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SOMETHING OLD SOMETHING NEW: AN APPROACH TO OBTAINING FISHERIES MANAGEMENT INFORMATION FROM A REMOTE PACIFIC ATOLL

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Something old something new: an approach to obtaining fisheries management information from a remote Pacific Atoll[1]

by

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Abstract

Four depletion fishing experiments were carried out at Woleai Atoll (Federated States of Micronesia) between May and June 1991 to estimate standing stock biomass of reef fish on the shallow reefs. Two experiments were conducted with a traditional leaf-sweep method and two with group spearfishing. The dominant fishes in each instance were surgeonfish and parrotfish, which formed between 60 and 90 per cent of the catch. Decline in the catch rate versus cumulative catch was observed for total, surgeonfish and parrotfish catches in each experiment and this was used to compute standing stock biomass. The standing stocks ranged from 5 to 25 t/km^2 with a mean of 12 t/km^2. The total fishable standing stock of shallow-water reef fishes on the shallow reefs of Woleai lagoon was estimated to be 60 t or about 470,000 fish. Spearfish catches contained a greater range of species and spearfishing tended to be positively biased to larger specimens of species common to both fishing methods. The results of this study are discussed with respect to the conservation and management of reef fish stocks in the remote atolls such as Woleai.

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Introduction

The Pacific Islands, north and south of the equator comprise for the most part small high islands and atolls, many of which are remote and with difficult communications. Further, the size of these small island states and territories means that manpower resources and services are limited, and are mostly concentrated in the urban centres. A good example is the Federated States of Micronesia (FSM) which comprises four states, Chuuk Kosrae, Pohnpei and Yap. Apart from Kosrae State, which is a single high island, the other states are a mix of high islands and atolls.

Yap State in the east of the FSM consists of the small high island of Yap Proper and an archipelago of 11 atolls to the north and east. Most of the atolls do not possess an air strip so communications are dependant on intermittent contact through national and state government shipping. The populations of the atolls or Yap outer islands have maintained much of their culture and customs. The main animal protein source in the atoll diet is fish, supplemented with meat from dogs, pigs, turtles and imported canned products.

Despite the retention of much of the traditions in the outer islands, fishing activities have been inluenced by the introduction of modern inovations including manufactured boats, outboard engines, diving masks, fins, spearguns, monofilament lines and nets. These items have greatly increased the fishing power of island fishermen and generated concerns about the level of fishing effort on the lagoons and reef in some of the outer islands. Further, annual population growth in the Yap outer islands is about 1.5 %, which, while not excessive, means that there will be a steadily increasing demand for fish, much of it coming by neccessity from the immeadiate lagoon and reef habitats.

Little information exits on the fisheries of the Yap outer islands other than observations made during anthropological studies. One of us (AS) has collected a great deal of material on the traditional fishing methods and customary fishing lore of the Yap outer islands during the late 1980s. At about the same time, fisheries management information for deep reef slope dropline fisheries elsewhere in the Pacific was being generated at several locations in the Pacific by short term intensive fishing experiments and the relationships between catch rates, cummulative catch and standing stock (Polovina & Shomura 1990). This led to the realisation by both of us that community fishing methods, as documented in the study of Yap outer island fisheries, could be used to perform a series of short fishing experiments where localised depletion of stocks through intensive fishing could be used to generate information on stock sizes, catch rates and species composition.

In this paper we describe such a study conducted during mid 1991 on the Yap outer island of Woleai. From the data generated by this study, it was possible to estimate the size of the standing stock of reef fish on the lagoon back reefs, quantify the catch rates and catch composition of two common community fishing methods and to estimate the recovery time for reefs depeleted by such methods. Further, the study showed the value of documenting the customary fishing methods in such a location as, through this information, it was possible to apply appropriate stock assessemnt methods to generate data for fisheries management.

The study site

Woleai Atoll is located at 7°22'N, 143°52'E and lies about 675 km to the east-south-east of Yap proper. The atoll is shaped in the form of a figure eight (Figure 1) and covers a total area of 47.89 km^2. The total land area amounts to only 4.5 km^2, encompassing a lagoon area of 28.7 km^2.

The area of shallow reef was estimated by planimetry from the most recent topographic chart to be 10.8 km^2, with 5.1 km^2 classed here as back reef. The larger of the two lagoons is the western lagoon which is about twice the area of the eastern lagoon. Depths in the centre of the eastern lagoon range from 20 to 35 m, while the western lagoon is deeper, with depths ranging from 35 to 50 m.

The population of Woleai is approximately 810 with about 525 people living on the islands of Tagailap and Falalap in the eastern lagoon. Employment opportunities are normally very limited on Woleai, but at the time of these investigations about 30 men were employed in the construction of an airfield and runway. Apart from canned meats bought at local stores, the main sources of animal protein are fish, pigs, turtles and dogs. Fish is the most common of these and communal fishing is an important activity to provide large quantities for social events such as marriages, funerals and holidays. Most fishing is carried out by the men of the atoll, although women glean the reefs at low tide for shellfish and small fish caught in baskets.

Community fishing methods

Roop *fishing*: **Roop** fishing, with a leaf sweep scare line and net, is conducted on any sloping back reef or, weather permitting, on some outer reefs. At Woleai there are specific sites used for **roop**. Calm seas and weak currents are required before **roop** can be done. The starting depth is variable, but is usually where the sea bed can be seen. The size of the initial sweep depends on the numbers of sections of **roop** scare-line and fishermen. **Roop** is normally practiced during the boreal summer months (June–August) only. It is best done as the tide drops, starting at the turn of the tide. It will be used at most about four times per summer (per island). The chiefs are the only ones to decide when it can be done. When a decision is made to conduct **roop** fishing, all available men are supposed to assist.

Gapiungiupiung *fishing*: **Gapiungiupiung** or group spearfishing can be performed at virtually any reef location, but is predominantly done on reef slopes (back reefs and especially outer reefs) adjacent to the wave break/surf zone. At least ten men are needed, although usually more are required. It is conducted either by the whole community or by the men of one or two canoe houses. The method usually requires calm seas and clear water, so is done mostly during the summer, although when conditions permit it can be performed any time of year. It can be carried out during any tide phase and level. There are no restrictions on how often it can be performed, and the decision to conduct rests with the chiefs or a group of men at the canoe house. If a fish trap is set on the reef, **gapiungiupiung** cannot be used within 400 m. It cannot be done on any 'closed' reefs. Traditionally, **gapiungiupiung** could only be done on the reefs owned by the participants. Now it can be done anywhere as long as permission is requested first (this is very rarely refused).

METHODS

Fishing methods

Four fishing experiments were carried out over a four-week period commencing on 15 May and terminating on 10 June 1991. Two fishing experiments were carried out using **roop** fishing and a further two by **gapiungiupiung**. The scare lines in both *roop* experiments were made from coconut sennit rope, traditionally manufactured by the men of Woleai. Wound on to the rope were strips of green coconut leaf (still attached to a strip of stem), fastened so that the leaves protruded from the rope (Figure 2).

The net used in both instances was a 4.5 cm mesh seine net, set in a V-shape (Figure 2) on the reef with part of the bottom temporarily sown to form a cod-end. The scare lines were joined and set in a circular pattern on the reef, and sunk on the bottom by weights attached to the rope. At intervals along the rope were small lines from the weights to the surface by which the rope could be lifted over the coral heads. The net was set on the lagoon side and inside the periphery of the fishing area (Figure 3), with the mouth of the V pointing toward the centre (i.e. towards the shallower water).

The scare line initially formed an incomplete circle, the gap being on the shallowest side of the fishing area. Fishermen bridged the gap to keep fish within the periphery of the fishing area. As the scare line was pulled the two ends overlapped, while at the opposing side the scare line was parted and each end attached to the mouth of the net. The scare line was steadily pulled to drive the fish towards the net (and deeper water). The fishermen followed behind and above the line to add their efforts to driving the fish and to prevent the line from snagging on the coral. As the fish were chased into the net, some fishermen crowded into the mouth to prevent them escaping, while others succeeded in closing the mouth and secured the catch.

On the first day of each **roop** fishing experiment, the scare line was laid down on the reef but was not hauled immediately. The periphery described by the scare line was marked with surveyor's tape, approximately every 10 m, so the scare line could be reset at the same location on successive days. Prior to sinking the scare lines on the first day, sightings were made at various points with a range finder to measure the diameter of the circle described by the coconut rope. In both instances the shape of the scare line was elliptical rather than strictly circular. The fishing was delayed slightly each day—approximately 45 to 60 minutes—to ensure that the fishing was done at about the same tide phase.

About 45 men were involved in **roop** fishing. A similar number of fishermen were employed for the **gapiungiupiung** fishing. The fishermen formed a circle in the water, then slowly swam to the centre, concentrating the fish which attempted to hide in amongst the interstices of the coral. The fish were speared with wire spears 1.5 to 1.8 m long. On the first day of fishing for each experiment, the fishermen paused in the water after the circle was completed and at a given signal dived to the substrate and tied pieces of surveyor's tape to the coral.

Prior to the signal for attaching the tape, sights were taken with the range finder to determine the shape and diameter of the fishing ground. Again, each day's fishing was delayed to allow the fishing to occur at the same tide phase. Unlike fishing with **roop**, each **gapiungiupiung** fishing experiment was timed to obtain the fishing effort. Fishing effort was expressed as the product of the number of men by hours fished. Fishing times varied from forty-five minutes to one hour, depending on when the fishermen began to lose interest in fishing as fish became scarce. When effort slackened, a halt was called to that day's fishing.

A summary of the four different fishing experiments by site, dates, gear and designation used in this report is given in Table 1. The four sites were all gently sloping back reefs within the lagoon and consisted of areas of hermatypic coral interspersed with areas of sand and coral bommies. The depths fished in each instance ranged from 1.5 to 5.0 m. The shape of the fished area in each instance was elliptical rather than strictly circular, based on a number of measurements of the diameter taken at different points on the periphery. The formula for an ellipse was used to compute the fished areas and these are also included in Table 1.

Biological data

After each day's fishing the catch was separated to species level, based on identifications in Masuda et al. (1980, 1984) and Myers (1989).The lengths of fish in the catch were measured to the nearest 0.1 cm and the weights recorded to the nearest 10 g. Where a large number of a particular species was caught, only a portion of the total was processed for length and weight data, but the total numbers and weight captured were recorded. The need to process the catch quickly so that it could be divided up and eaten meant that few other biological data could be collected. Sex was recorded where coloration or shape was obviously sexually dimorphic. Further, the bellies of fish were squeezed gently to see if they were in a ripe or spawning condition through the release of eggs or sperm.

RESULTS

Catch composition

In all, just over 100 species of fish belonging to 25 families were captured during the four fishing experiments on Woleai. The percentage composition of the catch by family taxon for each of the four fishing experiments by weight and numbers is given in Table 2. A more detailed record of the catch composition by species is included in Smith & Dalzell (1993). The catches from these inner lagoon back reefs were comprised principally of surgeonfish (Acanthuridae) and parrotfish (Scaridae). Surgeonfish and parrotfish together comprised between 70 and 90 per cent of the catch from leaf-sweep fishing, and between 60 and 80 per cent of the spearfishing catch. Overall, the commonest species in the catches was the small surgeonfish *Acanthurus nigrofuscus* which formed between 20 and 30 per cent of the catch by numbers from roop fishing and 7 to 8 per cent of the catch from spearfishing.

The first and second leaf-sweep fishing experiments captured a total of 41 and 53 species respectively. A greater number of families (Table 2), and hence species, was captured by the two spearfishing experiments. A total of 76 species was captured in the first spearfishing experiment, while a slightly smaller number, 69 species, was taken during the second experiment. The catches of both spearfishing experiments contained significant amounts of triggerfish (Balistidae), groupers (Serranidae) and wrasses.

Catch and fishing effort

The catch, fishing effort and catch per unit of effort (CPUE) in weight and numbers for the four fishing experiments are summarised in Appendix I. As the surgeonfish and parrotfish were the most important catch components, catches of these fishes were extracted from the raw data and are included in the Appendix 1. For the leaf sweeps, catch and catch rate are equivalent, while with spearfishing the CPUE was expressed as the catch divided by the product of the time spent fishing and number of spearfishermen.

Catch rates of leaf-sweep fishing ranged between 12.8 and 38.6 kg/set in the first experiment and 8.1 and 129.4 kg/set in the second. The CPUE of spearfishing ranged from 0.55 kg/spear-hour to 1.8 kg/spear-hour in the first experiment and 0.6 kg/spear-hour to 2.04 kg/spear-hour in the second. Catch rates declined appreciably for the total catch and for the surgeonfish and parrotfish in all four of the fishing experiments.

Biomass estimates

Where time series of catch and effort data are short and the effects of growth, mortality and recruitment negligible, the decline in catch rate is proportional to the initial biomass or standing stock (B_o). The depletion model of Leslie (in Ricker 1975) can be used with such catch and effort data to estimate B_o and the model takes the form:

$$C_t = qf_t\,(B_o - K_t)$$

where C_t is catch at time t, f is fishing effort, K_t is the cumulative catch and q is the catchability coefficient. In terms of CPUE the model can be rearranged such that:

$$C_t/f_t = qB_o - qK_t$$

and is a linear equation with a slope equal to q and an abscissal intercept equal to B_o.

The results of fitting the Leslie model to the catch data in weight and numbers from each of the four experiments are given in Tables 3 and 4 and the lines are shown fitted to the scatters of CPUE versus cumulative catch by weight in Figures 4 and 5. The data for the first and second days' fishing for the second group spearfishing experiment at Falalus were combined into a single data pair. The first day's fishing was carried out following a storm, and catch rates were depressed due to rough seas and rather strong currents.

The slopes of the line from the various regressions (b) shown in Figures 4 and 5 are equivalent to the catchability coefficient. Biomass in the fishing site was estimated from the regression parameters then converted to weight and numbers per square kilometre of reef. The total biomass of all fish ranged from 5.63 t/km^2 at Tagailap to 25.47 t/km^2 at Falalus, or 46,310 fish/km^2 to 177,570 fish/km^2.

DISCUSSION

The principal objectives of this study were to collect quantitative information on the catches by two community fishing methods, and to assess the potential for using such fishing techniques for stock assessment in a remote atoll where long-term records of catch and biological data were not available. On Woleai we were able to assess the effects of both leaf-sweep fishing with a fixed seine net and group spearfishing. Further, the selection of fishing sites permitted observations on reefs that had last been fished from as recently as a few weeks before our operations to over a year earlier. Clear reductions in CPUE were evident in all instances following periods of sustained fishing pressure and these were then used to estimate standing stocks on the fished reefs.

Standing stocks, as estimated from the two methods, ranged from 5.6 to 25.5 t/km^2 or 46,300 to 177,500 fish/km^2 respectively. Standing stocks were highest in the western lagoon where human populations are lowest and the reefs are fished less often than in the eastern lagoon. Although all catches were dominated by surgeonfish and parrotfish, the composition of the combined catches from spearfishing and from leaf-sweep fishing was significantly different ($\chi^2 = 599$, $p < 0.001$, 24 df.). Most of this difference was ascribable to the sizeable contribution of groupers and triggerfish to the spearfishing catch and the complete or virtual absence of these families from the leaf-sweep catch.

It is important to note here that our estimate of fish standing stock refers specifically to demersal species, mainly algal herbivores closely associated with the reef substrate. Further, both fishing methods are size-selective, although this is mostly a function of mesh size with the leaf-sweep, as opposed to the selection of larger sizes with spearfishing (Smith & Dalzell 1993). Many of the small fishes found amongst the coral, such as damsel fish (Pomacentridae) and fairy basslets (Serranidae, sub. fam. Antheinae), were not taken by the two gears employed. Further, evidence from the Philippines (Alcala & Gomez 1985; Dalzell et al. 1990) and the Great Barrier Reef (Williams & Hatcher 1983) suggest that the fusiliers (Caesionidae) comprise a major component of the biomass on coral reefs. No fusiliers were caught in any of the four fishing experiments, and small pelagic species in general, such as small carangids, scombrids and clupeoids, were mostly absent from the catches.

It is concluded from the present data that the two different methods probably provide reasonable estimates of the standing stocks of surgeonfish and parrotfish, but that leaf-sweep fishing misses those fish that are particularly adept at hiding in the holes within the coral, such as trigger fish and groupers. Clearly, these conclusions would be strengthened by carrying out further such studies in other atolls. It may, therefore, be more realistic to term our population estimates the fishable biomass or fishable standing stock, to distinguish this from the true density of fish on the reefs. For the purposes of an overall fishable biomass estimate for the back reefs of Woleai, the means of the four fishing experiments were used to estimate average densities of 12.6 t/km^2 or 94,000 fish km^2. The back reefs of Woleai lagoon cover an area of about 5.0 km^2 which gives an estimated total fishable standing stock of 60 t or 470,000 fish.

This estimate of standing stock does not include the populations of fish over shallow sand flats and sea grass beds, small pelagic fish in the lagoon, and demersal fishes on the lagoon floor, outer reefs and reef slope of the atoll. Together, these various fish populations form a considerable resource for the people of Woleai Atoll. Further, fishermen in Woleai fish on the open ocean for large pelagic species such as skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*), which are more abundant during the boreal summer. However, the fish stocks of the back reefs represent a constantly accessible source of protein to the people of Woleai in contrast to the outer reefs which may only be fishable at certain times of the year. Based on fish consumption patterns from the rest of the Pacific, Smith & Dalzell (1993) suggested that the total annual landings of fish on Woleai amounted to between 40 to 80 t. Other information which has come to our attention on Micronesian and Polynesian atolls (Connell 1991, Dalzell 1992) suggests that this may in fact lie in the range 80 to 120 t[1]. It remains to verify these estimates by direct observations and to observe the relative proportions that come from the lagoon, outer reefs and open ocean.

These fishing experiments may give some indication of the rate of recovery from such types of community fishing, where a large fraction of the biomass is captured. The intervals between our fishing operations and the most recent community fishing by the Woleaians ranged from three weeks to a year. Figure 7 shows that there is a linear relationship between the fishable biomass estimate in weight and numbers (Tables 3 & 4) and interval between periods of community fishing (Table 1).

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1 Smith & Dalzell (1993) used an annual per capita fish consumption figures of between 50 and 100 kg for based on dietary data for the whole of the Pacific Islands. Later information collected on Polynesian and Micronesian atolls suggest that a higher range of 100-150 kg is more appropriate.

The data suggest that following community fishing when the reef fish population is depleted, the biomass might increase by about 20 t/km^2 over a period of about 12 months. Some caution must be exercised, however, with interpretation of these results. First, the linear trend of the points may be misleading since it is likely that increase in biomass with interval between fishing will tend towards an asymptote as the fish population approaches the equilibrium biomass. Second, no account was taken of fishing by individuals on some or all of these reefs between the periods of community fishing. Third, no information was available on the amount of fishing effort expended on these reefs during the initial period of fishing. Certainly, it is not the common practice to fish one area of reef continuously, but to fish several times at different locations on the reef, so as to maximise catches and avoid poor catches from depleted areas. However, the results form an initial basis for setting moratoriums on fishing particular reefs, and give an indication of the expected increase in population size at least after a one year interval.

The management and conservation of reef fish stocks on Woleai and the other outer islands of Yap State are likely to be mainly influenced by the rate of human population growth. No records have been kept of current levels of catch or catch rates, and only anecdotal accounts from the islanders are available from which to formulate conclusions on the status of stocks. Not all the outer islands have lagoons and pressure on reef fish stocks is likely to be most apparent where reef area is limited and population density high, such as Satawal. Studies of the type described here may not be appropriate or practicable on these other islands, but information on fishing practices and contemporary catch rates need to be collected. Detailed records of traditional fishing and management in the outer islands have been made by Smith (in prep.), but more information on catch rates and catch composition need to be recorded to provide a reference for future management investigations such as those reported here.

During the field work we were asked by the Woleai chiefs to provide some recommendations for managing Woleai's reef fish resources. The following are management suggestions based not only on the project results, but also on our personal observations (for one of us [A.S.] those observations were made over a four-year period).

First, it must be clearly understood that Woleai's subsistence fishery has been strictly managed for centuries. Until about the late 1940s the regulations governing marine resources exploitation were very severe. These restrictions were related to the ritual and tabus associated with fishing, fishermen and fish, but their justification was cultural maintenance rather than resource management *per se*. However, those rituals, coupled with the reef tenure and use rights systems and the low-technology equipment, combined to indirectly ensure reef resources management.

In recent times some, but by no means all, of the restrictions have been eased or in some cases eliminated altogether. Today it would be socially impossible to re-impose all those old restrictions. However, there still remains a need for some control over fishing. Where traditional methods are still used, even in a modified form, and there is a willingness by the chiefs and fishermen to use customary controls, we encourage that practice.

For the reasons previously mentioned in this report, it is not possible to provide specific recommendations for management based solely on the results of this study. The following suggestions are provided for consideration by the chiefs and fishermen of Woleai, but may also be relevant to the other outer islands as well.

The first suggestions relate directly to the two fishing methods used in this study; others are more general. All suggestions have the aim of allowing the reef fish stocks to recover as quickly as possible after exploitation.

1. Roop:

– It would be advisable to maintain a minimum mesh size for the capture net no smaller than that currently used (4.5 cm). This will permit the smaller species and some juveniles to escape, which will assist with stock recovery.

– Spearfishing immediately after driving the fish during **roop** (to catch those fish that have avoided the sweep by hiding amongst the coral) should be avoided.

– The number of times that **roop** fishing is repeated at the same or adjacent locations during one summer be kept to an absolute minimum. The repetitive **roop** fishing in this study demonstrated that it was possible to quickly reduce the fish stocks in a short time. Also, Figure 6 indicates that there might be a linear relationship between the fishable biomass estimates and the interval between periods of community fishing.

2. Group spearfishing:

– The destruction of the coral habitat while spearfishing should be minimised. We noticed habitat damage sometimes occurred during **gapiungiupiung** fishing as fishermen tried to locate, spear and remove fish from their hiding places. Much of the coral that was broken during the process is extremely slow growing and the reduction in the amount of habitat available to the fish may limit the recovery of reef fish stocks in the area.

– The spearing of very small fish should be avoided.

– The interval between conducting group spearfishing exercises in an area should be as long as possible. Group spearfishing is a very efficient way to fish an area. The more intensively an area is fished then the longer the recovery will take.

3. General:

– The custom of closing reef areas to all fishing after the deaths of certain people should be retained. Similar closures are encouraged for areas where the **taufita** (fishing masters) consider reef fish stocks have been reduced too much. The length of closure should be for a long as is feasible and acceptable.

– The customary system of using different fishing methods during specific seasons to target different species in a number of areas should be encouraged. The recent trend to use only a few of the relatively easy methods (e.g. spearfishing) most of the time means that the same species will be targeted all year in most areas, possibly resulting in overfishing if fishing intensity is high enough. The more seasonal rotation in methods used and areas fished the better.

– The use of new methods and/or equipment should be allowed, but the effects of any introductions should be carefully evaluated, and if considered socially unsuitable or too damaging to reef fish stocks, should be prohibited or regulated. To some extent this has already occurred with flashlight spearfishing and monofilament gillnets.

In conclusion, this project demonstrated the utility of studying the traditional fishing activities and customs of a remote island such as Woleai, as it was possible to design a short term fisheries study that generated management information for this atoll. The present study could be improved on by estimating the annual harvest of finfish from the lagoon back reefs, particularly for surgeonfish and parrotfish, so that the production to biomass ratios could be calculated and the sustainable yield of these stocks estimated. Future projects of this type may want to include some provision for longer term or periodic monitoring of catches to supplement standing stock estimates.

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Table 1: Details of the four fishing experiments undertaken at Woleai Atoll, May–June 1991

Fishing experiment	Site	Area (ha)	Dates	Gear	Designation	Comments
1	Tagailap	1.32	15–17/5/91	Leaf sweep and stationary seine net	Leaf sweep 1	Fished three weeks previously by group spearfishing
2	Wottagai	2.12	21–24/5/91	Leaf sweep and stationary seine net	Leaf sweep 2	Fished six months previously by leaf-sweep fishing
3	Raiur	2.04	28–31/5/91	Group spearfishing	Spear fishing 1	Fished two months previously by spearfishing
4	Falalus	1.12	4–7/6/91 & 10/6/91	Group spearfishing	Spear fishing 2	No fishing on this reef for over a year

Table 2: Summary of the catch composition of the leaf-sweep and group spearfishing experiments

Family	Leaf sweep 1		Leaf sweep 2		Spearfishing 1		Spearfishing 2	
	% no.	% wt.	% no.	% wt.	% no.	% wt.	% no.	% wt.
Acanthuridae	48.49	35.10	62.92	46.51	42.62	38.00	56.48	37.86
Scaridae	27.01	32.11	29.22	46.21	14.24	21.62	21.08	39.98
Lethrinidae	12.08	13.13	0.46	0.68	1.18	2.38		
Mullidae	2.52	2.36	1.14	0.7	1.32	2.02		
Chaetodontidae	2.35	1.30	3.03	1.63	1.72	0.87	2.62	1.01
Labridae	1.34	1.14	1.26	1.26	3.82	3.89	3.41	4.32
Siganidae	4.7	11.21	0.34	1.44	1.98	4.81	0.42	0.95
Monocanthidae	0.50	0.40	1.2	0.78	0.79	0.64	1.85	2.18
Lutjanidae	0.34	0.87	0.06	0.05	0.66	1.10	0.14	0.20
Zanclidae	0.34	0.43	0.11	0.12	0.53	0.35	1.14	0.71
Balistidae	0.17	0.13	0.11	0.09	11.08	9.60	7.12	5.12
Malacanthidae					0.13	0.29		
Pomacanthidae			0.06	0.06	0.13	0.11	0.14	0.12
Diodontidae			0.06	0.44	0.53	1.61		
Holocentridae					6.86	2.56	0.14	0.12
Serranidae					9.76	6.21	4.7	5.66
Grammistidae					0.13	0.003		
Cirrhitidae					0.13	0.13	0.36	0.10
Ostraciidae			0.06	0.03	0.79	0.26		
Synodontidae					0.26	0.02		
Bothidae					0.66	0.97	0.21	0.23
Belonidae					0.13	0.04		
Fistularidae					0.13	0.27		
Tetraodontidae					0.13	0.31		
Carangidae	0.17	1.82			0.26	2.03	0.14	1.47

Table 3: **Summary of the regression coefficients and the fishable biomass estimates, by weight, from the application of the Leslie model to four stock reduction experiments at Woleai Atoll**

Fishing experiment	Catch component	Regression values			Estimated biomass (kg)	Biomass per unit area (t/km^2)
		a	b	r^2		
Leaf sweep 1	Total catch	72.64	–0.970	0.82	74.88	5.63
	Acanthuridae	90.60	–4.84	0.71	18.73	1.43
	Scaridae	35.70	–1.23	0.753	29.02	2.15
Leaf sweep 2	Total catch	280.58	–1.12	0.88	252.88	11.92
	Acanthuridae	110.30	–0.97	0.89	113.71	5.33
	Scaridae	155.82	–1.25	0.90	124.76	5.88
Spearfishing 1	Total catch	2.81	–0.0164	0.93	171.34	8.39
	Acanthuridae	0.81	–0.0104	0.92	77.60	3.80
	Scaridae	1.11	–0.0335	0.88	33.1	1.62
Spearfishing 2	Total catch	3.41	–0.0119	0.95	286.16	25.47
	Acanthuridae	1.301	–0.0120	0.913	108.51	9.66
	Scaridae	1.499	–0.0122	0.813	118.77	10.58

Table 4: **Summary of the regression coefficients and the fishable biomass estimates, by number, from the application of the Leslie model to four stock reduction experiments at Woleai Atoll**

Fishing experiment	Catch component	Regression values			Estimated biomass (no.)	Biomass per unit area (no./km^2)
		a	b	r^2		
Leaf-sweep 1	Total catch	1048.3	-1.715	0.56	611.3	46,310.6
	Acanthuridae	1638.3	-5.672	0.72	288.8	21,878.9
	Scaridae	329.7	-2.000	0.75	164.8	12,484.8
Leaf-sweep 2	Total catch	1886.0	-0.986	0.88	1912.4	90,207.5
	Acanthuridae	1037.7	-0.838	0.82	1238.5	58,419.8
	Scaridae	682.2	-1.297	0.95	526.0	24,811.3
Spearfishing 1	Total catch	13.30	-0.011	0.84	1269.3	62,220.6
	Acanthuridae	4.659	-0.007	0.97	678.1	33,240.2
	Scaridae	2.976	-0.022	0.77	132.6	6,500
Spearfishing 2	Total catch	16.35	-0.008	0.93	1988.8	177,571.4
	Acanthuridae	10.87	-0.011	0.89	1003.1	89,562.5
	Scaridae	3.903	-0.009	0.63	415.3	37,080.4

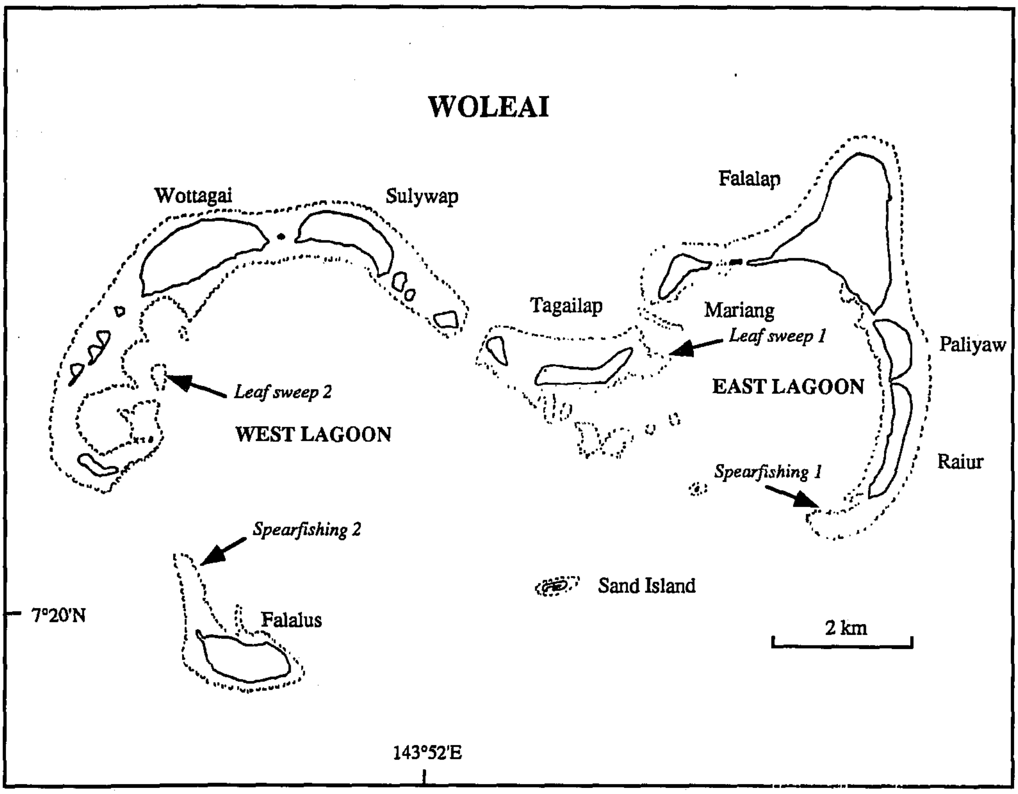

Figure 1. Map of Woleai Atoll showing places named in the text and the locations of the four fishing experiments

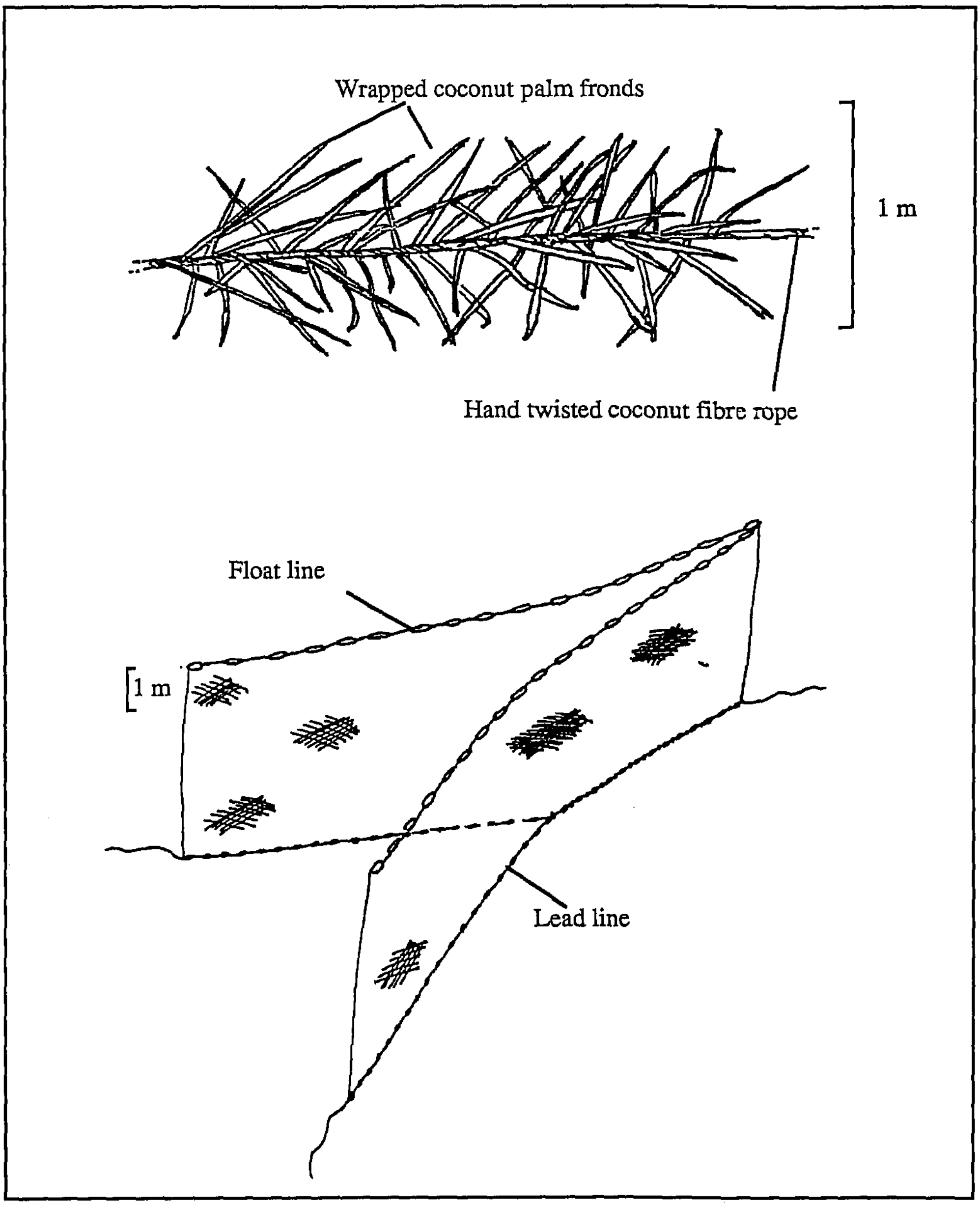

Figure 2. Details of the construction of leaf sweep (top) and the seine net deployed for roop fishing at Woleai Atoll

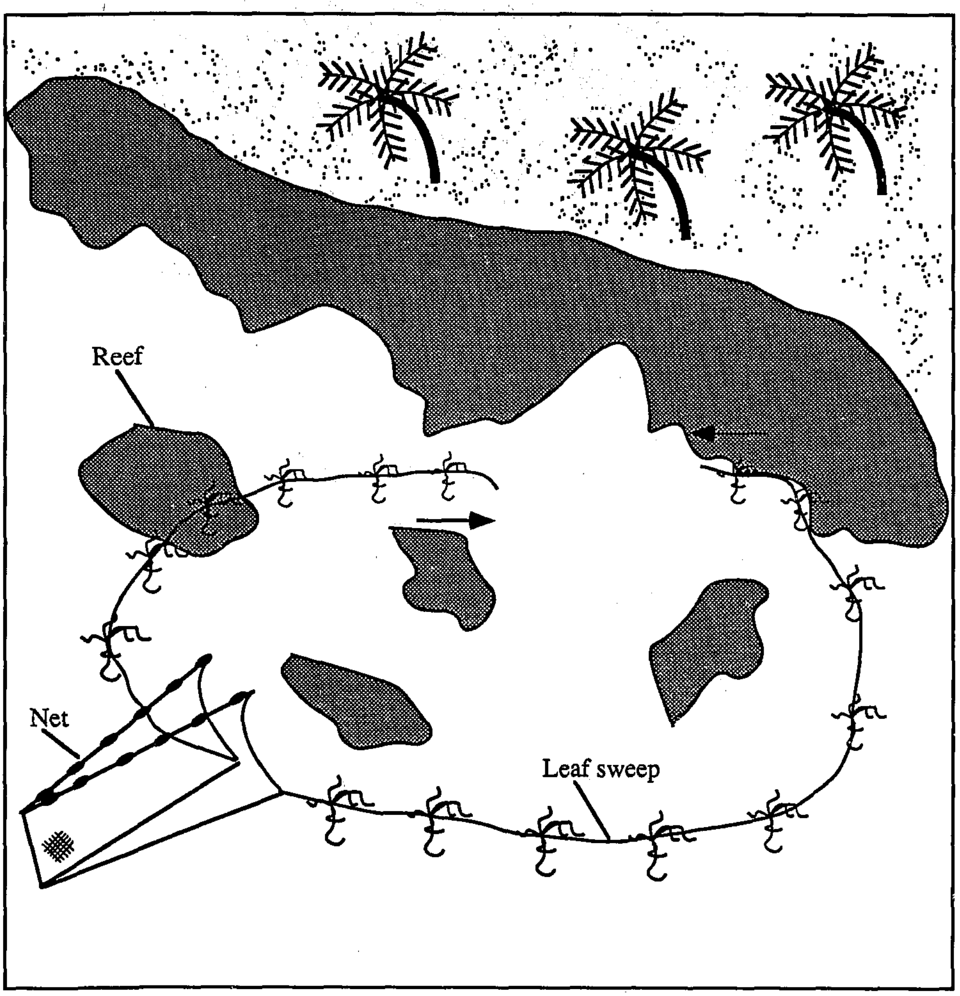

Figure 3. Deployment of the net and leaf sweep employed for roop fishing. The leaf sweep has been attached to the two wings of the net and is being pulled in the directions indicated by the arrows to shorten the diameter of the scare line and thus drive the fish towards the net

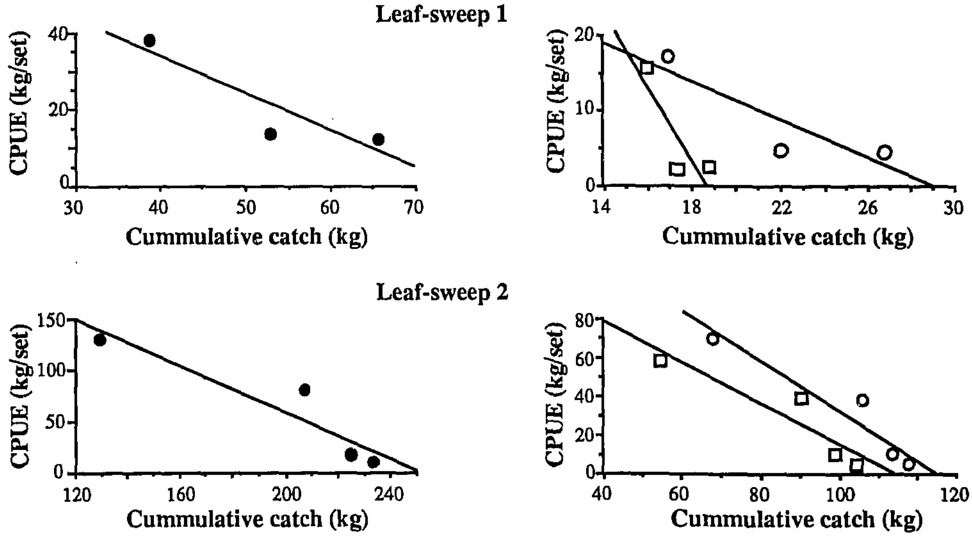

Figure 4. Catch rate versus cummulative catch of total catch (●), surgeonfish (□) and parrot fish (○) in the two leaf-sweep fishing experiments

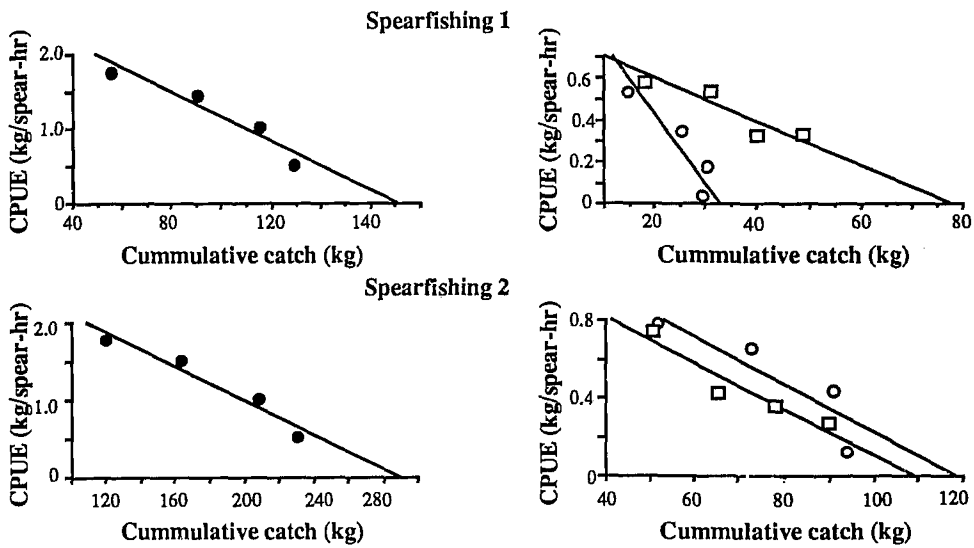

Figure 5. Catch rate versus cummulative catch of total catch (●), surgeonfish (□) and parrot fish (○) in the two spearfishing experiments

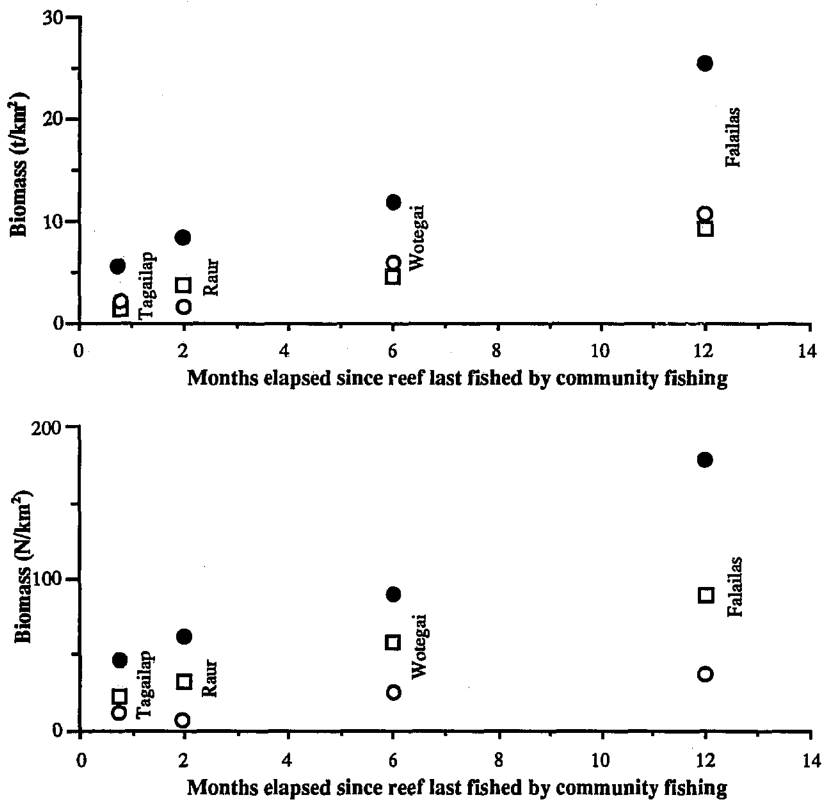

Figure 6. Estimated fishable biomass by weight (top) and numbers (bottom) for all fish (●), surgeonfish (□) and parrotfish (○)

Appendix 1

SUMMARIES OF THE CATCH, EFFORT AND CPUE BY WEIGHT AND NUMBERS FOR THE FOUR DEPLETION FISHING EXPERIMENTS AT WOLEAI ATOLL

Summary of the catch (weight) and fishing effort data for the first leaf-sweep fishing experiment

Day	Effort (sets)	Catch (kg)			Catch rates (kg/set)			Cumulative catch (kg)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	1	38.63	15.99	16.91	38.63	15.99	16.91	38.63	15.99	16.91
2	1	14.3	1.37	4.91	14.3	1.37	4.91	52.93	17.36	21.82
3	1	12.8	1.55	4.88	12.8	1.55	4.88	65.73	18.91	26.70

Summary of the catch (weight) and fishing effort data for the second leaf-sweep fishing experiment

Day	Effort (sets)	Catch (kg)			Catch rates (kg/set)			Cumulative catch (kg)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	1	129.42	54.47	68.01	129.42	54.47	68.01	129.42	54.47	68.01
2	1	77.74	37.26	37.74	77.74	37.26	37.74	207.16	91.73	105.75
3	1	17.96	9.17	7.83	17.96	9.17	7.83	225.12	100.90	113.58
4	1	8.09	3.02	3.93	8.09	3.02	3.93	233.21	103.92	117.51

Summary of the catch (weight) and fishing effort data from the first group spearfishing experiment

Day	Effort (spear hours)	Catch (kg)			Catch rates (kg/spear-hour)			Cumulative catch (kg)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	30.75	55.39	18.44	16.32	1.80	0.60	0.53	55.40	18.44	16.32
2	23.92	35.55	12.73	8.59	1.49	0.53	0.36	90.89	31.17	24.91
3	24.50	24.30	8.61	4.04	0.99	0.35	0.17	115.19	39.78	28.95
4	25.08	13.78	8.04	0.7	0.55	0.32	0.03	128.97	47.8	29.65

Summary of catch (weight) and fishing effort data for the second group spearfishing experiment

Day	Effort (spear hours)	Catch (kg)			Catch rates (kg/spear-hour)			Cumulative catch (kg)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	32.25	50.85	25.67	18.92	1.58	0.80	0.59	50.85	25.67	18.92
2	33.75	68.87	24.26	31.73	2.04	0.72	0.94	119.72	49.93	50.65
3	33.75	44.44	14.74	22.19	1.31	0.44	0.66	164.16	64.67	72.84
4	39.42	43.28	14.30	17.51	1.09	0.36	0.44	207.44	78.77	90.35
5	38.00	22.98	10.11	5.36	0.60	0.27	0.14	230.42	88.88	95.71

Summary of the catch (numbers) and fishing effort data for the first leaf-sweep fishing experiment

Day	Effort (sets)	Catch (no.)			Catch rates (no./set)			Cumulative catch (no.)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	1	419	252	115	419	252	115	419	252	115
2	1	67	19	23	67	19	23	486	271	138
3	1	101	21	23	101	21	23	587	292	161

Summary of the catch (numbers) and fishing effort data for the second leaf sweep fishing experiment

Day	Effort (sets)	Catch (no.)			Catch rates (no./set)			Cumulative catch (no.)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	1	923	543	293	923	543	293	923	543	293
2	1	593	397	149	593	397	149	1516	940	442
3	1	168	118	38	168	118	38	1684	1058	480
4	1	67	42	22	67	42	22	1751	1100	502

Summary of the catch (numbers) and fishing effort data from the first group spearfishing experiment

Day	Effort (spear-hours)	Catch (no.)			Catch rates (no./spear-hour)			Cumulative catch (no.)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	30.75	292	117	51	9.50	3.80	1.66	292	117	51
2	23.92	221	82	35	9.24	3.43	1.46	513	199	86
3	24.50	157	67	18	6.41	2.73	0.73	670	266	104
4	25.08	111	61	5	4.43	2.43	0.20	781	327	109

Summary of catch (numbers) and fishing effort data for the second group spear fishing experiment

Day	Effort (spear-hours)	Catch (no.)			Catch rates (no./spear-hour)			Cumulative catch (no.)		
		Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae	Total	Acanthuridae	Scaridae
1	32.25	353	224	65	10.95	6.95	2.02	353	224	65
2	33.75	354	214	88	10.49	6.34	2.61	707	438	153
3	33.75	262	131	67	7.76	3.88	1.99	969	569	220
4	39.42	276	141	70	7.00	3.58	1.78	1245	710	290
5	38.00	164	87	16	4.32	2.29	0.42	1409	797	306

Postscript to BP 47:

Dalzell, Paul & Andrew Smith - "Something old, something new: An approach to obtaining fisheries management information from a remote Pacific atoll".

Background to the Development of the Fisheries Depletion Experiment

The project was conceived as a result of a chance conversation between the two authors. One of the authors (AS) was explaining, with the assistance of some photographs, a traditional fishing method involving a leaf-sweep which was recorded during his study of traditional fishing methods in the outer islands of Yap State, Federated States of Micronesia. Dalzell suggested the possibility of using such a method for intensive (depletion) fishing experiments to gain an estimate of fish standing stocks. It took two years from this chance conversation until the project was successfully completed.

During the project's development Dalzell was a Fisheries Scientist with the South Pacific Commission. Smith had just completed two years in the outer islands of Yap State recording traditional fishing and management techniques, and had recently been employed as the Advisor to the Yap State Government's Marine Resources Management Division.

After some further correspondence between the authors to clarify our ideas, the next step involved securing approval in principle from the council of outer islands' chiefs, during one of their biannual meetings in Yap, to proceed with the project. No objections were raised at that meeting and so we continued with the project planning. The next hurdle was to obtain funding for the project. Considerable effort went into explaining and justifying the project proposal to both the Yap State Legislature and the South Pacific Commission. After those two bodies approved funding for the project, official requests to the specific atolls were made through the council of chiefs. Although this is the official procedure, it had a number of inherent problems. Often, what is discussed with a chief or chiefs at the council meetings in Yap only gets back to the island in an incomplete form, if at all. This can result in rumours which can have a lasting effect on any project proposal. To overcome this, in addition to meeting with the chiefs and discussing the project with them, specially written explanations of the project's aims, needs and benefits were provided in the vernacular. Immediately after the council meeting discussions were also held with outer island government officials, who, once they understood the purposes of the project, also advised those living out on the islands about the project. One of the keys to the success of the project was explaining the aims, needs and benefits of the work to as many people as possible, for as long as possible, to ensure that they understood what we wanted.

One of the hardest tasks was explaining to the chiefs, reef custodians and fishermen why we wanted to fish in the same place, with the same method, on successive days with the aim of catching less fish each day. The fishing methods we proposed to use are normally used in the same area only once or twice a year to get fish for a special occasion or for community use. To get permission to conduct this "strange" style of fishing we had to satisfactorily explain: 1) How much area we would require; 2) Why we wanted to fish-out an area; 3) What benefits they would see from the project; 4) How much manpower we would require; and 5) If they would be paid.

Due to considerable logistical problems related to the remoteness of the Yap outer islands, our initial proposal to fish on two atolls, one that has been heavily fished and one that is rarely fished, we had to alter our plans and work only on one atoll, Woleai. Upon arrival at Woleai for the field work, a meeting was held with all the men on the main island and representatives of those from the other inhabited islands within the atoll. The whole project was explained step by step, and any questions answered and problems resolved. The specific forms of the fishing methods we preferred were discussed and agreed on, and once they fully understood our requirements, they determined how many men would be required and the most appropriate locations to conduct the fishing. After this meeting the project progressed without any problems. Without their complete understanding and cooperation, it would have been impossible to keep

40 plus men from five separate islands in the atoll, normally engaged in subsistence activities, working five days a week for four successive weeks.

A number of factors contributed to the success of the project, not the least of which was luck! We were extremely lucky to have four weeks of virtually ideal weather conditions. Only once did we have some bad weather and that fell on a weekend. Familiarity with the fishing methods, how they are usually conducted, and what minor alterations were needed to satisfy the scientific objectives was essential to the project's success. This was achieved by one of the author's (AS) familiarity with the island's culture and fishing methods, knowledge which was acquired during the traditional fisheries project. The fact that AS is married to a woman from Woleai probably also contributed to some degree to the cooperation we received.

Payment of the fishermen, hiring of the necessary boats, and provision of outboard motor fuel for the time spent fishing ensured the men's continued interest. Payments were made after the completion of the work at each of the four fishing sites. Prior to the field work, considerable time and effort was put into ensuring that the fishermen would be paid in cash, rather than the usual government cheques which can take months to be issued.

After the project was competed and the report prepared, copies were sent back to the council of chiefs and to Woleai Atoll. On subsequent visits to the atoll Smith has continued to answer questions concerning fisheries management to the chiefs and fishermen.