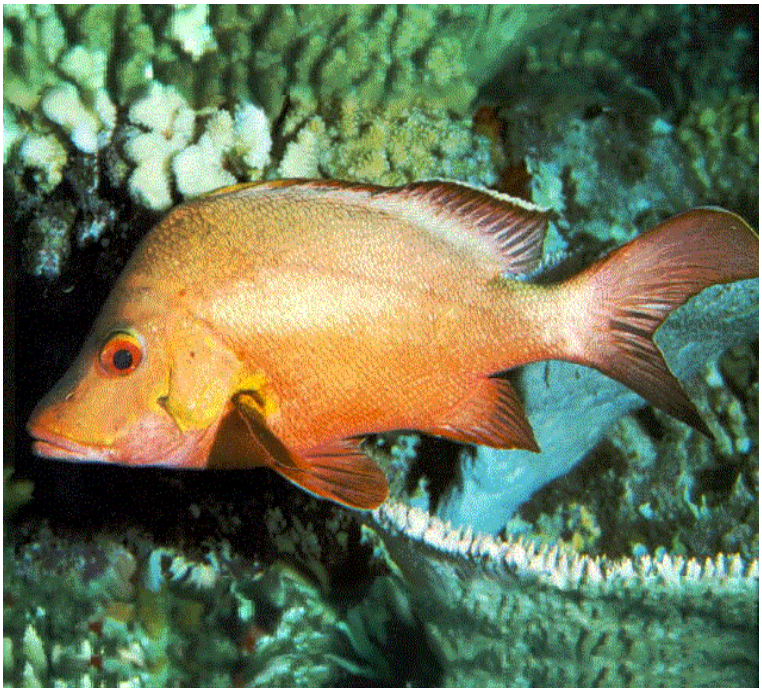
The Performance of Customary Marine Tenure in the Management of Community Fishery Resources in Melanesia

VOLUME 3

Biological Outcomes: The Value of CMT for Sustainable Resource Use



MRAG

July 1999

Acknowledgments

This project was funded through the UK Department for International Development (DFID) Fisheries Management Science Programme (FMSP), which is managed by MRAG Ltd. Throughout the project, MRAG enjoyed excellent collaboration with:

- University of the South Pacific, Marine Studies Programme
- Fiji Ministry of Primary Industries, Fisheries Division
- Government of Vanuatu, Fisheries Department

For the work reported in this Volume on biological outcomes, data were collected during fisheries monitoring programmes in each of Fiji and Vanuatu by the following locally appointed staff :

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* Epeli Qalo sadly passed away in April, 1997.

The Centre for Tropical Coastal Management Studies (CTCMS), Newcastle University, was sub-contracted to undertake the Underwater Visual Census component of this study. The Fiji UVC data were gathered by C. J. Barry (MRAG), A.J. Beeching (CTCMS RA), N.V.C. Polunin (CTCMS) and J.D. Anderson (MRAG) in May-June 1996, with additional data being collected from Tacilevu by J.D. Anderson alone in April 1997. The Vanuatu UVC data were collected by A.J. Beeching (CTCMS RA) and J.D. Anderson (MRAG) in October 1996, with additional data being obtained from Emua by J.D. Anderson alone in September 1997.

A number of people contributed to the analysis and reporting of the data: Nick Polunin (CTCMS) for Chapter 2; Chris Mees, Robert Arthur and Jim Anderson (all MRAG) for Chapters 3-4; Ashley Halls (MRAG) and Jim Anderson for Chapter 5. Chris Mees contributed Chapters 1 and 6, and compiled and edited the Volume.

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1 Value of CMT for Sustainable Resource Use - Introduction

1.1 Structure of this Volume

This volume of the report presents the results of analyses of the fishery appraisals undertaken through underwater visual census, and those from the fisheries monitoring programme. Results are presented for data gathered at both managed (tabu) and un-managed, or open access (control) areas within fishing sites for each country. The analyses presented here have been undertaken specifically to examine the status of resources at each of the study areas, and to evaluate if there was any measurable benefit from management actions at tabu areas. Comparisons between countries have not been made.

There are six chapters to this volume:

- This introduction outlines the background to the research and describes the expected effects of fishing and management on fishery resources;
- The second chapter presents the results of underwater visual census studies which examined habitat variability and differences in species assemblages by area;
- The third and fourth chapters examine uni-variate analyses of all-species abundance indices and fishing effort by study area, and those of biological parameters for key study species from the fishery monitoring programme;
- A fifth chapter presents multi-variate analyses of species and family abundance from the fishery monitoring programme to determine differences in species or family assemblages by area;
- The final chapter draws together and summarises the information contained in chapters 2-5 and draws conclusions on the effects of management with respect to the expected biological outcomes described in chapter 1.

Annexes to this volume provide detailed information to explain the analyses described in each Chapter. Summary details of the approach taken are provided in Volume 1, and a summary of the results and conclusions is given in Volume 2a and2b for Vanuatu and Fiji respectively.

1.2 Background

Considerable interest exists in developing traditional management systems based on Customary Marine Tenure (CMT), and combining them with scientific advice (Christy, 1982, Hviding and Ruddle, 1991, Doulman, 1995, Pomeroy, 1994). However, if existing traditional management systems are to be the basis of co-management initiatives for artisanal fisheries, it is necessary to ask, 'Exactly how effective are existing attempts at community management?'. There are several criteria by which one might seek to assess the potential of this approach to fisheries management, including biological sustainability and social equity. Within each of these broad criteria there are a number of issues (often controversial) that need to be addressed. Social issues are discussed in Volume 2. This volume of the report examines biological sustainability.

Questions that may be asked include:

- Management Boundaries: Do management measures based on marine tenure relate to biological distributions of fish stocks?

- Management Activities: Do management measures recognise key life cycle events (are they based on 'scientific' criteria e.g. spawning seasons, size at maturity), or is conservation an indirect result of other functions of marine tenure?

- Management success, enforcement: How do customary systems cope with increased stress (population pressures, commercialisation, immigration and emigration)? How effective is surveillance and enforcement both within the community and for outsiders 'poaching' community resources?

- Management success - what is the status of fishery resources inside managed areas and has management conferred any benefit compared to un-managed open access areas?

Volume 2 discusses the first three of these questions. In relation to management boundaries the key finding was that management areas are defined by land tenure and other political issues but not by the underlying patterns of fish stocks. Similarly, management activities related principally to political and cultural requirements rather than being defined by the biology of the resources affected by management actions.

In the light of these findings it is expedient to ask what is the management success of any interventions undertaken by the fishing community? To understand this, it is necessary to understand the effects of fishing on fish populations and the resources as a whole, and the likely effects of management interventions. The following Chapters of this volume of the report will examine the status of fishery resources within the areas and sites studied in relation to fishing intensity and any management interventions.

1.3 The effects of fishing

1.3.1 Background

A comprehensive review of the effects of fishing on coral reef fishes is provided by Russ (1991), and more recently by Jennings and Lock (1996) and Jennings and Kaiser (1998). A previous Fisheries Management Science Programme project (R5484) also reviewed the available literature (MRAG, 1996), and the following summarises details of the effects of fishing.

Population (single species) and community (multispecies) effects can be identified which act directly on the fish resources, or indirectly through mechanisms such as habitat modification. Technical interactions and gear selectivity (ie catchability) have an important influence on species composition of multispecies resources. Those species with higher catchabilities to a particular gear will be subject to greater fishing mortality and will be removed first leading to a greater proportion of other species in the catch (but not necessarily a greater abundance of other species). This is an effect of fishing on fish populations related to the choice of gear and will be apparent through the fisheries monitoring programme. However, care must also be taken not to interpret a change in target species or technological change, or differences between areas, as reflecting changes or differences in fish abundance. Underwater visual census studies enable the description of resources in situ, and are not subject to gear effects. However, certain species are cryptic or frequently under-recorded and so UVC also cannot provide the complete picture.

1.3.2 Single species effects of fishing

The effects of fishing on a single species may be summarised as a reduction of density and biomass, reflected as catch rate changes, an increase in total mortality and growth rate, a reduction in the mean length and modification of the size and social structure of the population (eg sex ratio at length and in total), and reduction of the reproductive capacity of the resource and its recruitment. The present study examined differences between fish populations in areas subject to different fishing pressures and management regimes. Factors studied were abundance (density and biomass), mean length, and mortality. Size and social structure and reproductive capacity were not examined.

Biomass

By removing fish from an area, fishing results in a reduction of the density (per unit area) and biomass of individual species. Biomass and density changes attributed to fishing are well reported, particularly for large predatory fish such as lutjanids, lethrinids and serranids (eg. Bohnsak, 1982; Munro, 1983; see Russ, 1991). If the catchability of a fishing gear remains constant, the catch rate, or catch per unit (of fishing) effort (CPUE), is an index of abundance of the resource. CPUE is therefore used to infer changes in biomass of fished resources. This index is the basis of fisheries production models which determine the initial (unfished) biomass (B_0) and sustainable yield. CPUE declines with fishing and is expected to decline linearly with the abundance of fish. However, over time as a fishery develops experience and improvements in fishing gear, for example may mean that the relative level of effort changes, and effort and catchability need to be scaled or standardised. Furthermore, a non-linear relationship between catch rates and abundance is predicted (Beddington, 1984; Cooke and Beddington, 1984) with implications for the estimation of abundance. Thus whilst the precise nature of the relationship between catch rate and abundance is uncertain, a measurable effect of fishing is catch rate change.

Catch rates are normally reported for a time series of data from a single location subject to fishing pressure. Spatial comparisons of CPUE have also been made for a number of locations subject to different levels of fishing pressure (eg. Gulland, 1979; Munro, 1983; Koslow *et al.* 1994). Spatial comparisons introduce another dimension : not only must catchability remain constant, in order to make inferences about abundance utilising spatial data, the ecological and productive characteristics of each location must be similar. Koslow *et al.* (1994) recorded significant differences in catch rates by location, related to fishing pressure, including declines in lutjanids and serranids. However, examples also exist of spatial comparisons where little difference in catch rate was observed despite different levels of fishing effort (see Russ, 1991).

Mean length

The age structure and growth rate of fished and unfished populations of fish may be expected to vary. Gulland (1983) described how both K and L_∞ would vary with stock density, and therefore with fishing pressure. As a stock is fished the density decreases giving rise to an increase in growth rate, and to an increase in the size of individuals of a given age, thus altering the age structure of the population. For example, it has been shown by several authors that depending on the state of the fishery (unfished / new or equilibrium), the level of fishing pressure can significantly affect the mean size of fish and their overall growth rate (Gulland, 1983; Schaap & Green, 1988; Filipsson, 1989; Klein, 1992; Ross and Nelson, 1992). Fishing tends to target larger individuals in a population leading to a reduction in mean length and change in length frequency distribution of fished and unfished populations.

Mortality

For a fish stock, total mortality (Z) increases with fishing effort (by definition, Z=F+M, and F=qf where F is fishing mortality, M is natural mortality, q is catchability and f is effort). However, mortality rates, and in particular, independent assessments of natural mortality, are difficult to obtain. Little information exists to illustrate the relationship between mortality and fishing pressure for reef fish. A spatial comparison of Jamaican fishing sites subject to different levels of fishing pressure demonstrated for a number of species including lutjanids and serranids that Z and F were higher at locations with higher effort, and similarly Z/K was greater at fished reefs than M/K from an unexploited bank (Munro, 1983; note M=Z at unfished locations).

1.3.3 Multispecies effects of fishing

Ecosystem overfishing occurs when intensive fishing on a multispecies resource leads to changes in the community structure (Pauly, 1979; 1988). Examples exist in the Philippines (Russ and Alcala, 1989), in the Caribbean (Koslow *et al.* 1994). Changes in the relative abundance (species composition) of species in a multispecies stock are related to fishing intensity, the relative catchabilities of the species and the level of interaction between them. Removal of competition, predators or prey are postulated to lead to species composition changes. Jennings and Kaiser (1998) in reviewing the available information, however, conclude that such effects are not ubiquitous and that changes in species abundance or even local species depletion are rarely dramatic except where species occupy ‘keystone’ roles. Only a tiny proportion of species are in this category. They conclude that most predator prey relationships in food webs are weak.

In general, fishing tends to remove top predators. They are targeted as highly valued food fish (although many examples of where prey fish are the target also exist). Furthermore, aspects of their biology tend to make them more vulnerable to fishing: they tend to be aggressive predators with high catchability to gear such as baited hooks and lines; they are slow growing so even if the number of fish remains constant, the biomass will be reduced and the relative proportion of predators to fast growing species in the catch will change; they have relatively lower reproductive capacity and take longer to reach maturity so higher total fishing mortality will occur before spawning resulting in a lower spawning biomass - recruitment may be reduced.

From fishery independent underwater visual census (UVC) work in fished and unfished locations, and from catch and biological data, there exists much evidence of single species (abundance and size differences, including members of the lutjanidae, lethrinidae and serranidae) and multispecies (changes in catch composition) responses to fishing (Craik, 1981a; 1981b; Bohnsak, 1982; Russ, 1984; 1985; Ayling and Ayling, 1986; Lock, 1986; Koslow *et al*. 1988; Samoilys, 1988; Russ and Alcala, 1989;Ayling *et al*. 1992; Polunin and Roberts, 1993; Koslow *et al*.,1994; Watson and Ormond, 1994; Jennings *et al.* 1995). These studies indicate that fishing results in a reduction in abundance of the top predators and reduction in average size of fish.

Removal of predators is postulated to lead to increase in prey (eg. Beddington and Cooke, 1982; Beddington, 1984; Munro and Smith, 1984; Koslow et al, 1988). However, little evidence exists for this for fish in coral reef systems and observations contradict these predictions. For example, prey release was not found to occur in Seychelles (Jennings *et al*, 1995), and following experimental removal of adult groupers from reefs in the Red Sea, no change in the abundance or species composition of prey occurred (Shpigel and Fishelson, 1991), although examples of invertebrate prey release are known (eg. Mclanahan and Muthiga, 1988, see also Jennings and Lock, 1996). Similarly, little evidence exists to indicate that removal of prey results in measurable changes of fish, individually or in total, at other trophic levels (such as a reduction in predator populations, see Russ, 1991). These examples relate to local overfishing of predators and it is likely that due to spatial connectivity of the resources, stocks can be maintained despite fishing. By contrast the example of the Caribbean (Koslow *et al*, 1994) relates to gross overfishing of the whole system. Lacking sources of replenishment, community responses become detectable.

Natural variations in recruitment are also offered as an explanation of the failure to detect community effects. Larval supply is considered to be a more important control on abundance than predation (Doherty and Williams, 1988). Where predation effects are most likely to be significant is on survival of newly settled fish. High rates of mortality of coral reef fish are experienced in the first year, and much of this occurs within the first week after settlement (Shulman *et al*., 1983; Doherty and Sale, 1986; Doherty and Williams, 1988), although strategies to reduce this such as different ‘nursery grounds’ and adult feeding areas have developed. However, natural variability in recruitment means that changes in the abundance of prey fishes due to reduction in predators through fishing will be difficult to detect. For example, Kulbicki and Wantiez (1990) reported up to a 13 fold decline in biomass and density estimates from trawl surveys in New Caledonia which were unrelated to fishing. The largest changes observed related to faster growing species including lethrinidae, rather than slow growing species.

MRAG (1993) argue that if populations are below their carrying capacity due to factors such as fishing, predation, disease, environmental and recruitment variability, then significant competition will not occur. Indeed, evidence for resource limitation due to competition is lacking (Doherty and Williams, 1988).

It is concluded that environmental influences, particularly in relation to egg and larval production and settlement, are likely to have a greater impact than biological interactions. Similarly, in fished populations, technical interactions are likely to have a greater measurable effect than biological.

In the present study, the time series of data available from the fisheries monitoring programme were insufficient to enable the detection of multi-species effects over time. Thus multi-species comparisons between sites were made using spatial comparisons of data gathered from areas accross a range of fishing pressures and subject to different management regimes.

1.4 Effects of management

The management instruments employed by fishing communities in each of the sites in Fiji and Vanuatu were described in Volume 2. Briefly:

- In Fiji, study sites fall into two categories: those fished commercially (Vitogo and Tavua) and those fished semi-commercially (Verata, Naweni and Tacilevu). Licensing and restricted entry are the most common form of management. A short term closed area was applied in Naweni. In Verata one area is closed to commercial fishing by non residents, and Tacilevu has no management instruments applied. Licencing regulations apply at both the commercial fishing sites. At Vitogo non-residents require a licence to fish although there is no limit on the number of licences. At Tavua licensing is also applied to non-residents.

- In Vanuatu long and short term tabus, or closed areas, were applied at Emua, Lelepa, Pellonk, Wala and Uripiv. At Pellonk there is additionally an annual six month ban on spear fishing at the reef edge, although this ban has not been respected (Volume 2, chapter 1). Atchin had no explicit management instruments applied.

Thus in relation to study sites there are three types of management :

- Closed areas - or Marine Protected Areas;
- Licensing / restricted entry;
- Gear controls.

Management actions may be applied to meet biological, social and economic objectives. The latter have been discussed in Volume 2. In this Volume we examine the biological effects of management on the resources. Volume 2 indicated that management interventions in both Fiji and Vanuatu were undertaken for cultural and political reasons rather than for any considerations for the sustainability of the fisheries resources.

The lack of biological management targets set by fishing communities means that in the present study it is necessary to define our own criteria for management success. Management interventions may be expected to mitigate, in part, the effects of fishing described above. Management generally aims to prevent overfishing and to optimise the benefits gained from exploitation either in terms of food production or economic rent. The purposes of management and the different means of achieving this have been reviewed in previous FMSP projects (R4682, R5484, see MRAG 1996).

The principal methods for optimising yield and preventing overfishing include regulation of age at first capture and regulation of catch or effort. Regulation of size at first capture may be achieved directly, by imposing gear restrictions or minimum size limits (although mortality of returned fish is an issue), and indirectly by introducing closed seasons or closed areas corresponding to spawning periods, spawning grounds or known juvenile and nursery habitats. Fishing mortality may be controlled directly through restricting catches through quotas, or by limiting effort by means of restrictive licensing of vessels (fishermen) or gear. Closed seasons and closed areas also act to limit fishing effort.

These methods have been developed for single species stocks, and in the multi-species, mutli-gear situation, as is the case for study reef fisheries in Fiji and Vanuatu, it is seldom possible to implement a management strategy directly related to regulation of age at capture, and indirect means and controls on effort or catch are more appropriate. However, in subsistence and small scale fisheries where there may be a lack of alternative livelihoods such restrictions are not always practical. In these circumstances it has been argued, and the FAO 'Precautionary approach to fisheries' (FAO, 1995) recommends, that marine protected areas be developed. They provide resilience to overexploitation thereby reducing the risk of stock collapse.

Closed areas (or reserves or marine protected areas) reduce the amount of the resource vulnerable to capture and eliminate or reduce fishing effort on part of the stock. As a fisheries management tool, reserves are also expected to enhance fisheries yields outside the reserve through movement of adults and increased recruitment to fishing grounds, and to lead to localised 'recovery' of depleted resources. In addition to protection of fish stocks, they may have other important functions such as conservation of important habitat types (eg. nursery areas). Closures may be permanent or temporary, and in some cases fishing may be permitted under certain conditions or with certain gear. The variety of closed areas are reviewed by Roberts and Polunin (1991), and more recently a comprehensive review of models applied to marine reserves has been provided by Guénette *et. al.* (1998).

Closed areas are generally considered applicable to small scale artisanal and multispecies fisheries. Complete understanding of population and community dynamics is not required, simplifying data collection, and, together with some form of community management, they may more easily be enforced than classical management methods. A body of literature exists on reserves and confirms their role in permitting the recovery of depleted resources (e.g. Wantiez *et al*, 1997; Russ and Alcala, 1998a; 1998b); an increase in biomass and individual size of fish within them occurs, and species richness may also increase. The extent of spillover effects to adjacent areas is however less well understood. Circumstantial evidence from a study in the Philippines suggests increases in fish catches outside reserves which were related to periods of closure (Russ, 1989). If this occurs, it is not known whether it is sufficient to compensate for the net loss of yield arising from closure of part of the fishing grounds and it may be the case that overall yields can locally decline. Not all fishermen regard reserves as beneficial. They may lead to a false sense of security and a belief that the resources are being 'managed' when they are not. As a centralised fisheries management tool reserves may also be an expensive option, and require strict enforcement, but within the context of community management they can be effective.

To be effectively implemented, marine reserves require an understanding of fish movements and behaviour, and optimal densities of fish to enable dispersal. It is argued that there is a need for more research to determine the optimal size, number and location of reserves (Bohnsack, 1998). Roberts (1998) argues that in order to achieve fishery and conservation goals, it is appropriate to establish a dense network of reserves incorporating a wide variety of habitats and locations.

In relation to the study sites closed areas (or reserves) are in fact the most commonly applied management tool. To investigate their effectiveness one needs to examine the size, abundance and species richness of fish within them, in relation to the effectiveness and period of closure.

Licensing was commonly applied at commercial fishing sites in Fiji, but since there were no limits to the number of licences the benefits are economic and not biological - that is there was no limited entry applied. Thus whilst the fishery may be argued to be managed for social and economic reasons, from a biological perspective, these fisheries have not been managed / controlled, and management actions may not be sustainable. At semi commercial sites where commercial fishing by non Vanua is banned this has effectively introduced a control on effort restricting it to native fishers only.

Gear restrictions have been applied in Pellonk (spear gun ban) both reducing fishing effort (or else redirecting it to alternative gear types) and potentially affecting size at capture, although there was no particular evidence that spear guns targeted a different size range from other methods (see Chapter 2).

Summary

This Volume, on Biological Outcomes will address the questions: If traditional models of community management are to be the basis of new co-management initiatives, how effective, across a range of fishing and population pressures, are existing attempts at community management in terms of biological sustainability? What is the status of fishery resources inside managed areas - has management conferred any benefit compared to un-managed open access areas - Management success?

To investigate the success of any management interventions, for fish populations and communities it is necessary to understand :

The effects of fishing

Single species effects

- Reduction in density and biomass (and cpue);
- Reduction in mean length;
- Increase in growth, and size at age;
- Increase in fishing mortality.

Multi-species effects

- Changes in species assemblage (predators are depleted first);
- Changes in species richness.

The effects of different management actions

For study areas there are 3 types of management:

Closed Areas

- Eliminate/reduce fishing effort on part of the stock;
- Recovery of depleted stocks, reversing fishing effects;
- Protects important habitats.

Licensing / restricted entry

- Reduce effort - Moderation of the effects of fishing.

Gear controls

Depending on the gear these will:

- Reduce effort - Moderation of the effects of fishing;
- Affect size at capture;
- Alter species composition.

In order to study fishing & management effects, this Volume will examine management success across a range of fishing pressures at different sites in Fiji and Vanuatu using a combination of two methods:

Underwater Visual Census, to describe:

- Habitat characteristics;
- Species and family abundance, & spp. assemblages;
- Species length differences.

A Fisheries monitoring programme, to describe:

- Species length, growth and mortality differences;
- Species and family abundance, & spp. assemblages.

Managed areas are expected to have low or zero (closed areas) fishing effort - and for these, only UVC data may be available.

Throughout this Volume, the effects of fishing on single species and communities of fish, and how management actions have moderated those effects will be examined through:

- Direct comparisons between tabu (managed) and open access areas;
- Correlation of study variables (e.g. mean length, cpue, abundance) with the level of fishing effort applied, to see if this explains any observations derived.

Summary details of study sites and the level of fishing in them follows Table 1.1-1.4.

Vanuatu

Table 1.1. Summary details of the area codes by site in Vanuatu, and the management interventions applied to tabu areas

Site	**Codes, tabu**	**Management**
Atchin	200-206	None
Emua	261-264; 263T, 264T	Closed areas, 263T before data collection, 264T during
Lelepa	241-250; 246T	Closed area
Pellonk	231-233; 233T	Closed area, 6 month spear gun ban at reef edge
Uripiv	221-225, 222T	Closed area
Wala	211-217; 213T 214T, 215T	Closed areas

Table 1.2. Summary details of the catch recorded by area within Vanuatu fishing sites from the fisheries monitoring programme. Catch is expressed as a proportion of the sustainable yield, calculated on a yield per unit area basis, and the the range of catches and average over all areas within each site is given for open access areas, and compared to that in tabu areas.

Site	Catch as % MSY@5mt/km^2	
	Open access	**Tabu areas**
Atchin 97	0-401% (Av. 82%)	
Atchin 98	1-168% (40%)	
Emua 98	25-28% (26%)	61% (264T)
Lelepa 97	0-78% (14%)	108% (246T)
Lelepa 98	0-130% (26%)	157% (246T)
Pellonk 97	1-15% (8%)	6%
Uripiv 97	3-111% (38%)	0%
Uripiv 98	2-75% (22%)	6%
Wala 97	0-435% (163%)	54%
Wala 98	0-224% (77%)	0%

Fiji

Table 1.3. Summary details of the area codes by site in Fiji, and the management interventions applied to tabu areas

Site	Status	Codes, tabu	Management
Vitogo	Commercial	2-9	Licensing/goodwill
Tavua	Commercial	121-inshore 122-offshore	Licensing /goodwill
Verata	Semi commercial	14-19, 16T	Native fishing only
Naweni	Semi commercial	20, 201T	Closed area, data follows reopening
Tacilevu	Semi commercial	21	

Table 1.4. Summary details of the catch recorded by area within Fiji fishing sites from the fisheries monitoring programme. Catch is expressed as a proportion of the sustainable yield, calculated on a yield per unit area basis, and the range of catches and average over all areas within each site is given for open access areas, and compared to that in tabu areas.

Site	**Catch as % MSY@5mt/km^2**	
	Open access	**Tabu areas**
Vitogo 98	5-129% (Av. 43%)	
Tavua 98	30-47% (39%)	
Verata 97	1-6% (4%)	3 %
Verata 98	1-6% (4%)	4 %
Naweni 97	6%	9%
Naweni 98	16%	1%
Tacilevu 97	19%	
Tacilevu 98	15%	