish named in the schedule to these By-laws,

except pursuant to and in accordance with the provisions of a permit issued pursuant to these By-laws.

5. *Council may grant permits* - (1) subject to these By-laws and to the provisions of any Act, the Council may grant to any person a permit, subject to such conditions and for such period as the Council thinks fit, to take any fish named in the Schedule to these By-laws for the purpose of -

(a) sale within the areas to which these By-laws apply.

(b) consumption at any wedding, funeral, birthday, family reunion, investiture, kave eva, opening of a community or public building, or any other similar function where large numbers of the public are likely to attend.

(c) export for sale provided the proceeds of such sale are utilised in a project in Aitutaki or for the benefit of the residents of Aitutaki (whether such project shall be situated on Aitutaki or on any other island in the Cook Islands).

(2) Without limiting the conditions that the Council may impose pursuant to sub-clause (1), a permit issued by the Council may contain conditions prescribing -

(a) the number of fish which may be taken;

(b) the type and size of fish;

(c) the part of the lagoon from which such fish may be taken;

(d) the names of the person authorised to take fish;

(e) the expiry date of any permit.

(3) Where either the Mayor, Deputy Mayor or Clerk of the Council is of the opinion that for reasons of urgency it would be impracticable for the Council to consider an

application for a permit, for any of the purposes referred to in By-law 5(1)(b) herein then either the Mayor, Deputy Mayor or Clerk may consider the application and if satisfied upon its merits grant a permit in accordance with these By-laws.

PART II - SPEARFISHING

6. *Use of underwater breathing apparatus while fishing prohibited* - No person shall use any underwater breathing apparatus while -

(a) spearfishing.

(b) gathering any species of fish[5].

(c) setting or gathering any set net or collecting.

PART III - NETFISHING

7. *Hauling of nets* - No person shall set, pull, haul or retrieve any net or pull or haul any rope warp or chain attached to or used with any such net, other than by hand.

8. *Restrictions on nets in channels* - (1) No person shall use or set any net in or within 100 metres (109 yards) of any harbour or channel customarily used by a boat.

(2) No person shall use or set any net in a channel between two motu so that the net either by itself or together with or in conjunctrion with any other net, extends more than one third of the distance that is the width of the channel between two motu, measured at right angles to the bank of that channel at the place that the net was set.

9. *Set nets* - No person shall -

(a) use or be in possession of a set net having a length exceeding 100 metres (109 yards)[6];

(b) use or be in possession of a set net having a depth exceeding 4 metres (13 feet);

(c) use or be in possession of a set net with a mesh of less than 60 millimetres (2½ inches) in diameter[7];

(d) set a net within 100 metres (109 yards) of any other set net.

(e) set or use more than one set at any one time;

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5 This would need to take into account the specialised need for aquarium fish collectors to use SCUBA, if such a fishery were ever considered.

6 Hopefully this takes into account more than one net being joined together, otherwise it would need to be explicitly stated that the length of any nets joined together should not exceed 100 metres.

7 Presumably this means the "diameter wet and stretched".

(f) use a set net unless at least one person shall be and remain in the immediate vicinity of the net during the whole of the time it remains set.

10. *Drag nets* - (1) No person shall -

(a) Use or be in possession of a drag net having a length having a length exceeding 75 metres (82 yards);

(b) Use or be in possession of a drag net with a mesh of less than 60 millimetres (2½ inches) in diameter;

(c) Use more than one drag net at any one time.

(2) Notwithstanding subclause (1) of this By-law, it shall be an offence to use or be in possession of a drag net with a mesh of less than 60 millimetres (2½ inches) provided such net -

(a) does not exceed 25 metres (27 yards) in length and

(b) is used solely for the purpose of catching bait fish.

PART IV - MISCELLANEOUS

11. *Appointment of Enforcement Officers* - (1) The Council may by resolution from time to time, subject to such terms and conditions as the Council may consider necessary to impose, appoint able and suitable persons to be Enforcement Officers for the purposes of these By-laws.

(2) Every appointment made by the Council under these By-laws may be terminated at any time by the resolution of the Council

12. *Functions and powers of Enforcement Officers* - Every Enforcement Officer appointed under these By-laws shall be responsible for enforcing the provisions of these By-laws and in the performance of those functions shall have and may exercise the following powers only namely:

(a) To carry out such inquiries and investigations as may be necessary to determine whether or not any breach of these By-laws has been committed.

(b) To open and search wherever necessary any package, box, baggage and any other container of whatever kind to determine whether or not any breach of these By-laws has been committed.

(c) To impose immediate fines not exceeding $200 upon any person found to have committed a breach ion these By-laws or any condition imposed by the Council in the permit issued to such person, and issue an official receipt to that person for the amount of the fine paid.

(d) To confiscate all the fish found in the possession of a person contrary to the provisions of these By-laws and to dispose of such fish in the manner directed by resolution of the Council.

(e) To institute or cause to be instituted any legal action against any person who has committed a breach of any of the provisions of these By-laws.

(f) To demand the production of any permit for inspection.

13. *Protection of Enforcement Officers* - Any Enforcement Officer appointed by the Council pursuant to these By-laws shall not be liable to any civil or criminal action in any Court for any act or thing lawfully done and performed by such Enforcement Officer in the performance of the functions and in the exercise of any of the powers conferred uopn him by these By-laws.

14. *Enforcement by Police of these By-laws* - Every member of the Police shall have and may exercise the powers conferred uopn the Police by Section 19 of the Outer Islands Local Government Act 1987 and shall enforce the provisions of these By-laws and exercise the powers conferred upon Enforcement Officers by By-law 12 of these By-laws.

15. *Power of entry and search* - A Police Officer, if he has reasonable cause to suspect that a person has committed an offence against these By-laws may, without warrant, enter upon any premises and conduct searches and wherever necessary, enforce the provisions of these By-laws.

16. *Destructive fishing methods* - (1) No person shall use any explosive, or any poisonous substance to capture fish.

(2) No person shall, whether with or without the assistance of any instrument, remove shell fish from coral if the methods in which the shell fish are removed would, having regard to the continued application of such methods, endanger coral or coral reefs.

PART V - PENALTIES

17. *Penalty* - (1) Every person commits an offence who acts in contravention of these By-laws or in contravention of any permit issued hereunder and shall on conviction be liable in respect of a first offence to a fine not exceeding $200.00 and on a second or subsequent offence to a fine not exceeding $300.00 or to 3 months imprisonment or to both such fine and imprisonment.

(2) The Court may, in addition to any other penalty order the forfeiture to the Crown of any underwater breathing apparatus or net, used by an offender in the commission of an offence under these By-laws.

(3) Where any fish has been confiscated pursuant to these By-laws such fish shall be disposed of by the Police under the instructions of the Island Council.

18. *Repeal* - The Outer Island (Aitutaki Paua) by0laws 1988 are hereby repealed.

M. Taruia
Clerk of the Executive Council

These By-laws are administered by the Office of the Local Government.

BY AUTHORITY
T.KAPI, Government Printer, Rarotonga, Cook Islands - 1990

SCHEDULE

(Sections 4 and 5)

Size limits and maximum daily number of fish

Species	Size limits	Maximum daily number
Paua	75 millimetres (3 inches)	20
Kai	50 millimetres (2 inches)	20
Ariri	So that the Ariri in its complete shell cannot pass through a metal ring the inner diameter of which is 1½ inches (38mm)	20

APPENDIX V – RELEVANT NATIONAL LEGISLATION

1989, No.33 Marine Resources Act (*EXTRACT)*

...

2. *Interpretation* - in this Act unless the context otherwise requires:

... "Fish" means any aquatic plant or animal, whether piscine or not; and includes any oyster or other mollusc, crustacean, coral, sponge, holothurian (bech -de-mer), or other echinoderm, turtle and marine mammal and includes their eggs, spawn, spat and juvenile stages...

"Fishery" or "Fisheries" means one or more stocks of fish or any fishing operation based on such stocks which can be treated as a unit for the purposes of conservation and management, taking into account geographical, scientific, technical, recreational, economic, and other relevant characteristics...

PART I
FISHERIES MANAGEMENT AND DEVELOPMENT

3. *Designated Fisheries* - (1) The Minister may, by Notice in the Gazette on the recommendation of the Secretary, authorise a fishery as a designated fishery where, having regard to scientific, economic, environmental and other relevant considerations, it is determined that such fishery:

(a) is important to the national interest; and

(b) requires management and development measures for effective conservation and optimum utilisation.

(2) A fisheries plan for the management and development of each designated fishery in the fisheries waters shall be prepared and kept under review.

(3) Each fisheries plan shall -

(a) Identify each fishery and its characteristics including the present state of its exploitation;

(b) Specify the objectives to be achieved in the management of each fishery;

(c) Specify the management and development strategies to be adopted for each fishery;

(d) Designate those fisheries for which licencing or other management measures may be established;

(e) Specify, where applicable, the licencing programme to be followed for other fisheries, the limitations, if any, to be applied to local fishing operations and the amount of fishing, if any, to be allocated to foreign fishing vessels;

(f) Take into account any relevant traditional fishing methods or principles.

(4) In the preparation and review of those parts of the fisheries plan concerning fisheries in or directly affecting fisheries in lagoons over which Island Councils exercise jurisdiction, consultations shall be held with the Island Council and any Local Fisheries Committee for the island concerned, or where no such committee has been appointed, any local fisherman likely to be affected.

(5) Each fisheries plan, and each review thereof shall be submitted to Cabinet for approval, and shall be impolemented on such approval.

4. *Local Fisheries Committee* - (1) The Secretary may appoint a Local Fisheries Committee in any island to advise on the management and development of fisheries in relation to that island.

(2) Each Local Fisheries Committee shall consist of such persons as the Secretary may appoint. The members of the Committee shall hold office at the pleasure of the Secretary.

(3) In appointing members of a Local Fisheries Committee, the Secretary shall have regard to the need to secure adequate representation of all interests in the fisheries sector, including commercial and subsistence fishermen, fish farmers, sport fishermen and tour operators.

(4) The functions of the Local Fisheries Committee shall be to -

(a) Advise the Secretary or his designee on issues related to the management and development of fisheries in relation to the island;

(b) Make recommendations to the local Island Council with respect to the adoption or amendment of by-laws regulating the conduct of fishing operations and the issuing of fishing licences for any designated fishery on the island; and

(c) Perform such other functions as the Secretary may from time to time require.

5. *Power of Island Councils to recommend the promulgation of bylaws* - (1) Each Island Council may recommend the promulgation of bylaws in respect of any designated fishery of the island in accordance with the procedures set out in section 15 of the Outer Islands Local Government Act 1987.

(2) Every bylaw recommended for promulgation under this section shall be consistent with the relevant provisions of the fisheries plan and with this Act and any regulations made under this Act.

(3) Every bylaw recommended for promulgation under this section shall not be promulgated until it has been officially approved by the Minister.

(4) A bylaw promulgated on the recommendation of an Island Council under this section may -

(a) Require that any person shall not engage in fishing or the cultivation of fish in any designated fishery of the islands unless that person has obtained a licence from the Island Council; and

(b) Prescribe the conditions to be attached to any fishing licence or class of fishing licence issued by the Council; and

(c) Regulate the conduct of fishing operations in designated fisheries with a view to reducing gear conflicts; and

(d) Provide for other such matters consistent with the fisheries plan as may be necessary to ensure the proper regulation of the designated fishery.

6. *Power of Island Councils to declare seasons* - (1) An Island Council may from time to time, by resolution publicly notified, declare for the whole or part of a designated fishery of the island -

(a) closed seasons, during which no person shall fish for the species or in the area or areas specified in the declaration; and

(b) open seasons, during which fishing for the species or in the area or areas specified in the declaration is permitted.

(2) A resolution shall be publicly notified for the purposes of this section by posting a copy thereof in a conspicuous place in a post office or other building to which the public has access on the island.

7. *Power of Island Council to issue licences* - (1) An Island Council may, in accordance with any applicable bylaw promulgate on its recommendation under this Act, issue to any person, a licence authorising him to engage in fishing or other specified operations relating to fishing or the cultivation of fish in any designated fishery of the island and in the area or areas and for the period of time specified in the licence.

(2) An Island Council may attach to any licence issued pursuant to this section such conditions consistent with the applicable bylaw as it may deem necessary.

(3) Any Island Council shall notify in writing each applicant of its decision on licence issuance under this section within fourteen (14) days after application has been made, and shall include reasons for each decision it makes.

(4) Any licence issued under this section shall be issued within fourteen (14) days after application has been made.

(5) A copy of every decision made under this section shall be transmitted promptly to the Minister who may, after consultation with the Island Council concerned, affirm, vary or reverse that decision.

(6) Any person who is affected by, and is dissatisfied with a decision of an Island Council made under this section may appeal, within thirty (30) days of the date of the decision, to the Minister, who may after consukltation with the Island Council concerned, and after fifteen (15) days of the date of appeal, affirm, vary or reverse the decision of the Island Council.

(7) Any decision of the Minister varying or reversing a decision of the Island Council shall immediately be communicated in writing to the Island Council concerned and shall come into effect 10 days after the date of that communication.

(8) Every person commits an offence who acts in contravention of any bylaw promulgated on the recommendation of the Island Council, or in contravention of any other action taken by an Island Council pursuant to this Act, and shall be liable to a fine not exceeding $2,000, and, if the offence is a continuing one, to a further fine not exceeding $500 for every day that the offence has continued.

8. *Right of Fisheries Officers to address Island Council meetings* - (1) The Secretary or his designee, or any Fisheries Officer shall be entitled to advise any Island Council and address any meeting of an Island Council in relation to any matter referred to in sections 5, 6 or 7, and the Island Council shall have regard to his submissions.

(2) Any Island Council intending to consider any matter referred to in sections 5, 6 or 7 at a meeting shall give adequate notice to the Secretary and the local Fisheries Officer for the Island and shall afford the Secretary, his designee and the local Fisheries Officer adequate opportunity to attend the meeting at which that matter is to be considered.

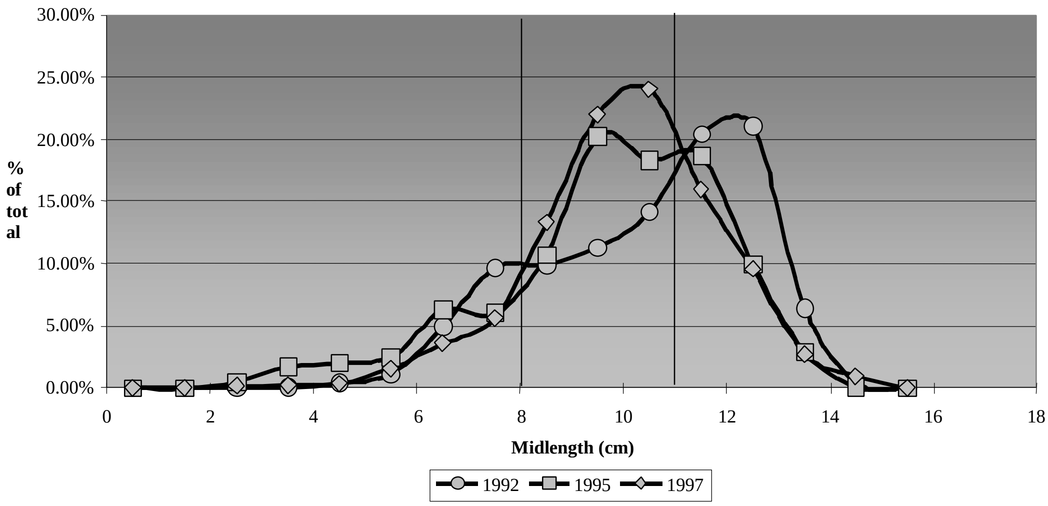
(3) The Clerk of the Island Council shll promptly transmit copies of the relevant portion of the minutes of any meeting of the Island Council at which any matter referred to in sections 5, 6 or 7 has been considered to the Secretary and the local Fisheries Officer for the Island...

APPENDIX V - Summary of trochus transect data from three surveys

Time of survey	Aug-92	Jan-95	Jan-97
Total area of trochus habitat (sq m)	4,627,200	4,627,200	4,627,200
Average shell diameter (cm)	10.37	10.22	10.20
Total area covered by transects (sq m)	13,600	28,800	15,000
Number of shells counted in transects	1,052	998	1,378
Est. total population for all available habitat	432,357	163,351	452,435
Average density (shells per hectare)	774	347	919
Number of shells in transects >11cm	358	316	402
Number of shells in transects <=8 cm	301	190	159
% of population of legally harvestable size	37.34%	49.30%	59.29%
Est. number of legally harvestable shells	161,447	80,530	268,243
30% of legal number	48,434	24,159	80,473
TAC based on 30% of legal number (tonnes)	12.11	6.04	20.12
50% of legal number	80,724	40,265	134,122
TAC based on 50% of legal number (tonnes)	20.18	10.07	33.53
Largest shell seen (cm)	18.4	15	15
Smallest shell seen (cm)	2.1	3	2.5

All sites combined

Aitutaki Trochus length-frequency



Note: The data used to produce the two summaries above is available on the SPC website at "http:\\www.spc.org.nc\coastfish\Reports\ICFMAP\national_publications.htm", along with a digital copy of this report.

See Nash et al (1995) for a summary of previous information.

NOTE: Appendices 6, 7, and 8 of this report, consisting of a draft paper to introduce the Aitutaki fishery management Bylaw amendments to the Cook Islands Executive Council, suggestions for amending the bylaws themselves, and a draft brochure explaining the bylaws to visitors, are not reproduced here. They may be included, at the discretion of the Ministry of Marine Resources, after the bylaw amendments have been considered by the Executive Council.

Dr Tim Adams
Director, Marine Resources Division,
Secretariat of the Pacific Community