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Evaluating the role of science in Community Based Adaptive Management of coastal resources in Fiji

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In loving memory of my mother

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Acronyms

ABM	Agent Based Model
CBAM	Community based adaptive management
CI	Conservation International
CMT	Customary marine tenure
CPUE	Catch per unit effort
EBM	Ecosystem based management
EwE	Ecopath with Ecosim
EEZ	Exclusive Economic Zone
ELEFAN	Electronic Length Frequency Analysis
FIT	Fiji Institute of Technology
FAO	Food and Agriculture Organization
FLMMA	Fiji Locally Managed Marine Area Network
FSPI	Foundation of the Peoples of the South Pacific-International
GIS	Geographic Information System
IAS	Institute of Applied Science
ITQ	Individual transferable quotas
IUCN	World Conservation Union
LF	Learning Framework
LMMA	Locally Managed Marine Area Network
MARXAN	Marine Spexan
MIDAS	Marine Integrated Decision Analysis System
MPA	Marine Protected Area
MRIS	Marine Resource Inventory Survey
MRI	Marine Resource Institute
MSY	Maximum Sustainable Yield
MTI	Marine Trophic Index
NASA	National Aeronautics and Space Administration
NGO	Non Governmental Organisation
NOAA	NOAA National Oceanic and Atmospheric Administration
ParFish	Participatory Fisheries stock assessment software

PCDF	Partners in Community Development
RM ANOVA	Repeated Measures Analysis of Variance
SA	Stock Assessment
SAUP	Sea Around Us Project
SLO	Site Liaison Officer
SMD	Standardised Mean Deviation
SOPAC	South Pacific Islands Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SST	Sea Surface Temperature
TNC	The Nature Conservancy
UB	University of Boston
USP	University of the South Pacific
UVC	Underwater Visual Census
WCS	Wildlife Conservation Society
WI	Wetlands International
WWF	World Wildlife Fund

Abstract

Community-based adaptive management (CBAM) has generally been accepted as an effective means to sustainably manage coastal ecosystems and small scale fishing activities. This particularly applies to areas where indigenous communities have significant control over their resources through customary marine tenure (CMT) such as the South Pacific. In Fiji CBAM is employed as a national strategy for coastal area management with over 300 communities involved. Activities are coordinated by the Fiji Locally-Managed Marine Area (FLMMA) Network which aims to integrate modern scientific knowledge with traditional management and governance systems for improved coastal area management. The use and degree of natural science required to support CBAM, however, is not well defined and viewpoints vary greatly between stakeholders and managers. This thesis highlights the actual and the potential use of natural science to be integrated into CBAM and support sustainable management at various levels of governance. Particularly, existing approaches such as participatory community-based biological monitoring are discussed. Statistical analysis of generated data was used to review the quality of this key scientific input to CBAM. Interviews were conducted with managers, scientists, government personnel, and community members to determine different stakeholder priorities and information needs for the CBAM approach. This allowed to examine how current efforts are addressing these priorities and needs at various governance levels and where potential use for future science interventions lie. Existing biophysical data from Fiji were compiled to propose suitable methods for predictive coordinative planning such as modelling approaches. In addition, alternative monitoring and evaluation methods are discussed. The study suggests that the supporting function of natural science to CBAM has not been fully exploited to date. Current procedures to generate site based scientific knowledge tend to be limited in their scope, and appear to be having limited direct impact on management of coastal resources. The main issues that prevent effective use of existing scientific knowledge are a lack of clearly defined objectives, a lack of capacity, deficient communication of scientific outputs, and a need for increased community education and training. These limitations combined with the degree and capacity to which communities can effectively benefit from the collection and interpretation of data based on scientific methodologies without continuous external input, need to be revised. At mid and national level and for improved project facilitation, there is potential to use novel approaches. This however, will require the amelioration of capacity and support functions.

Chapter 1:
General Introduction

1.1 Background

Fiji has a rapidly growing population (Fiji Islands Bureau of Statistics, 2007) of about 900.000 people of which 99.9% are living on or near the coast (WRI, 2005). As a consequence, coastal resources in Fiji are under increasing pressure. A large proportion of the population are directly dependant on coastal resources for their livelihoods and as daily source of protein. It is estimated that at least 60% of all rural households are involved in subsistence fishing with landings of about 21,600 t/yr (FAO Fishery and Aquaculture Country Profile Fiji, 2008). Small-scale commercial inshore fishing is estimated at producing annual landings of about 9,320t (FAO Fishery and Aquaculture Country Profile Fiji, 2008) representing a prime income sources for communities although it is carried out mainly as part time occupation in Fiji alongside with other obligations, e.g. farming (Adams et al., 1997).

Fiji's inshore fishery is a multi-species multi-gear fishery (Veitayaki, 1995). While women generally supply fish on a daily basis for subsistence purposes by means of gleaning or netting in the near shore area (Vunisea, 1996), men focus on fishing for artisanal/commercial purposes and often use motorised boats, hand lines and spear guns (Vunisea, 1997). Fishing behaviour is opportunistic since Fijians are generalists in their consumption. Some resources however are specifically targeted by fishers due to their high yielding value e.g. certain sea cucumbers species, trochus, giant clams, and a few fin fish species.

Fiji

Fiji is an archipelagic nation comprising about 322 mainly volcanic islands in the South Pacific Ocean stretching from 12°-21°S latitude and 176°E-178°W longitude. The island group lies 1,770 km northwest of New Zealand and has a total land area of 18,272 km^2 with a coastline of 5010 km^2. Fiji is divided into 14 provinces, each being subdivided into several districts. The group includes two large high islands, Viti Levu and Vanua Levu, several medium-sized high islands, and numerous small islands and atolls of which most are surrounded by fringing and barrier coral reefs. Coastal fisheries are predominant but fishing and aquaculture also take place within the three large river systems, a few lakes and some man-made impoundments (FAO Fishery and Aquaculture Country Profile Fiji, 2008).

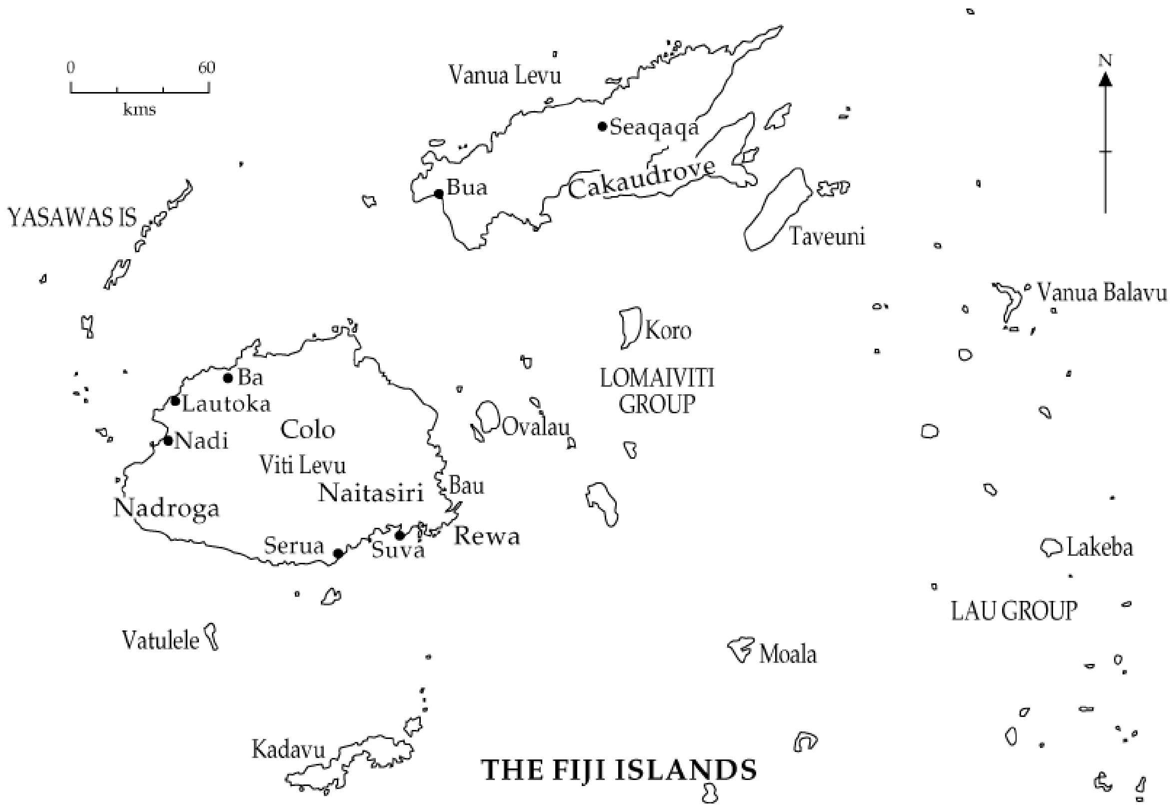

Figure 1. The Fiji Islands (source: www.pacificmagazine.net)

The Challenges

A recent study by Bell et al. (2008) suggests that Fiji is among 11 Pacific Island Countries whose inshore fishery will not be able to even meet the forecast needs of coastal resources to ensure food security. Another study by Newton et al. (2007) classified Fiji's inshore fishery as already being over-exploited whereas Wilson et al. (2008) advocate coral loss as "the overriding agent of change". There are several challenges which have to be faced in order to preserve the productivity and functionality of coastal habitats into the future. Especially, multi-species fisheries can mask overfishing of vulnerable species which has nevertheless been reported by many communities (The DemEcoFish Project, 2004; pers. comm. Alifereti Tawake, FLMMA project manager). This can be linked to a range of influencing factors. The increasing access to more efficient fishing gear (e.g. motorised boats, spear guns), population increase as well as increased cash needs for fuel, church and school fees accelerate pressure on marine resources. Additionally, environmental degradation is fuelled by increasing levels of urbanisation and industrialisation along with poor land use practices caused by logging and unsustainable farming (Watling and Chape, 1992). This entails the pollution of coastal waters and siltation of reefs placing increased pressure on the coastal environment and their fisheries (WWF South Pacific Fiji Country Profile, 2008).

Community and Customary tenure structure

To address these issues effectively, management initiatives have been set up which use area based management systems that build on Fijian community systems and traditions. Indigenous Fijians are the customary resource owners of the land and inshore area which is divided by Customary Marine Tenure (CMT) into 410 traditional fishing grounds (*qoliqoli*). These are ranging in area from 1 to 5,000 km^2 (Muehlig-Hofmann, 2007a), covering the coastal area and isolated islands from the low water mark to the fringing reefs. Each *qoliqoli* is the communal property traditionally owned by the communities which live in the adjacent area. Communities are built on a hierarchically structured social kinship system based on clans (*mataqalis*) in which the chief and his/her clan are regarded as the guardian of the land, the inshore area and all the people who live in it. Land, sea and people are traditionally considered as a connected system which is called the *vanua*. Within a community the accumulation of individual wealth is prevented by sharing most of the gained resources or goods (Capell, 1991). Under CMT indigenous Fijian communities can restrict access of outsiders to their *qoliqolis* and have unlimited subsistence fishing rights. Nonetheless, they are obliged to obtain a fishing license if engaging in commercial fishing activities. Although CMT is acknowledged by the government the legal ownership has not been granted to the communities. The chief has the final say in decision making but traditional leadership has weakened in several communities in recent times (Muehlig-Hofmann, 2007b). A transition is taking place where the effects of capitalism continue to undermine communal structures and promote individual accumulation of wealth (Shuster et al., 1998). Whereas this is often the case in near urban areas other more remote communities seem less prone to this development.

Customary management and CBAM

In Fiji customary marine management systems are based on community imposed spatial and temporal restrictions on harvesting. Individual villages or districts can set up so called tabu areas, which function like marine protected areas (MPAs) and can be in place from a few months to years. Traditionally such areas were established after a chief’s death or an important community member and lasted for 100 days. This gesture of respect also ensured plenty of easily harvestable fish for the community and their visitors at the end of the mourning period (The LMMA Network, 2005). Additionally, customary management measures like effort, gear, and species restrictions have been reported in the Pacific region (Cinner et al., 2007a). Because of their perceived potential to meet both conservation and community goals, these traditional resource management techniques are being revitalised by communities, governments, and NGOs, and are incorporated into the modern national and regional marine conservation strategy in the Pacific. This is because traditional management systems alone are not likely to withstand the profound social and economic changes with the resulting increased pressure on natural resources (Cinner et al., 2007b).

The management of nearshore resource use in Fiji, and in much of the Pacific, has offered a great challenge to centralised management systems. Western fisheries management frameworks have often failed to adapt to varying circumstances and localised issues due to various reasons from geographic range of Pacific island states to a lack of compliance and enforcement capacity. Modern efforts of community based management in the Pacific have had better success (Govan et al., 2006; Lam, 1998). While there are several approaches to integrated management, CBAM, first defined in Govan et al. (2007a), utilises a model where the lead role is played by the local resource users. Involved in CBAM are communities, local stakeholders, and relevant institutions (project partners). The adaptive management is based on the revision of an agreed and implemented management plan which is monitored and adapted in regular intervals if necessary (Govan, 2007a; Govan et al., 2008a). Because Fiji has strongly community driven decentralised governance systems, CBAM as management approach seems to be the most suitable concept. CBAM is a bottom-up approach to management rooted in the reality of local communities, and is centred on their needs. This stands in contrast to Western management concepts which often follow a top-down approach based on science requiring substantial funds to carry out surveys to give management advice. Monitoring and evaluation measures within CBAM in Fiji are therefore also largely community-based. The aim is to integrate modern scientific knowledge with traditional management and governance systems to address local issues and create management plans to promote sustainable coastal fisheries practices.

However, CBAM has a relatively low priority on science-based management not only because modern science has had no traditional role in local management and management decisions can be expected to be made within social and socio-economic frameworks. Therefore, it could be argued that the involvement and active participation of local resource owners has a greater priority than science-based management optimisation. Nevertheless, scientific information is important not only to communities but even more so at mid (district & provincial) and national level planning and management for making best informed decisions. Thus, the role of natural science in CBAM is often challenging to define. Generally, scientific information for management purposes can come from existing scientific knowledge or it can be derived through additional surveys. These surveys can be used to target specific stakeholder priorities and information needs or they can monitor and evaluate ongoing management efforts. At present the role of natural science and its degree of application for CBAM in Fiji is not very clearly defined. Therefore, an evaluation is required of its actual and potential role at different governance levels for sustainable management of coastal resources in Fiji.

1.2 Objectives of study

The thesis investigates to what degree and in what form natural science research and scientific knowledge are applied to support CBAM and provide information to decision makers and stakeholders in Fiji for sustainable management of coastal resources. This was done at the local community as well as at the mid and national planning level, as they should be providing a general framework for the community based efforts. However, due to the prevalence of community driven coastal management in the South Pacific, the focus of the present research lies on subsistence and artisanal/small-scale commercial inshore fisheries. In order to evaluate the role of natural science in CBAM and mid and national level management it is vital to have a thorough understanding of its actual applications. Thus, it is important to assess stakeholder priorities but also determine information needs for the current management approach. This will help to examine the effective use of natural science and allow detection of potential gaps or alternative approaches. Furthermore the current use of science is examined by providing an analysis of the ongoing community-based monitoring efforts. This allows investigating the nature, quality, and value of this key scientific input to the CBAM approach.

In addition the potential role of modified or additional science based tools for inshore marine resource management in Fiji was examined. The analysis presented here concentrates on modelling approaches based on available biophysical data for predictive coordinative planning to address stakeholder needs and interests.

The present study is structured around 4 specific objectives, namely:

Chapter 2: To examine CBAM for coastal resource management in Fiji and its relationship to the district, provincial and national governance levels.

Chapter 3: To define stakeholder priorities and information needs for decision making in the CBAM approach at different governance levels and determine the use of existing information.

Chapter 4: To analyse the current role of natural science in the CBAM approach using the example of ongoing community-based biological monitoring surveys. More specifically the role of existing data and the actual and potential utilisation and degree of scientific knowledge in providing management support.

Chapter 5: To evaluate the potential use of natural science (including alternative survey methodologies and modelling based on existing data) to provide scientific information for the support of management planning for CBAM and mid/national planning levels.

Chapter 2

The CBAM approach in Fiji and its links to various governance levels

2.1 Coastal management in Fiji

In order to evaluate the role of natural science in CBAM and mid and national level management it is vital to have a thorough understanding of this management approach in Fiji.

Central planning as a national development process began in Fiji during the 1960s (Brookfield, 1979), however, sustainable resource management was not a management target, nor were the local communities involved in the process. Only during the 1990s it was recognised that communities as customary resource owners are vital to decision making and implementation processes. This novel approach induced close collaboration with communities and marked the shift from top-down to bottom-up community-based participatory planning and management. Past experiences have shown that conservation can be successful only if the needs of the local resource owners are accommodated (Bell, 2007). Involving people in community-based resource management requires a long-term interest in the process, patience and understanding. (Veitayaki et al., 2003). This is one of the major reasons why externally developed management initiatives, that are often limited to short time periods, have had very limited success. The change to CBAM has been accompanied by other alterations. Along with the shift from a centralised to site-based grass-root approach, non-governmental organisations (NGOs) and the University of the South Pacific (USP) began to replace many of the government's roles in project implementation and community engagement. Simultaneously, a shift from terrestrial, forest-centred initiatives to marine projects occurred, supported by funding priorities of foundations and private donors (Lees, 2007). One major regional initiative for the promotion of community-based coastal management was the establishment of the Locally-Managed Marine Area (LMMA) network which operates in the South East Asian and South/Central Pacific region. The LMMA network was initiated in 2000 to function as a learning network based on the Learning Framework (The LMMA network, 2004), a biological, social, socio-economic, and governance related monitoring & planning tool.

2.2 The FLMMA Network

In 2002 the FLMMA network was founded as the first country-level network to operate independently within the overall network. While FLMMA functions within the LMMA framework and is implemented through the Learning Framework (LF), it has been adapted to a Fijian background. Its origin dates back to the 1990s when residents of some communities realised that the marine resources in their *qoliqoli*s were becoming scarce (Veitayaki et al, 2003). The FLMMA vision is "to promote the conservation and sustainable use of marine resources in Fiji, by working together and sharing experiences between Locally Managed Marine Area (LMMA) Network members and partners and to empower local communities to manage and monitor their marine resources, through awareness, skills building, and improved dissemination of information" (The LMMA Network, 2005). The mission statement "Everlasting Fish for our Future Generation" mirrors the strong food security driven approach. In contrast to a conventional spatially limited approach, FLMMA was developed as a low-cost, low-tech, simplistic approach that spreads funds equally across all partner sites.

FLMMA network partners and members are communities that have adopted the FLMMA approach, government agencies, educational institutions, and local and international NGOs (see Appendix I). The secretariat is held by the Fisheries Department which adopted the FLMMA approach as the national management strategy in 2004 (pers. comm. Margret Tabunakawai, Fisheries Department Officer). The FLMMA network partners and members collaborate on the basis of a memorandum of understanding (MoU) and the Social Contract. Although not legally binding, the members commit themselves to base their work on good social relations and to improve conservation for the good of the communities and the marine environment (The LMMA Network, 2005). In addition, the MoU contains an information and data sharing policy that requires agreement of individual members for the use of their data.

Alternative approaches to community based work exist in Fiji, which are not always focused purely on coastal resource management or on the FLMMA model. Other members place their focus on tourism issues or communication and a strongly science focused ecosystem based management (EBM) model is being trialled as well. Since the annual FLMMA meeting in November 2007, CBAM is officially defined as the FLMMA approach and will be referred to as such in the thesis.

2.3 Management strategies

The Institute of Applied Science (IAS) has been supervising the expansion to the current 217 FLMMA sites by helping the communities to set up and implement specific management plans to counter resource depletion and secure local livelihoods (The LMMA Network, 2008). Under this management regime, resource owners set aside specific areas of their fishing grounds to allow resources to recover. These tabu areas can be permanent, temporary or rotational and they can either be species-specific or restricting the extraction of all resources. The tabu areas, of which 222 have been set up so far, are often temporarily opened after a certain time period for fund raisings or village functions. These closures are nested within a larger managed marine area, the locally managed marine area (LMMA) (see Figure 2). LMMAs are based on the reasoning that more sustainable fisheries can be achieved through training and informing resource users on how to limit fishing and harvesting and (in some cases) monitor the success of this work.

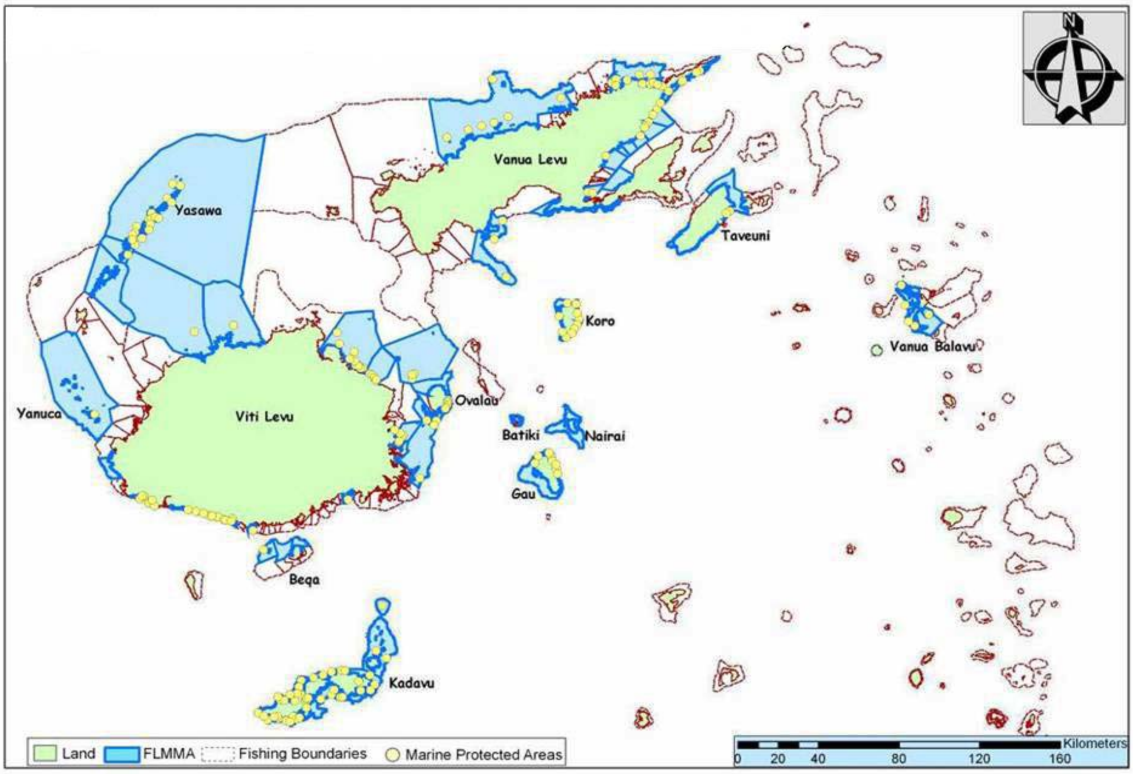

Figure 2. FLMMA Network sites (adapted from: The LMMA Network, 2007)

The goal of FLMMA is to create a network of LMMAs across Fiji's 410 qoliqolis. FLMMA is estimated to cover around 10,460 km^2 or a third of Fiji's inshore fishing area (The LMMA Network, 2008). Furthermore, Fiji's government committed itself "to effectively manage and finance 30% of Fiji's inshore and offshore marine area (EEZ) within a comprehensive, ecologically representative network of marine protected areas by the year 2020" (pers. comm. Margaret Tabunakawai, Fisheries Officer). FLMMA's contribution to this commitment will focus on the inshore area.

It is proposed in the LF that tabu areas are assumed to provide the following benefits: a source of eggs, larvae, and/or juveniles for relevant species and a source of mature individuals of certain species. Thus it is expected, under certain assumptions such as community compliance and appropriate reserve location that resource abundances will increase inside and outside the tabu area (Parks and Salafsky, 2001). Empirical evidence for increases in size, abundance and biomass of fish within marine reserves have been piling up (for a review see Roberts and Polunin, 1991; Bohnsack, 1996; Roberts and Hawkins, 2000). However, an increase in open surrounding areas due to net-movement of adult fish (density dependent spill-over) as well as an export of larvae and juveniles (recruitment enhancement) has been rarely empirically proven. A response, an actual recovery or increase in biomass due to protection, will vary among species and reserves, and will likely be affected by a suit of factors such as the degree of movement, reserve design, and length of protection (Roberts and Hawkins, 2000).

Additional management measures which are promoted by FLMMA are sustainable harvest strategies within the LMMA. These include awareness raising on the effects of harmful fishing methods. However, these strategies are not clearly defined and it is uncertain in which way they are actually being implemented at the site level. Additionally, small development projects, some of which are land-based, are suggested like building of pig pens, re-planting of mangroves and giant clam re-stocking have been carried out in some sites (refer to the LMMA support guide for proposed management options: Govan et al., 2008a).

To conclude, the focus for coastal resource management strategies in Fiji lies on the following categories:

- Setting up tabu areas
- Promoting sustainable harvest strategies
- Future up-scaling of tabu areas/LMMAs to a national network

2.4 FLMMA site based approach

The implementation of the management strategies at the site level follows according to the adaptive management cycle. As illustrated in Figure 3, the process starts with communities approaching one of the FLMMA partners and initiating a meeting in which the true interest and intention of the respective community is assessed. A planning workshop follows in which the whole community takes part. Marine resource awareness and management is promoted and information is shared on resource availability and its use via participatory rural appraisal (PRA) techniques. In PRA an outsider facilitates and enables local people to conduct their own data collection and analysis (Chambers, 1992). The LMMA guidebook (Govan et al., 2008a) provides a framework for this process; the draft version has been used as a field guide for several years previous to publication.

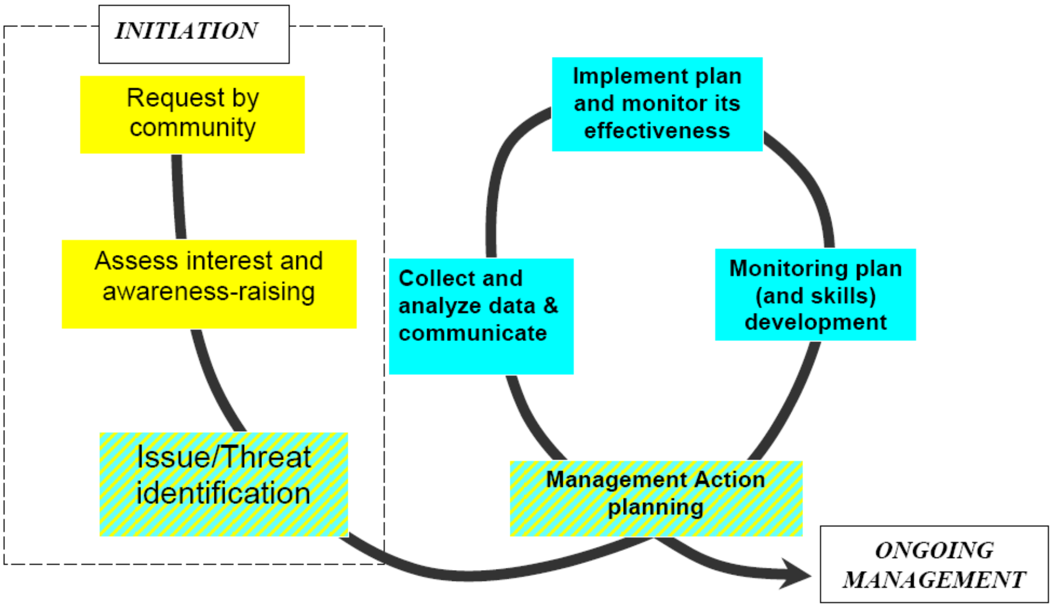

Figure 3. The adaptive management cycle (Tawake, 2007)

Simple ecological concepts are taught and a resource map of the fishing ground is drafted in which community members indicate the spatial distribution of marine resources and habitats, major fishing spots and other properties like current directions. The output of the workshop is a Management Action Plan which contains identified threats, the ways how these are going to be addressed, by whom and over which period of time. Shortly after, the tabu area is set up often near the village for better enforcement and accessibility. To evaluate the effects of the tabu area on marine resources a second workshop is held to design a monitoring plan and to develop biological monitoring skills with a group of community members (community-based biological monitoring is further discussed in Chapter 4). After both plans are implemented the project process is revised with assistance of the FLMMA partners. In the long run communities are expected to carry out the management and revision of the project progress themselves.

2.5 Contemporary levels of governance

The contemporary governance system in Fiji combines traditional with modern governmental institutions. Additionally, traditional administrative structures exist which are strictly hierarchical from tribe to clan and sub-clan to extended families to individual households. Presented governance levels are based on information given by a key informant due to the lack of secondary data on this topic.

Community level:

Through CBAM this level is the most active in terms of management and conservation. Each village (*koro*) has a *qoliqoli* committee that is represented by the fish warden(s) who are in charge of enforcing the tabu, the monitoring team and the village headman (*turaga ni koro*). The committee which is in consultation with the chief is responsible for the implementation of the management plan. It also gives management recommendations at village meetings. Additionally, groups are set up (e.g. youth groups) which are appointed with certain tasks from the management plan.

District level:

At the district (*tikina*) level the chiefs, the village headmen and the district representative hold *tikina* meetings about every three months representing their villages. A district comprises about five to six villages. The meetings are usually concerned with poaching and licensing issues and are mandatory for the respective government officers to attend; other representatives (project partners, scientists etc) can also be invited. These meetings are a useful instrument for decision making, advertise the idea of CBAM, and to function as dissemination of general information back to the village level.

Provincial level:

Each of the 14 provinces in Fiji has its provincial extension office. There is no research carried out at this level and the work is largely fisheries development driven (see above). Management support teams have been established in two provinces (Kadavu, Cakaundrove) and two districts (Macuata, Kubulau) as a first step to decentralise national efforts and to strengthen the link to the communities. At this level meetings are held by the provincial council which are attended by the district representatives (*matani tikina*) and the fisheries officers of each district (usually only one to two).

National level:

Coastal resource management at the national level is represented by government departments, in particular the Department of Fisheries. The Department is divided into the Research Division and the National Extension Office. The Research Division carries out the Marine Resource Inventory Survey (MRIS) since 2002 with the goal to survey every *qoliqoli* via Underwater Visual Census (UVC) techniques to establish *qoliqoli*-wide management plans. Also a research station is run which focuses on clam aquaculture and turtle conservation. The Extension Office disseminates the information provided by the Research Division and enforces the regulations from the Fisheries Act (established in 1942), which prohibits destructive fishing practices and imposes minimum sizes on a number of reef species. The Fisheries Department accommodates 15 research staff members and about 30 extension officers. However, despite ongoing surveys the Department is mainly fisheries development driven and amongst others involved in license issuing and managing of ice-plants (for more information on the Fisheries Department refer to Hand et al., 2005).

Information dissemination is not only flowing from the national to the community level but also bottom up through a suit of mentioned meetings which happen at all levels and who are initiated by the village, district and provincial councils.

Governance structure between local communities and local representatives with the government body are very complex, thus Figure 4 concentrates on the major links relevant to coastal resource management, especially fisheries.

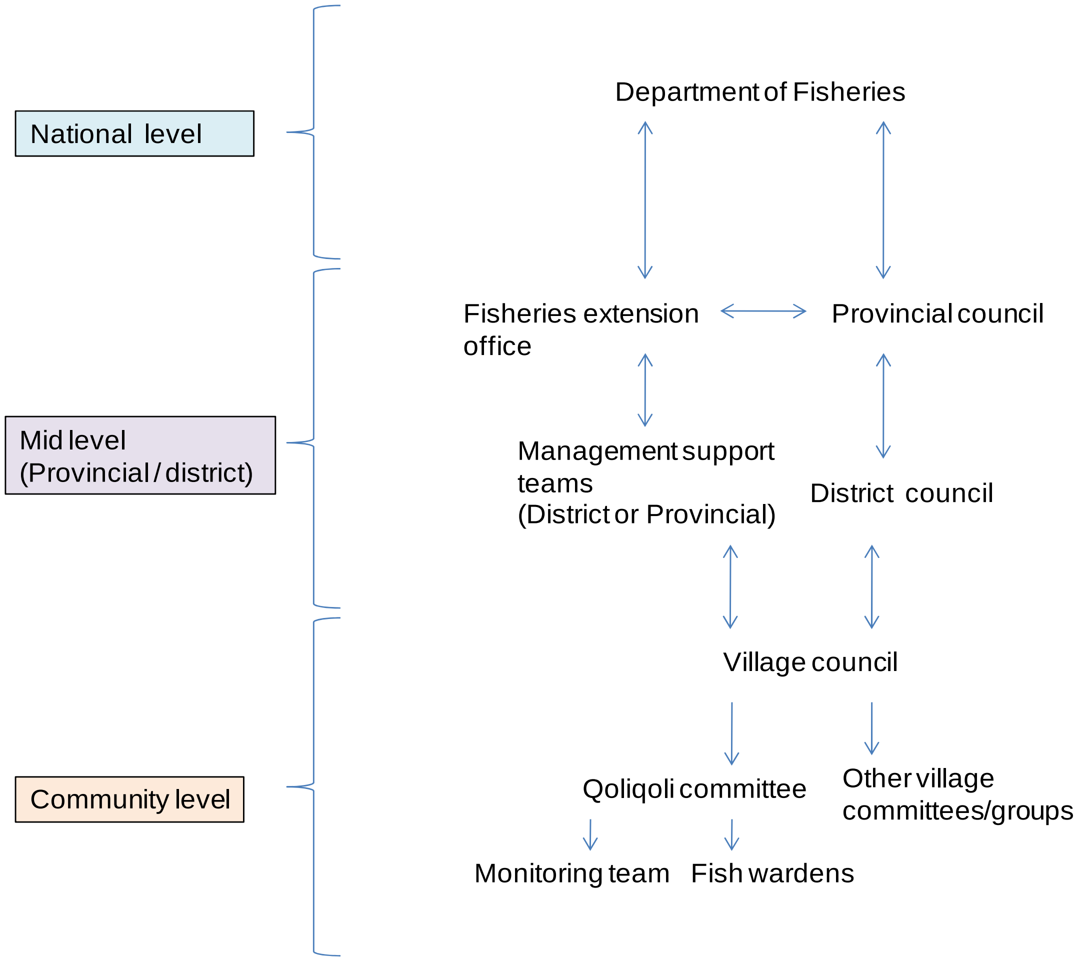

Figure 4. Diagram of contemporary governance levels in Fiji

2.6 Brief discussion on the content

CBAM in Fiji has many obvious benefits. The current participatory approach of raising awareness and setting up tabu areas will also most likely yield a higher commitment from the communities regarding the government plans to establish the planned 30% MPA network. However, to ensure the CBAM model to be self-sustaining it has to be low-cost, community-driven, adaptive, and providing enough training and management relevant education. It is unrealistic however to expect all communities to take on management issues without any future help; therefore it is vital to establish appropriately trained support functions which have to increase with numbers of involved communities. Those have risen enormously in the recent past and there are still new communities initiating a request to FLMMA. While this speaks for the success of the approach the sheer number makes it increasingly difficult due to a lack of trained staff and time to supervise all communities equally and provide them with management recommendations and relevant information. As a result not all FLMMA sites receive the same attention and it might be questionable if all of the communities reach a level of (near) self-sufficiency. On-the-ground resource management advisors would be best suited to support this fragile system (Muehlig-Hofmann, 2007a).

Fijian society is structured into various governance levels and holds potential to build more support functions. Although support teams are now being established to help with the management and planning process, the government bodies as well as the support committees and teams remain highly understaffed and may not be adequately trained to fully provide necessary scientifically based information and backgrounds. There is also debate about the long-term effectiveness and sustainability of the tabu areas and even about whether over-harvesting has diminished as a result of the projects (Lees, 2007). Tabu areas are believed to induce density dependant spillover of adults and dispersal of larvae and eggs into the open harvest area. These effects have rarely been quantified and the only well documented recovery in Fiji exists for a mud clam (*Kaikoso*; *Anadara antiquata*) tabu area near Ucunivanua village, Tailevu (Aalbersberg et al., 2005). However, there is documented evidence of perceived benefits from at least some of the sites (Lees, 2007) which reported improving catches in the short to medium term. Also, there is evidence that indicators of empowerment, opportunity, and ownership are improving for the involved communities.

The concept of long term tabu area closures and the need for management is taken up very differently by various Fijian communities. While some communities have deliberately extended the tabu status for a 5 to 10 year period, after having witnessed an increase in resources, other communities opened their reserve on a regular basis. This has occurred despite recommendations given to close them for at least three to five years and is usually done to provide money for certain functions or village projects and other necessities. The decision on the length of protection period will mostly depend on community reliance on marine resources for subsistence use and source of income. Different community objectives on whether an increase in fish abundance within the tabu area or within the fished area is perceived as the main management goal will also affect the choice of strategy.

Evidently, the management focus lies on the tabu areas while more attention should be paid to manage the whole fishing grounds. MPAs are accepted as efficient management tools particularly in areas where more specific measures are harder to enforce (Jones, 2001; Willis et al., 2003). However, in CBAM strategies should be adapted to suit local challenges, thus tabu areas should not be seen as a universal remedy (Govan et al., 2008c). The success will be linked not only to social factors like compliance and enforcement from the communities’ site but also to ecologically based design criteria. These criteria and the response patterns of certain species to area closures are still not very well understood in Fiji. Therefore, the promotion of tabu areas should be done with caution and realistic expectations. While it is certainly a vital tool for the long-term management of inshore marine resource management, it still requires important supporting frameworks such as a functional fisheries management and integrated terrestrial management. For these strategies appropriate information is needed. Focussing the attention on the community level, has led to resources being managed at a social and not at an ecological scale. While some species are very site-attached and may recruit back to the same area, marine populations are strongly interconnected. Adults can move long distances and their larvae can disperse over areas larger than those which are currently managed.

The success of the CBAM approach however, is not just a question of scale and choice of management strategies. It will ultimately depend on the communities' capacity and interest to adapt to the changes that occur, and on the mid and national government's capacity to provide an adequate framework and support functions to sustain the process. One requirement to achieve this goal is to improve communication between stakeholders and provide them with enough information that is relevant to resource management and decision making thereof.

Chapter 3

Information needs and stakeholder priorities for CBAM in Fiji

3.1 Introduction

Any successful management approach relies on adequate information for decision making. This information can originate from existing scientific or traditional/ local knowledge or can be generated through scientific surveys. As described in Chapter 2, FLMMA aims at raising awareness amongst communities and at providing existing scientific information and concepts on sustainable resource management of the inshore areas. The information is said to come from relevant scientific publications which includes recommendations on appropriate locations for tabu areas and time frames of protection (pers. comm. Alifereti Tawake). However, what and how much information is provided at the site level may vary depending on the community's knowledge and on the respective facilitators or project partners. Also socio-economic and community-based biological monitoring is carried out in some sites to provide additional management relevant information (refer to Chapter 4 for more details).

It is crucial that appropriate information needs are being identified and addressed at all levels to enable best-informed decision making and co-ordination of management strategies. Furthermore, management priorities have to be addressed as well because such efforts are likely to result in higher compliance and subsequently more effective management. Conducting stakeholder interviews and surveys can be used to investigate these key questions. Having this knowledge will help to identify the potential of existing and novel science in addressing these priorities and how this can be implemented in a Fijian context. As pointed out in the previous chapter, the focus of coastal resource management strategies in Fiji lies on the establishment of tabu areas, sustainable harvest strategies, and on future up-scaling of tabu areas to a provincial or national network. Additional scientific information is needed to ensure that these tools are used appropriately to maximise their benefits. However, scientific information needs cannot be assumed to necessarily match with stakeholder priorities in a country where the role and use of science is not well defined. This might imply a trade-off between these two issues in order to arrive at realistic and implementable strategies.

Additionally, providing management relevant information to stakeholders may not necessarily result in its application since other issues might be of higher priority. Therefore, it is important to assess to which degree the provided information has been incorporated into the management process.

3.2 Methods

Sampling Design

A descriptive approach was selected for the collection of the data due to the nature of the study. The assessment of stakeholder priorities and management information needs at different governance levels was based on informal, unstructured, and semi-structured interviews (see below) with interview partners from the Provincial and National Department of Fisheries, FLMMA practitioners, and informants from seven communities in Kadavu province (see Figure 5). Additionally, it was also attempted to give a brief overview whether communities implement information and recommendations given by FLMMA partners and whether it influences their decision making. Most of the collection of information and its analysis depends on the oral response by the key informants and the interviewees from the communities due to the lack of availability of written records on the issues looked at. Additionally, secondary data were consulted as well as expert knowledge to provide a set of required basic management information needs to successfully implement focal management strategies. Interview and sampling methods used are described further below based on Bernhard's Research Methods in Anthropology (2002). Interview partners and key informants, which are defined as knowledgeable individuals for the respective field of interest (Pelto and Pelto, 1978), were identified by the following sampling methods:

Purposive sampling

In purposive sampling informants are identified and chosen according to the purpose or field of interest to provide the information needed by the researcher. FLMMA key informants were chosen through purposive sampling since the researcher was already familiar with their line of work.

Haphazard sampling

This technique is often used in exploratory research since it takes advantage of the presence of anybody who is available and willing to give the requested information. During the Kadavu field trip community members would either volunteer as informants or were assigned by the village headman.

Snowball sampling

In this kind of sampling technique key individuals are asked to name others who would be suitable informants for the research topic. This approach was chosen to identify informants from the national and provincial Fisheries Department which were suggested by FLMMA key informants.

Field methods & data collection

Unstructured interviews

Sitting down with an informant and talking about the research topic based on a clear plan but with limited control over the interviewee's responses was mainly used throughout the field trip in Kadavu. Topics included perceptions on tabu area success, how the tabu had been chosen, use of provided information from the workshops, monitoring, resource management as well as information needs and areas of interest in coastal management.

Informal interviews:

This method is characterised by a total lack of structure or control but is particularly useful when building greater rapport and to uncover relevant topics that might have been overlooked before. Informal interviews were used in several cases during community interviews with informants who were not familiar with parts of the research topics to give the informant the chance to express certain topics relevant to him or her.

Semi structured interviews:

This method follows an interview guide with a written list of questions and topics that need to be addressed in a certain order but still give the informant the chance to expand on certain topics to reveal additional information. This technique was used to interview FLMMA key informants and informants from the Fisheries Department to name stakeholder priorities and management information needs at various governance levels. FLMMA key informants mentioned a number of questions which were raised by communities and which they identified from their work experience as stakeholder priorities (N=3). These questions were grouped into four thematic topics. Furthermore, they identified stakeholder questions from mid and national planning levels. Stakeholder questions and information needs from provincial and national planning levels were also identified by Fisheries Research and

Extension Officers from the National Department (N=5) and the Provincial Fisheries Office in Kadavu (N=1).

Field trip

Community interviews in seven communities were conducted during a one week excursion in March 2008 to evaluate information needs and priorities at the site level and to assess the current use of available information for management decisions. The field trip took place along the North-East coast of Kadavu province (see Figure 5), which lies 80 km to the South of Viti Levu. Kadavu is the fourth largest island of Fiji with a population of about 10,000, and is still largely rural with only minor developments and little infrastructure. A total of 17 interviews were held with 29 community members individually (N=12) or in focus groups of two (N=3), three (N=1) or eight (N=1) respectively. Informants ranged from 16 to 55 years of age, a third of which were women. Interviews were mainly conducted in English by the researcher herself or in Fijian with the help of an interpreter.

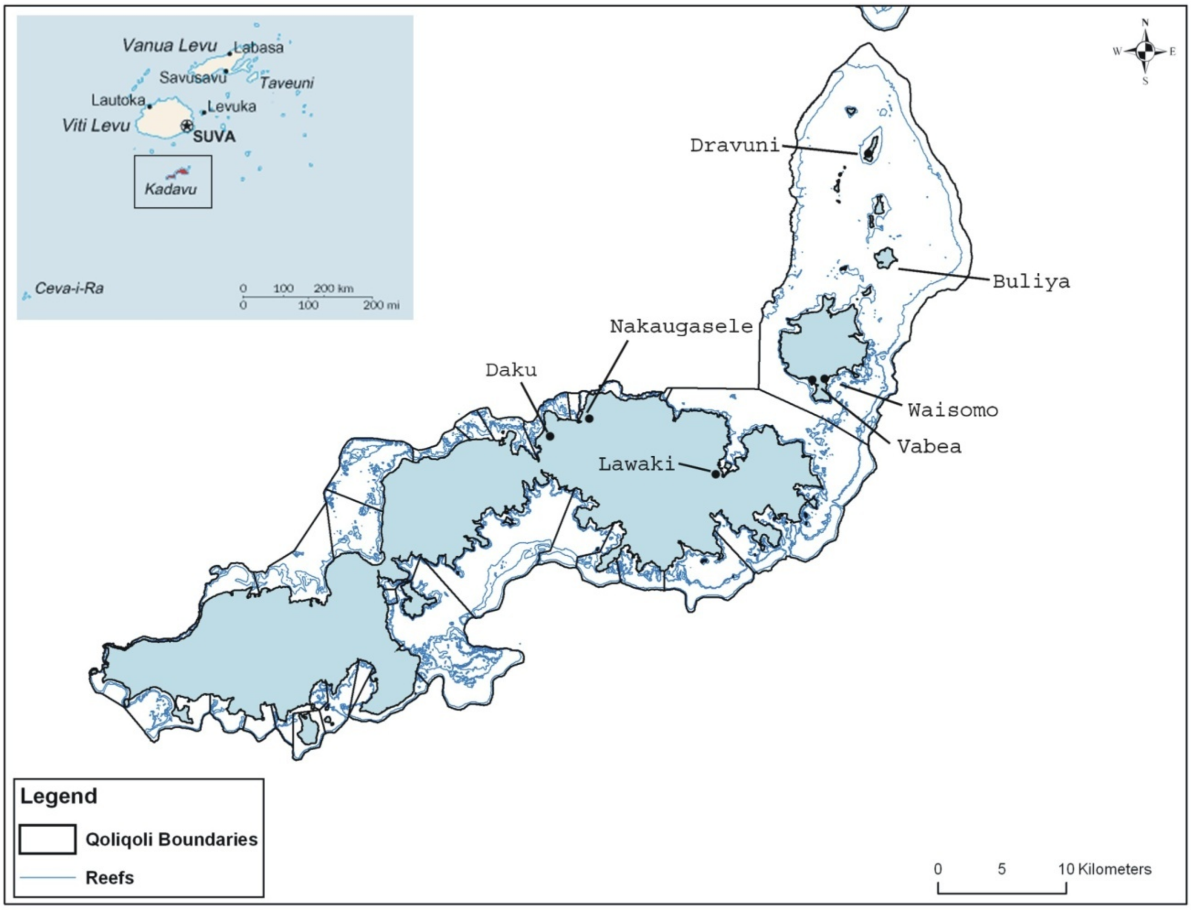

Figure 5. Map of Kadavu

Constraints in data collection

Since the informants during the field trip were randomly assigned to the researcher little control was given over the knowledge of an interviewee on the particular research topic. Community members shared in many cases additional information which was not directly relevant to the research topic (for interview summaries refer to Appendix II).

While the data collection had to be adapted to an informal interview style in some cases, it also provided a brought overview over the communities and illustrated a great range of interest in management related topics. It also yielded interesting information and broadened the researcher's understanding of village dynamics and daily life issues.

A great restraint however, was the limited period of time available for conducting the interviews due to which only a fraction of the topic could be covered in the given time. The results were therefore analysed with some key informants to share experiences.

3.3 Results

Use of provided information

From community interviews it was indicated that in five of the seven villages the location of the tabu area was chosen due to bio-geographical reasons. Some interviewees mentioned that a healthy reef was chosen in an area with favourable hydrological patterns. Only one community said they were planning to move the area in front of their village since they had received lots of poaching from Suva. Similarly, community members said to have closed the tabu area for 5 years with opening events in two villages. All interviewees indicated that the location and the length of protection status were chosen by the community; it seemed however, that both were based on FLMMA's recommendations.

An exception was noticed in women; only two interviews were conducted with women due to their absence at the management meetings. Some women from the focus group in Dravuni village who had recently moved there, weren't aware of the tabu area that was established a couple of years ago. And none were informed about the planned relocation of the area from the current location upstream to a location near the village which might affect their shore based fishing activities. Interviewed women were talking about how they would catch fish but not about management related issues. In terms of awareness raising on unsustainable fishing practises and additional management strategies however, different results were found. One interviewee mentioned that he learned from the workshop not to stand on corals to "not destroy the house of the fish".

Particularly, awareness of fishing impact on marine resources differed between interviewees. In two cases, resource abundance was still believed to be in unlimited supply whereas others mentioned overfishing as the reason for declining catches.

> *"God made man to dominate nature. He will provide us with unlimited fish"*
> (Community member from Nakaugasele)

> *"We caught less and less because before we took more than our families could eat."*(Community member from Daku)

However, several young informants also said that *duva* was still used, a fish poison which is banned nationally, and some admitted to go poaching regularly in the adjacent *qoliqoli*. Also coral pounding a method in which corals are pounded with sticks to scare fish out of their refuges was still practised although they realised damages in coral and a change in composition and behaviour of reef fish. Spear gun fishing and mangrove cutting were also mentioned as recreational activities in two villages.

> *"Conservation is important but making money is more important."*
> (Community member from Dravuni)

Stakeholder priorities at various governance levels

Community level

Information priorities of stakeholders at the site level identified by key informants and through community interviews did in many cases not overlap (see Table 1). FLMMA key informants were strongly focussed on questions related to tabu area design, degree and length of protection, and on providing communities with quantitative guidelines on their fishing activities. In contrast to that, community interest was based on more general and additional knowledge on species and management strategies A third of all community informants mentioned no management related information priorities. These interviews were held with women and young male community members. However, out of the other two thirds of informants who mentioned a range of interests, the most frequently voiced priority (50%) was that they wanted more management support and were interested in learning about other tools apart from the tabu area to improve catches. The paramount chief of Ono Island stressed the importance of managing the *qoliqoli* as a whole and not just to focus on the closed area. A quote by a community member from Daku summarises the need for additional management related information and support:

> *"We don't know what we don't know, this is why we need FLMMA's support."*

Also, a common priority mentioned by a third of the interviewees was the general request for additional awareness trainings and workshops for repletion.

"Before the workshop we didn't know about the importance of protecting the reef, we didn't care about it"

"If you tell it to us once, we will forget; if you tell it lots of times people will remember." (Chief of Waisomo)

Additionally to that, information on life history patterns particularly of economically high valued sea cucumbers and the movement of finfish was mentioned as a priority in a fourth of all interviews.

Mid and national levels

Informants from the Fisheries Department were particularly focused on surveying the inshore fishery and the *qoliqolis*. At the national level, a major interest was the establishment of a quota system for the artisanal and commercial inshore fishery. As a basis, logbooks had to be filled out by license holders since 2006 which to date generated questionable information. The Head of the National Fisheries Extension Office Eroni Talemaikanacea mentioned that "recording is not part of their life; they simply want to catch as much as possible". Informants from the government clearly prioritised fisheries related issues above the planned up-scaling to a national network of marine reserves. In particular, monitoring and stock assessment were named to be of key interest. In contrast, FLMMA key informants were more interested on whether the individual tabu areas were working as a connected network of marine reserves.

Information needs at various governance levels

Generally, at both planning levels basic information on the status of the fishery and its resources as well as marine reserve effects need to be present or provided, although with differing resolution. At the mid and national planning level information needs to be more focused on how to coordinate current approaches and generate network relevant knowledge such as the effects of marine reserve networks. This would also require clear objectives and design criteria for the network. At the site level, providing basic information on life history patterns of key resources, an increased knowledge on additional sustainable fishing practises and management strategies, as well as general effects of different tabu area designs are the most basic and important information needs to effectively manage the inshore fisheries.

Table 1 shows the summarised results from interviews with key informants, the Fisheries Department and community members on management related information priorities and interests. Table 2 summarises respective key information needs identified by the researcher.

Table 1. Management related stakeholder priorities and questions; (N) = Numbers of responses from community interviews (N=17)

	Community level		**Mid/national governance level**
Identified by	**communities**	**key informants**	**government (gp) & key informants (ki)**
Management related questions & priorities	**Biological information** 1. Information on fish migration pattern (2) 2. Information on live history patterns and aquaculture of sea cucumbers (*Holothurians noblilis*) (2) 3. Life history & habitat requirements of fish (1) 4. Ecological connectivity of mangrove systems (1) 5. Size limits of finfish (1) **Alternative management strategies** 6. More support and additional management ideas apart from the tabu area (6) **Additional training** 7. More workshop and awareness trainings (4) **Other** 8. Back reporting of research outcomes (Sea grass project in Buliya) (1) 9. Why do fish become poisonous? (1) 10. How to keep the tabu area tidy (1)	**Design of tabu areas** 1. What is the effect of tabu area size on marine resources to ensure food security? 2. What is the effect of tabu area location on marine resources? What habitat composition does it need to have? 3. Is one large tabu area or a number of small ones more effective to ensure food security? **Time frame of protection status** 4. What is the optimal timeframe for a marine reserve/ tabu? 5. How effective is a temporal tabu compared to permanent ones? 6. How long should a tabu area be closed before opening? **Tabu area openings** 7. What is the effect of harvesting strategy (e.g. total harvest) during a tabu area opening on marine resources? 8. How can communities decide on how much to take during the opening? 9. What is the effect of duration of tabu area openings? How long should they be opened for? 10. What is the effect of frequency of tabu area openings? **Spillover, (Maximum) Sustainable Yield** 11. Is the tabu area generating any significant spillover for the rest of the *qoliqoli*? 12. What amount can be fished outside the tabu areas to ensure the sustainability of stocks?	**Networks of tabu areas and connectivity (ki)** 1. How do adjacent FLMMA sites affect/ complement each other? 2. What effects may networks of tabus have on fishery stocks and on biodiversity priorities? **Management related issues (gp)** 3. How much is being caught for subsistence and artisanal purposes? 4. What is the maximum sustainable yield of a fishing ground? 5. Performing stock assessments 6. Monitoring/ Surveying all *qoliqolis* in Fiji 7. Establish a system of quotas to regulate the harvest 8. Pick resilient sites to climate change

Table 2. Management information needs (identified by the researcher)

	Community level	Mid/national governance level
Information needs	• Effects of different tabu area designs, degree, and length of protection • Knowledge on additional sustainable fishing strategies such as optimum size ranges and sustainable catch levels of key resources • Life history information on finfish and invertebrates: age of (length at) maturity, reproduction, population doubling times, recruitment and habitat requirements during different live stages • Additional awareness of fishing impact on resources, particularly of harmful fishing practises (e.g. also on economic repercussions) • Holistic, ecological knowledge regarding the connectivity of systems • Continuous flow of management relevant information particularly for women and the youth • Information on implications of certain management strategies to deal with uncertainties	**Marine reserve network** • Effects of networks of marine reserves • Clear objectives and design criteria for the marine reserve network • At least basic knowledge on hydrological patterns (connectivity of different coastal habitats) • Larval transport: how are local marine populations connected • Fish distribution in space and time over their entire life histories • Benthic habitat distribution, abundance of various benthic habitat types, particularly in near shore environments **Fisheries management** • General knowledge of the fishery (exploitation for artisanal and subsistence purposes) • Productivity & sustainable capacity of the coral reef fisheries in Fiji • Improved knowledge on monitoring & survey design for the Marine Resource Inventory Survey (MRIS) **Others** • Identifying reef areas and affected communities of higher threats to environmental degradation and climate change

3.4 Discussion

Use of provided information

Some of the literature suggests that in general local communities possess neither the capacity nor a traditional trust in modern science (e.g. Moller et al., 2004). Scientific information might appear to be an abstract construct which may prove to be outside of communities' considerations and is only marginally used for decision making. At present it remains unclear to which degree such information actually influences the adaptive management process. When recommended measures conflict with socio-economic considerations, the latter are likely to be more important to communities. This especially pertains to several informants who applied destructive fishing practises and went poaching regularly despite their knowledge on the impacts. However, location and length of protection of the tabu area was consistently reported to be based on biological and ecological considerations. Further detailed research of community criteria and decision making is important to evaluate this question in depth. Thus, presented results shall provide the ground for further investigations.

Stakeholder priorities at various governance levels

Community level

Questions identified by key informants seemed to rather reflect stakeholder priorities like giving specific advice to communities for tabu area management. Since the FLMMA protocol names the sustainable resource management within the whole LMMA as one of their major strategies it was surprising that answers from informants emphasised a lack thereof. The mentioned need for additional management strategies and support apart from the tabu area might also indicate that current efforts are not meeting community expectations and do not work effectively enough to sustain or increase catches. However, due to the small geographical range of sampled villages, findings may not be generalised and may be area specific. A third of the informants did not formulate any management related information needs or priorities. These interviews were held with women and young male community members who are traditionally not actively involved in the decision making process. Therefore, they have a minor role in management. This was particularly the case with women who were either absent or only had an observer role at the management meetings throughout the field trip. Appropriate ways have to be found in the future to address this issue. Another explanation for the lack in mentioned information priorities was that management itself did not seem to be considered as a priority by these informants. It also seemed that it was easier for individuals who had attended an additional workshop to talk about management issues and voice interest in certain areas. The repeated call for more workshops however, might have also been a result of delivering economic revenues for the villages (pers. comm. Isoa Korovulavula, research fellow at IAS) since every visitor pays a fee of FJ$20 per night. Answers also exemplify the ongoing dependence on information and support from FLMMA.

Mid and national levels

Information priorities raised by government department personnel did not overlap with those identified by key informants. While the latter where again more focused on tabu areas in a larger context in terms of creating a network of marine reserves, the fisheries department seems more concerned with fisheries related information needs. This makes sense to a certain extent since crucial information like time lines of catch statistics and information on artisanal/subsistence fishery is hardly available. Until recently, statistics from the Fisheries Department’s Annual Report were relying on a value from a fishery survey carried out in 1978 onto which 200mt were annually added (pers. comm. Bob Gillet). Also, the licensing system still lacks any form of scientific basis. It was also identified from interviews with informants from the mid and national planning levels that a general lack in human and financial capacity is a major constraint to addressing current priorities and identified information needs. At both levels the importance of scientific information was recognised but ongoing work is still largely development driven which is also reflected in 80% of the diplomas of Fisheries Department personnel (pers. comm. Alifereti Tawake). An informant from the provincial office in Kadavu indicated that they would rely on scientific information from USP and due to a lack in staff and monitoring capacity they were using the amount of sold ice from a near-by ice plant as indicator on current fishing levels.

Information needs at various governance levels

Community level

Information needs at the site level largely reflected identified community and key informant priorities. Although community informants did mention rather unspecific or general needs for increased support, awareness and additional management strategies are among the focal needs at the site level. Information that is vital to CBAM and that is already available to some extend is regarding the life histories of key resources. Unfortunately, such information is insufficiently provided to the communities, although it would be highly relevant to certain management related questions, such as design criteria and the prediction of indicator response or time frame for recovery of certain species (necessary duration of tabu closure). Since the implementation of marine reserves will affect recruitment only after a number of years equal to the age of maturity, this would be needed to establish reference points for management interventions. Also, implementation of MPAs typically increase yields only in fisheries with excessive effort and do not address other impacts that can prevent recovery of exploited stocks. MPAs generally can only produce greater catches than conventional management when habitat heterogeneity and movement dominate (Roberts et al, 2003). On the other hand marine reserves will have the greatest effect on species with sedentary or sessile juveniles and adults and on non-migratory reef fishes (e.g. Botsford, 2005). FLMMA advocates tabu areas as the answer to stock recovery. But especially with regard to the very small size range of the tabu areas, resource recovery during a short to medium term cannot be guaranteed. Stakeholder priorities named by key informants will therefore require additional targeted research to produce knowledge that allows the quantification of reserve effects under different designs and degrees of protection. It is vital to avoid raising unrealistic expectations among the communities but also to examine the existing issues of marine resource management and to evaluate a range of options that might be applied separately or combined. These could be more conventional measures e.g. establish rules of thumb on sustainable harvest levels and common sense strategies like effort relocation away from spawning aggregations (Johannes, 1998).

Mid and national levels

Scientific information needs for the establishment of a network of marine reserves are manifold. It needs to be ensured that the individual marine reserves are functioning as a network which is connected through spillover and larval dispersal envelops. Understanding the degree of connectivity and the driving processes is vital for planning at the provincial or national level. In addition other important factors such as representativeness of habitats and whether there is some level of replication within the network need to be addressed. Many of those information needs are common because only little empirical research has contributed evidence for certain effects. Many criteria are based on assumptions and critical information of larval dispersal and home range of adult fish are still largely unknown, as are the effects of varying degrees of habitat representation. All of this information is currently largely unknown for Fiji. There is also no clear concept on how to design the network. Aisake Batibasaga, the head of the Fisheries Department, said that the government commitment was overly optimistic and that it should rather be aimed at protecting 10% as a start. He also stressed the importance to have permanent reserves within the network. It will be vital however, to establish a set of criteria according to the design for the future network. These criteria can then be applied to scientific decision support tools to facilitate the network design. The former government committed itself to the 30% goal thus, it remains to be seen whether the current and future governments will implement this plan.

Chapter 4

The present role of science in CBAM – a case study of community-based biological monitoring

4.1 Introduction

Natural science based information is important and provides the basis for the FLMMA approach in Fiji. As mentioned in Chapter 2, existing scientific information is used to raise community awareness, and provide guidance for adaptive management. For the FLMMA approach, scientific knowledge is communicated especially during the initial workshop(s) with the intent that this information exchange will be refreshed during follow-up visits. Community-based biological monitoring is the second stage where science is important. It is the key scientific input to CBAM at the site level.

Monitoring the progress of a project is an integral part of any management system, especially in adaptive management which tests implemented strategies for potential adaptation. In addition to the FLMMA based monitoring, several other monitoring regimes for management of Fiji's coastal resources exist. These vary greatly in effort from highly scientific to volunteer based programmes (this includes also FLMMA partners). Biological monitoring activities within the CBAM approach, however, are strictly community-based and are carried out by or in collaboration with the communities. Participatory monitoring approaches have received increasing international recognition over the past couple of years (Abbot and Guijt, 1998, Uychiaoco et al., 2001, Danielsen et al., 2005). Surveying the status of marine resources and evaluating the success of management tools is one of the multiple benefits community-based biological monitoring is believed to have (Tawake et al., 2003; Govan et al., 2008a). These also include providing a mechanism for community involvement and increased project ownership. Outputs are intended to guide decision making for adaptive management.

For this purpose, community members are trained to carry out biological monitoring of their fishing grounds via underwater visual census (UVC) techniques. UVC has been widely adopted for the use of monitoring changes in the abundance (and size-frequency) of reef fish within marine protected areas (Bell et al., 1985; Russ and Alcala, 1996).

Monitoring activities within FLMMA are based on the LF which proposes the survey of more than 80 management success indicators to become a full member of FLMMA. Only two of these are biologically monitored via UVC. They are described as “species health” (size and/or abundance per area or time) and “habitat health” (percent intact habitat). Other indicators are aimed at monitoring social and socio-economic changes and are beyond the scope of the present thesis. Further to the existing biological monitoring, a national catch per unit effort (CPUE) survey has been launched in November 2007 spearheaded by IAS with approximately 80 participating villages Fiji wide. IAS is also coordinating most of the community-based monitoring and data analysis and manages the data in the IAS database. At present IAS is consulting 184 sites of which about 70 sites (40%) are estimated to have already undertaken at least one biological monitoring survey (pers. comm. Alifereti Tawake).

In contrast to the above mentioned quantitative monitoring all other management strategies are being evaluated during the revision of the management action plan. Such ‘perception-based’ approaches have also been explored in the broader Pacific region.

Govan et al. (2008b) identified three main audiences to whom community-based biological monitoring results are of interest to (see Table 3). Perceived benefits and certain knowledge can potentially educate the wider academic or interested public and feed back into FLMMA and LMMA network, region or nation-wide learning and planning.

Table 3. Audience and common purposes for bio-monitoring (adapted from Govan et al., 2008b)

Communities	• Community involvement; increase in project ownership • Adaptive management; as an evaluation tool for project progress
Project, NGO, government planning and donor staff	• Effectiveness assessment for planning, financial or donor reporting purposes • To answer stakeholder questions
Wider academic audience and interested public	• LMMA network learning • High quality data could be used for publishing in peer-reviewed journals

The monitoring programme of the FLMMA network was designed to deliver many of these benefits. However, the rapidly increasing membership, limited resources, and novelty of this approach have brought with them many challenges. Analytical efforts of the survey data were undertaken by FLMMA to examine general trends across sites for network and academic learning. So far the analysis yielded limited statistically significant results (pers. comm. James Comely, research advisor to IAS), and it is said that no reliable measure of impact was found to date (Govan et al., 2008b). As a consequence, discussions are ongoing by IAS and FLMMA on the robustness of generated data to be used by communities for CBAM, and on its future role in the network. These issues require a closer inspection of the goals set, goals achieved, and the way monitoring has been utilised.

Therefore, the present study aims to critically examine the current monitoring efforts, based on nationwide data collected by IAS, to provide recommendations to improve the use of existing and future monitoring.

More specifically the presented study focuses on the two following aspects:

1. Is the biological monitoring data of sufficient quality to provide scientifically sound evidence for success of tabu areas as management measure to improve fish abundance?
2. To what degree do communities use their monitoring results for decision making and adaptive management purposes?

4.2 Methods

Community-based biological monitoring

The community-based monitoring is an integral part of FLMMA membership and is normally initiated through site liaison officers (SLOs) from IAS or partner institutions which includes training and support. First, a biological monitoring workshop is held in which a monitoring plan is drafted and up to five, (usually) male community members, are being trained in UVC techniques. The monitoring follows an adapted BACI-design (Before-After-Control-Impact)[1] which concentrates on monitoring the effects on certain indicator species within the closed (tabu area - impact) versus the exploited (control) area over time. However, there is no specific agreed upon objective or sampling design (in terms of replication, spatial distribution, etc.). The LF only states that data should be collected both inside and outside the tabu area "to help determine possible safe haven, spillover, and/or seeding effects" whereas the LMMA support guide suggests that control sites can either be close to the no-take area or at any other distance. The Community Based Biological Monitoring Training Guide (Tawake et al., 2003) suggests however, that 4 transects are placed in the tabu area and two transects are placed on either side of the reserve to detect such a spillover effect. This was indicated as one of the standard procedures (pers. comm. Alifereti Tawake). The biological monitoring covers a variable set of indicator species that are selected during the initial workshop. These indicator

[1] There is no baseline data available since the tabu areas looked at were first surveyed after their implementation.

species are chosen by the community usually according to their cultural, economic, and biological importance (Tawake et al., 2003). They are then monitored by the following monitoring methods used within FLMMA:

a) Belt transects (100m x 5m) for finfish and invertebrate counts (absolute density)
b) Quadrates (1m x 1m) on line transects for the assessment of benthic cover (usually percent hard coral cover)
c) Timed swim counts for indicators in mangrove environments

For details on the monitoring training and the suggested methodologies refer to the Community Based Biological Monitoring Training Guide (Tawake et al., 2003) or the Community Biological Marine Monitoring Training Video (The LMMA Network, 2003). This DVD is distributed to the communities during the initial workshop for explanation and revision of the monitoring methods. Monitoring is usually carried out annually under supervision of IAS members for 3 consecutive surveys. Monitoring results are presented and analysed with their support during a village meeting after the surveys. When communities conduct the monitoring independently, they are only being reminded of when to monitor (pers. comm. Alifereti Tawake). They are then expected to self-sufficiently communicate, interpret and use the results for the adaptive management process. The data is also sent back to IAS or collected by a site liaison officer for central storage and further analysis for network learning.

Analysis of IAS community-based biological monitoring data

To date, statistical analysis of FLMMA survey data has been focusing on meta-analysis using Standardised Mean Differences (SMDs) and rates of change between different sampling events. For the following analysis, descriptive and inferential statistics were applied to determine overall treatment effects at the site level, and to assess whether the data is showing a change in indicator abundance a) within and b) between tabu areas and control sites over time.

Database examination

The IAS community-based biological monitoring database (received on the 10th of June 2008) was examined. A summary table of all monitoring sites listed in the database was created with coded survey frequencies of the open and closed area per year and in total (see Appendix III). A total of 66 sites were listed in the FLMMA database as being surveyed while the data of only 53 sites have been entered so far. Out of these 53 sites, 27 had monitoring data for at least two surveys, and another 12 of these have completed three or more surveys. A second summary table (see Appendix IV) was created featuring these 12 sites with a complete list of sampled indictors (55 in totals) and their frequencies.

Data selection process

To enable a statistical comparison of the data, sites and indicators were selected according to the following criteria:

1. Sites with at least three concurrent surveys for both the open (control) and the closed (tabu) areas.
2. Surveys with at least three transects carried out in both open and control site.
3. Out of these only indicator species which were sampled in at least three completed surveys for both the open (control) and the closed (tabu) site.
4. From these indicators only the ones which were sampled at three or more sites were chosen.

The selection yielded a set of ten sites and seven indicators. The raw data was screened to look for unusable or corrupted data.

- The 2002 data set for the open and closed area for Lekanai was discovered to be identical and had to be discarded. As a result only two sampling events remained which violated the first selection criteria and the whole data set was excluded from further analysis.
- The Vanuaso data was excluded because the data for 2002, 2003, and 2004 showed discrepancies between the original count and 100/m^2 column which could not be resolved.
- The 2003 data for Namada was excluded from the analysis because it could not be established which part of the raw data was from the open or closed areas.
- The 2007 data for Daku was filtered out due to insufficient transect replication (only the tabu area was monitored with one transect.)

With the Lekanai and Vanuaso data set removed a total of eight sites and seven indicators remained and were chosen for further analysis; this equals 68 comparisons for the opened and closed areas. Furthermore the data had to be consolidated and corrected in some cases to make a statistical comparison possible (see Table 4). While most of the indicators were sampled at the genus or family level, in some sites (N=5) and for certain years and indicators a more detailed survey was carried out with two to six indicators at the species level. These were pooled for standardisation (indicated as MI in Table 4). Additionally, data from two sites (Namada and Naovuka) had to be converted because they changed their sampling design from one year with replication at the site level (four stations inside and outside the tabu area with four 20m long transects each) to the conventional four 100m long transects inside and outside the area. However, tabu areas are generally too small to allow statistically independent replication at the site level, resulting in pseudoreplication. To reduce bias from potential pseudoreplication and to allow comparison with other sampling events individual transects were pooled at the station level and extrapolated to a 100m transect length (count x 1,25) for standardisation. Data are presented in N/500m^2.

Table 4. Site and indicator data used for analysis: c=corrected; MI=multiple indicators; SR= site replication; TL= change in transect length; UD= unusable data

Sites / Indicators	Daku	Nasegai	Naovuka	Nasau	Namada	Vatu-o-lalai	Votua	Navakavu
	2007 UD	-	2002 SR	-	2003 UD, 2006 SR	-	-	-
Emperor	4b; MI; c	3o,4b; ID+	3o,4c; 1SR, 1TL, c	-	3b; MI; SR; TL; c	-	-	3b
Giant Clam	4b	-	3o,4c; 1SR, 1TL, c	4b	-	3b	-	-
Grouper	3b	3b		4b	-	-	-	3b
Parrotfish	4b; MI; c	3b	3o,4c; 1SR, 1TL, c	4b	3b; SR; TL; c	3b	3o,4c	3b
Rabbitfish	4b	-	3o,4c; 1SR, 1TL, c	-	3b; SR; TL; c	-	-	-
Sea cucumber	4b; MI; c	3o,4c; MI; c	3o,4c; MI; 1SR, 1TL, c	4b	-	-	-	5b; MI (04,05,06); c
Surgeonfish	4b; MI (2006);c	3o,4c; MI; c	3o,4c; MI; 1SR, 1TL, c	4b	3b; MI(2004); SR; TL; c	-	-	-

Through SLO interviews and available written records additional site information was gathered to enhance analysis and interpretation of the data (see Table 5). However, it was found that most of the additional information was not consistently available and varied between different sources. Information on opening events was initially not gathered by IAS because it was not regarded as a vital source of information. Recently, IAS started to gather the data for such openings but for the few sites for which information exist, bias of retrospective anecdotal data proposed cautious interpretation. Effects due to potential poaching cannot be quantified but have frequently been reported and may be significant in some sites. Tabu site selection has been left entirely up to the communities and would be expected to have a strong influence on potential effects of management measures. Some communities have chosen to protect healthy, productive reef areas whereas others have opted for less functional or productive habitats in hope to restore the area or because they didn't want to sacrifice a valuable fishing ground. These initial differences in habitat quality and indicator abundance imply different expectancies for recovery rates.

Table 5. Information on tabu areas: C= coral reef; S= Seagrass; S/R= Sand/Rubble; M= Mangroves; MA= Macroalgae; P= Protection; R= Restoration; *Tabu area has been relocated in 2004

Site name	Date(s) of opening	Status	Tabu area set up	Survey period	Survey period [yrs]	Habitats within tabu area	Size [km2]	Nr of transects
Votua (Nadroga)	Not opened	P	2002	05/2003-08/2007	4	C, S/R, MA	0.8	4
Vatu-o-lalai	Not opened	P	2002	04/2003-07/2006	3	C, S/R, MA	0.5	3; 4
Namada	Opened June 06 (1 day)	R	05/2002	05/2004-03/2006	2	C, S/R	0.5	4
Navakavu*	Not opened but ongoing poaching	R	2002 01/2004	03/2003-04/2006	3	C, S, M	2.9	4
Daku	Annually for 2-3 weeks after Christmas	P	06/2002	12/2002-12/2006	4	C, S, M	2.9	5;3
Nasegai	Not opened	P	02/2003	06/2004-02/2006	2	-	1.2	5;4
Naovuka	Opened	R	-	10/2002-08/2006	4	-	0.2	4
Nasau	Opened	R	08/2003	04/2005-03/2007	2	-	2.4	6/4;3

The data analysis

The mean indicator abundances were plotted against their survey dates for comparison and interpretation of overall treatment effects and differences between and within open and closed areas. The results provided the basis for further inferential statistics. The data were tested for normality and equality of variances using STATISTICA 8. Since both assumptions for a parametric test were violated, the nonparametric Wilcoxon paired-sample test for dependent samples (Wilcoxon, 1945) was chosen to detect a statistically significant change in abundance inside and outside the tabu sites. The interaction between indicators and management tool over time was tested here to see whether the tabu area is actually working to increase abundances. Therefore, the null-hypotheses for each test states that $\mathbf{H_0: u_1 = u_{last}}$ and $\mathbf{H_0: u_1 = u_{max}}$ where u_1 and u_{last} represent the mean of the population sampled at the first and the latest survey listed in the database and u_{max} signifies any intermediate peak often observed in the time series. To compare tabu with control sites over time, a Repeated Measures ANOVA

(RM ANOVA) was chosen, which is the standard test for repeated measures of treatment and control sites over time. This parametric test accounts for multiple comparisons of repeated measurements over time and is more powerful than alternative nonparametric tests. Since the frequency distribution of most data sets was left skewed, the data were log-transformed to achieve a normal or near-normal distribution. For this analysis only data sets with survey data for both tabu and control areas were used.

Additional data collection

SLO interviews

To explore the actual utilisation of community-based biological monitoring for adapting management and decision making, semi-structured interviews were conducted with seven SLOs who are responsible for consultation and supervision of community monitoring. This provided insights on how the individual monitoring processes of a) data gathering, b) communication, c) interpretation and d) management adaptation are being implemented by the communities. SLOs indicated the frequency of occurrences of all 4 steps from the recorded monitoring sites (N=27). This data provided additional and vital information to create a more comprehensive picture on monitoring activities that have not been quantified to date. Additionally, SLOs also shared their experience on how well and willingly the communities were performing these tasks. They also indicated main drivers behind community decision making and the benefits and limitations of the current monitoring programme. Supplementary, informal interviews with FLMMA community members from various villages during the Kadavu field trip and at FLMMA meetings provided some information on community perception on current monitoring efforts.

Field trips

Two field trips to Silana (Tailevu province) and Lawaki (Kadavu province) were conducted to take part in the biological monitoring and get a first hand impression on how the monitoring procedures are implemented at the site level. Participant observation was used to assess benefits and limitations thereof such as sampling issues. Participant observation is a method in which the researcher is a part of, and participates in, the activities of the people, group, or situation that is being studied.

4.3 Results

Statistical analysis of IAS monitoring data

The RM ANOVA was used to detect statistical differences between tabu areas and control sites for each survey event over time (see Table 6). Significantly higher abundances in the tabu areas compared to the control sites at the first survey were detected in a fourth of all comparisons (24%). This occurred furthermore in 38% of the tests for the intermediate surveys (second, third, and forth survey where available), while significantly higher abundances in the control sites also occurred in 12% of all comparisons. These numbers decreased to 29% and 6% respectively at the last survey. The most consistent and significant increases within the tabu compared to the control sites were recorded for Daku and Nasau which coincided with higher replication during the sampling. Relating to indicators this was the case for emperor and surgeonfish.

Table 6. Results from RM ANOVA of time series data between tabu and control sites: * significant at p<0,05; ** significant at p<0,01; NS: not significant >0,1; (+) / (-): tabu area significantly higher / lower than control site; values in bold - data that showed a non-normal distribution after transformation;

Indicator	Survey	Site							
		Naovuka	Daku	Vatu-o-lalai	Navakavu	Votua	Nasegai	Namada	Nasau
Rabbitfish	1	**NS**	NS					NS	
	2	* (-)	* (+)					NS	
	3	**NS**	* (+)					NS	
Giant clam	1	**NS**	**NS**	NS					**NS**
	2	* (-)	**NS**	0,058 (+)					**NS**
	3	**NS**	**NS**	* (+)					**NS**
	4		**NS**						
Surgeonfish	1	NS	** (+)				**NS**	** (+)	** (+)
	2	NS	NS				**NS**	NS	* (+)
	3	** (+)	* (+)				**0,077 (+)**	NS	* (+)
	4		NS						* (+)
Grouper	1		* (+)		NS		NS		* (+)
	2		0,076 (+)		NS		0,076 (+)		* (+)
	3		* (+)		NS		* (+)		* (+)
	4		NS						NS
Parrotfish	1	NS	NS	* (+)	NS	NS	**NS**	NS	NS
	2	NS	** (+)	* (+)	* (+)	NS	**NS**	** (-)	* (+)
	3	** (+)	* (+)	NS	** (+)	** (-)	**NS**	NS	** (+)
	4		NS						NS
Sea cucumber	1	**NS**	NS		NS		NS		NS
	2	**NS**	NS		NS		NS		* (+)
	3	**NS**	* (+)		NS		0,06 (-)		
	4		NS		** (+)				
	5				* (+)				
Emperor	1	**NS**	**NS**		NS		**NS**	NS	
	2	** (-)	**NS**		NS		** (+)	* (+)	
	3	**NS**	* (+)		* (+)		**NS**	NS	
	4		**NS**						

Wilcoxon pair-wise comparison tests showed where detectable statistical differences were found between different sampling periods within tabu areas (Table 7) and control sites (Table 8). The first test value (t_1 with t_{last}) compared the first with the last available monitoring event and the second test value (t_1 with t_{max}) compared the first with an intermediate peak value, where this was observed. Statistical significance is set at the standard alpha value of $p<0,05$ (*) but values at $p<0,1$ are also indicated since a 10% chance of committing a type II error of rejecting a true null hypothesis is still sensible given the community-based utilisation of the data.

Out of the 34 tests which were run for the tabu sites to compare the first with the last monitoring event, 20% showed a significant increase over time at the $p<0,1$ alpha level and only 3% at the $p<0,05$ level. For the control sites the values were 11% and 3% respectively. Within the tabu areas 15 intermediate peaks were registered of which half were significantly higher than the initial abundance of the indicator at the $p<0,1$ level and another 20% were statistically significant at the $p<0,5$ level. Out of the 11 intermediate increases in abundances within the control sites, 45% were tested as significant at $p<0,1$ and 35% at $p<0,05$ (the latter all occurred in Nasegai). Abundances within the tabu areas significantly decreased in 10% of all tests between t_1 and t_{last} at $p<0,05$; all occurred at the same site (Nasau). Abundances over time did however not decrease within the control sites.

The most consistent and significant increases in indicator abundances were recorded for surgeonfish, emperor, and sea cucumber.

Table 7. Significance levels of Wilcoxon pair-wise comparison within the tabu area : * significant at p<0,05; NS: not significant >0,1; NA: test failed; (+) / (-): $t_{last/max}$ significantly higher / lower than t_1

	Naovuka		Daku		Vatu-o-lalai	Navakavu	Votua		Nasegai		Namada		Nasau
	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{last}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}
Rabbitfish	NA	0,068 (+)	NA	* (+)							NS	0,068 (+)	
Giant clam	NS		NS		NS								NS
Surgeonfish	0,068 (+)		NS	NS					0,068 (+)		NS	0,068 (+)	* (-)
Grouper			NS			NS			0,068 (+)				* (-)
Parrotfish	0,068 (+)		NS		NS	NS	0,068 (+)	0,068 (+)	NS	NS	NS	0,068 (+)	* (-)
Sea cucumber	0,068 (+)		NS	NS		0,068 (-); NS [1]			NS	* (+)			* (+)
Emperor	NS	0,068 (+)	NS	0,08 (+)		0,068 (+)			NA	* (+)	NS	NS	

[1] Due to tabu area relocation in Navakavu, the first value refers to the initial tabu area and the second value for the final area;* is significant at p<0,05

Table 8. Significance levels of Wilcoxon pair-wise comparison within the control area: * significant at p<0,05; NS: not significant >0,1; NA: test failed; (+) / (-): $t_{last/max}$ significantly higher / lower than t_1

	Naovuka		Daku		Vatu-o-lalai	Navakavu		Votua	Nasegai		Namada		Nasau
	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}	t_1 with t_{max}	t_1 with t_{last}
Rabbitfish	NS		NA								0,068 (+)	0,068 (+)	
Giant clam	NS		NS		NA								NA
Surgeonfish	NS		NA						NA	* (+)	NS		NA
Grouper			NA			NS			NA	* (+)			NA
Parrotfish	NS	NS	0,068 (+)	NS	NS	NS		NS	NA		NS		NS
Sea cucumber	NS		NS	NS		0,068 (+)	NS		* (+)	* (+)			NA
Emperor	NA	0,068 (+)	NA	0,068 (+)		0,068 (+)	0,068 (+)		NA	* (+)	NS	NS	

Following are graphs displaying changes in mean abundance over time and standard errors of the seven identified indicators per site.

Surgeonfish

Two sites, namely Nasegai and Naovuka, showed a strong increase over time within and between treatments (closed and open sites). The mean value of surgeonfish within Nasegai's tabu area roughly doubled between surveys and was seven times higher at t_{last} compared to t_1 over a time period of only two years. The value for Naovuka's latest monitoring was five times higher compared to the previous survey and even over 130 times higher compared to the first survey over a period of four years. Both comparisons are significant at p<0,068. A significant decrease in abundance of the indicator species was detected within the tabu area of Nasau. Only the open site in Nasegai showed a significant difference in t_1 and t_{max} comparison of mean values whereas the other control areas exhibited no variation whatsoever. Initial values were consistently higher in the tabu area (about eight times) than in open sites.

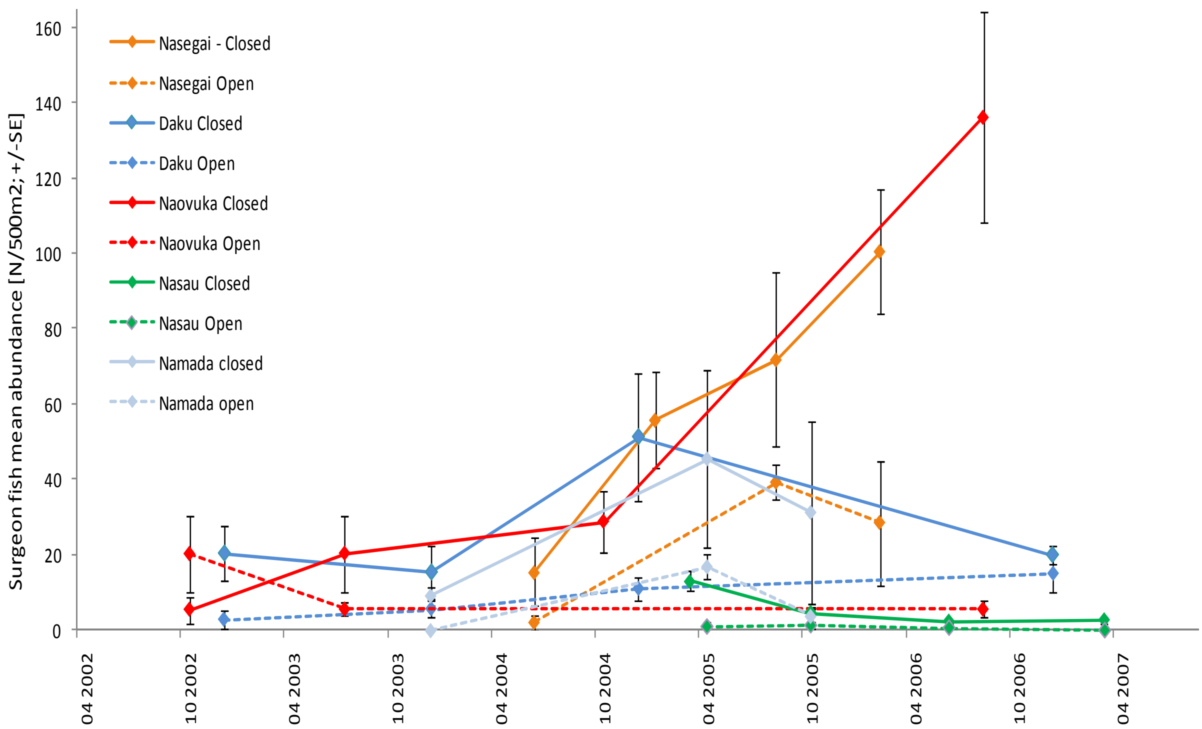

Figure 6. Surgeonfish mean abundance

Giant clam

The data from all sites show very low initial abundances and no statistically significant changes were detected within or between tabu and control sites. The data from Daku exhibits a fivefold decrease over time. This data also showed the highest variability and the standard errors for each monitoring event were almost of the same magnitude as the mean value. Little variation was displayed however between the tabu and the control site.

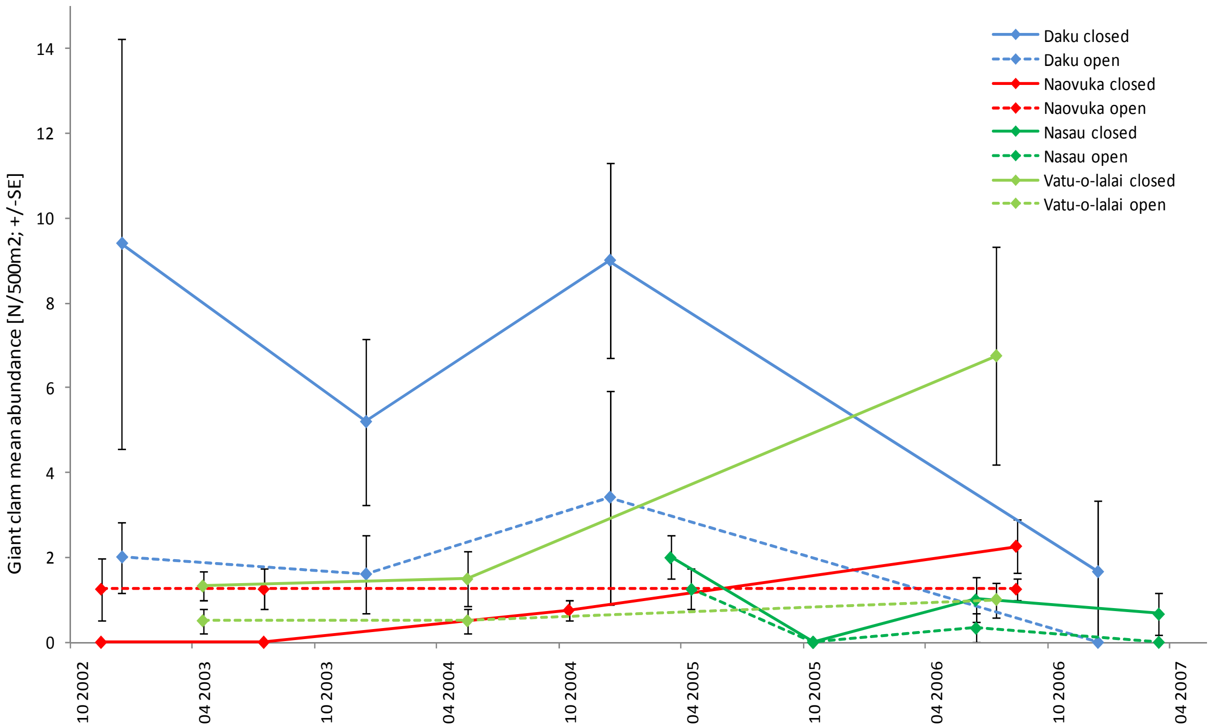

Figure 7. Giant clam mean abundance

Rabbitfish

Both Daku and Naovuka displayed very similar changes in mean values over time within and between sites. They showed a significant ($p<0,05$ and $p<0,1$) four and more than tenfold intermediate increase respectively within a year from the second to third survey. A decline with equal magnitude followed and resulted in similar abundances as the initial values. The Namada data follow an almost symmetrical distribution where the open area values are about one and a half times higher than in the tabu area, both intermediate values are also significantly higher at $p<0,1$ level. However, the data distribution suggests some sort of a bias.

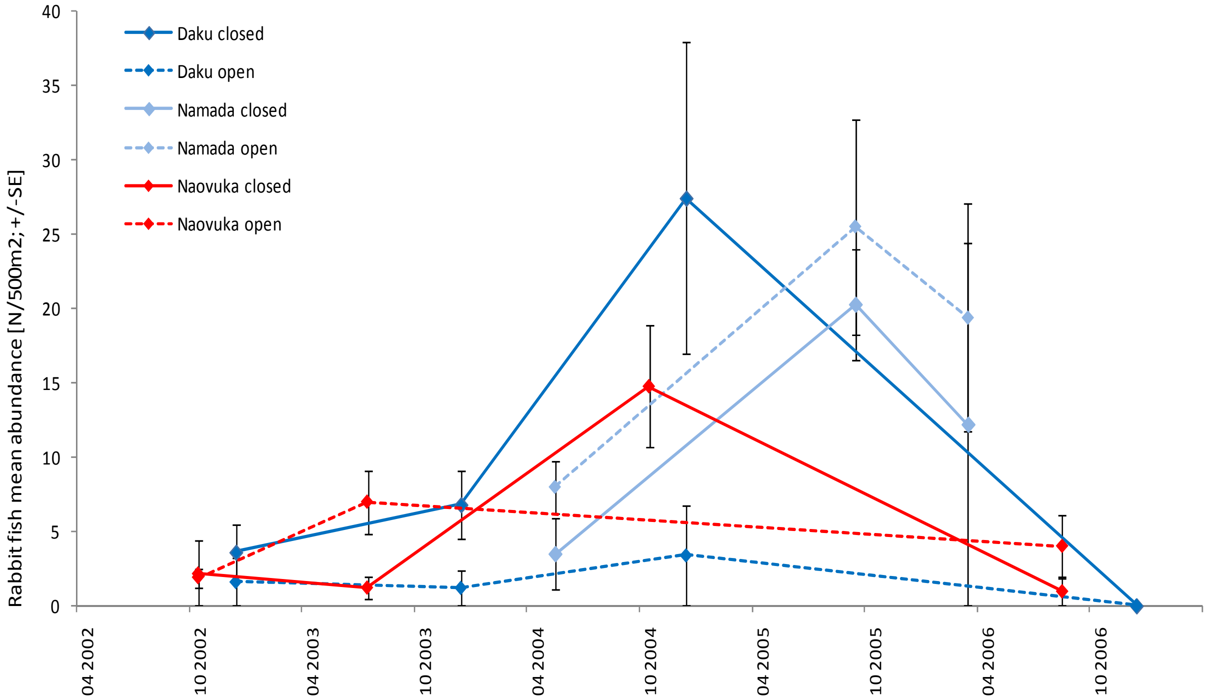

Figure 8. Rabbitfish mean abundance

Grouper

Only the data from Nasegai showed a significant increase in the tabu area over time at the p<0,1 level, with very high standard errors thus variation in data. Navakavu did not show any differences whereas mean values in the tabu areas from Daku and Nasau have declined, the latter significantly at p<0,05.

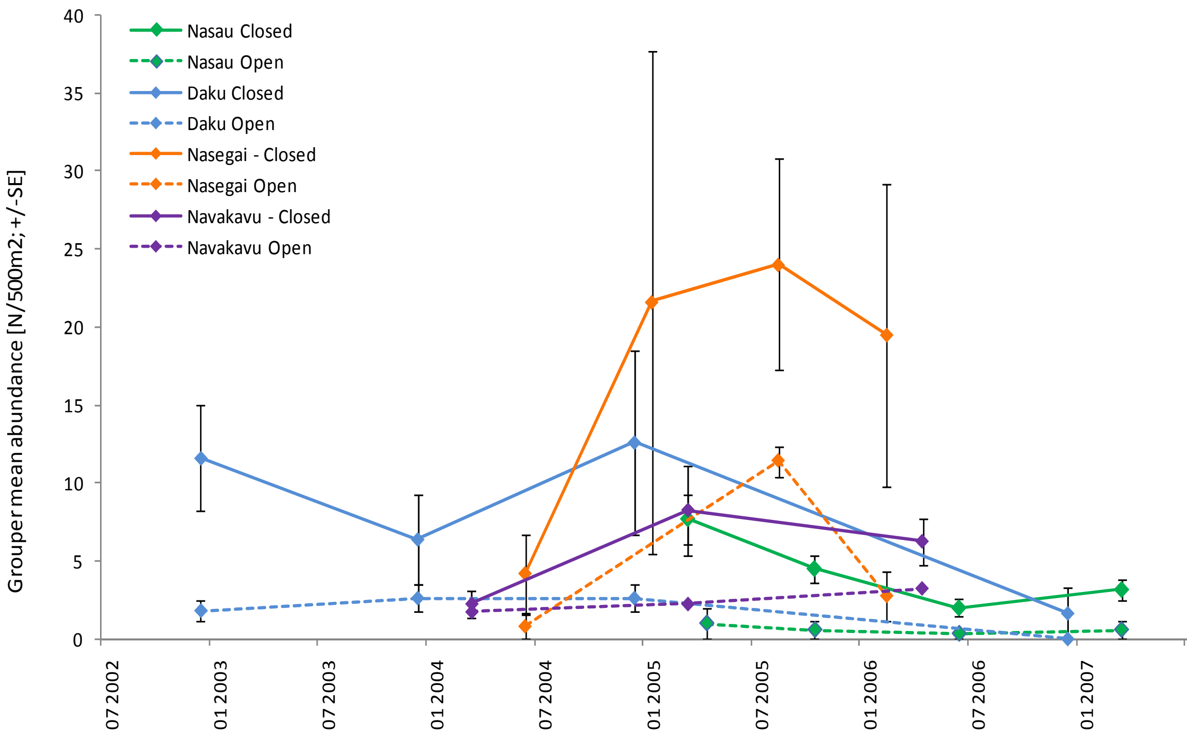

Figure 9. Grouper mean abundance

Parrotfish

Parrotfish was the only consistently monitored indicator across the sites looked at. Initial abundances were higher in the tabu compared to the open area of three sites. Four sites did not show any variation or differences in BACI comparisons. An initial outlier value was detected for Vatu-o-lalai with a mean of 250 individuals per $500m^2$. The mean abundance was reduced to a third within one year although the test detected no statistical significance. The Nasegai data exhibit an intermediate peak with a three and a half times increase followed by a decreased to the initial value. The Wilcoxon test showed a significant increase between the initial and the latest survey within the tabu area at $p<0,1$ for Naovuka and Votua and a significant decrease at $p<0,05$ for Nasau.

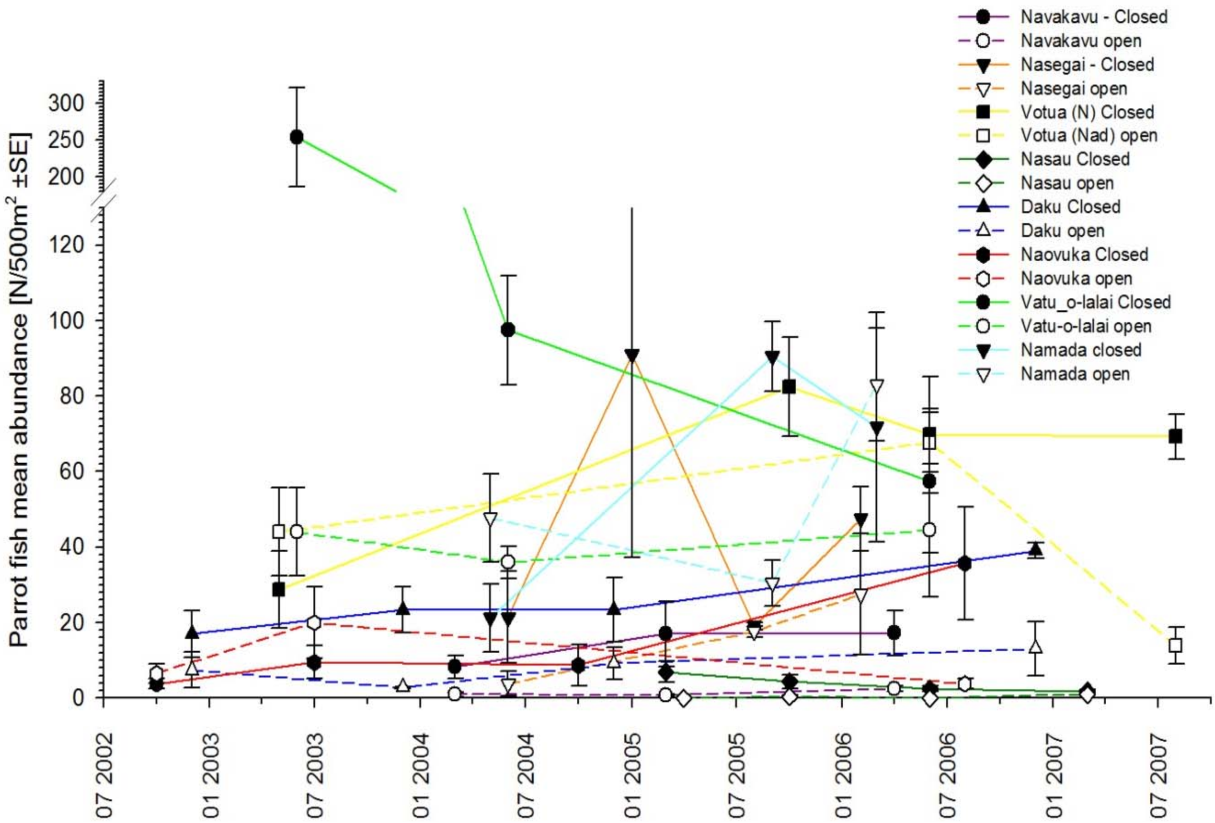

Figure 10. Parrotfish mean abundance

Sea cucumber

Although the abundances from Nasau and Naovuka displayed very little difference, the Wilcoxon test detected significant increases within both tabu areas. Whereas the tabu areas of the remaining three sites behaved similarly, after an intermediate peak (significantly higher in Nasegai), the mean values dropped back to initial value. Navakavu exhibited a very high abundance in sea cucumbers which was more than 15 times higher than all other sites; both values for inside and outside collapsed after the first survey although statistically not significant. The only open harvest area which showed a sign of recovery was Nasegai during the intermediate survey with a significance level at p<0,05.

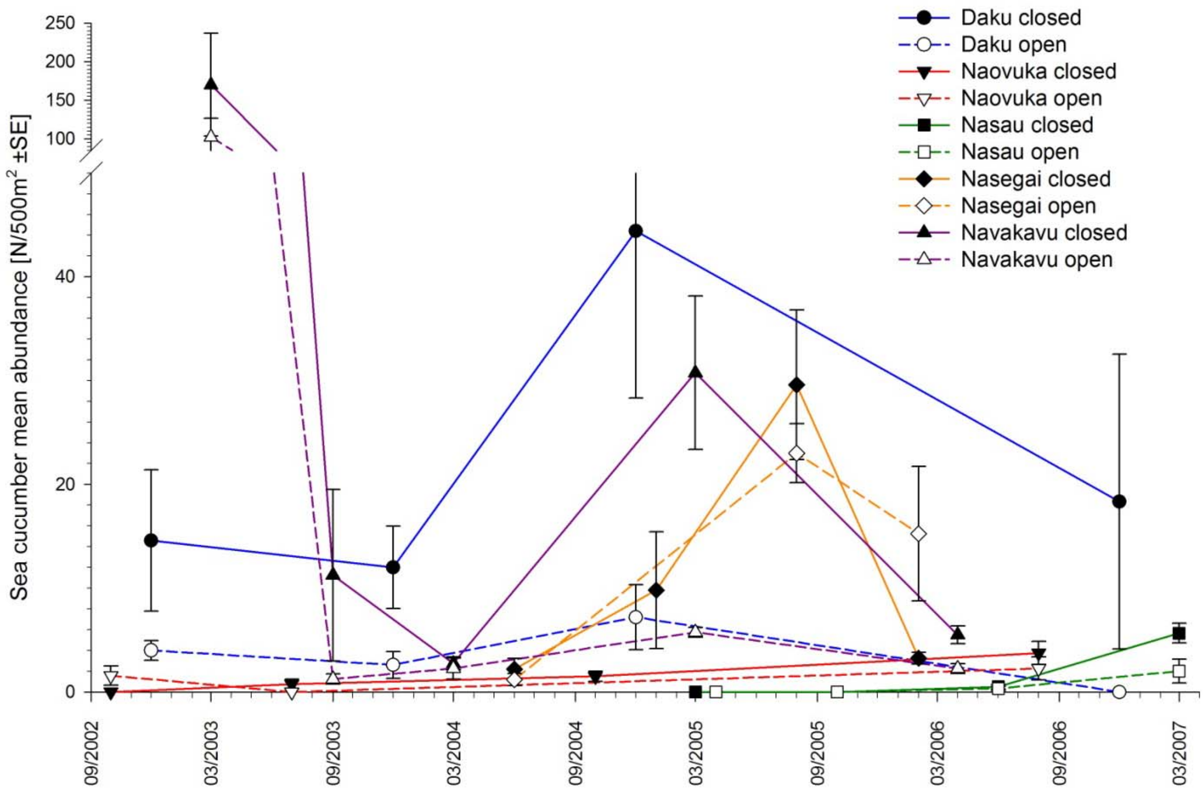

Figure 11. Sea cucumber mean abundance

Emperor

Initial mean values of closed and open sites compared with values from the last available monitoring showed that four of the five sites displayed no differences in mean abundance of emperors. Within the tabu areas of these sites mean abundance reached an intermediate peak which was significantly higher for three sites and which returned to the initial mean values over a six months to two year period. The abundance of the open areas showed a similar pattern but with lower magnitude. Namada showed the highest, more than tenfold, increase of emperor abundance for the intermediate monitoring event over a time period of only 16 months. This was followed by a steep decline to initial abundance levels over six months. However, both comparisons were not statistically significant and showed very high standard errors. The remaining site Navakavu showed the only constant increase in mean emperor abundance over time within the tabu area; values for the open and closed site were 6 and three and a half times bigger after three years of protection and significant at p<0,068.

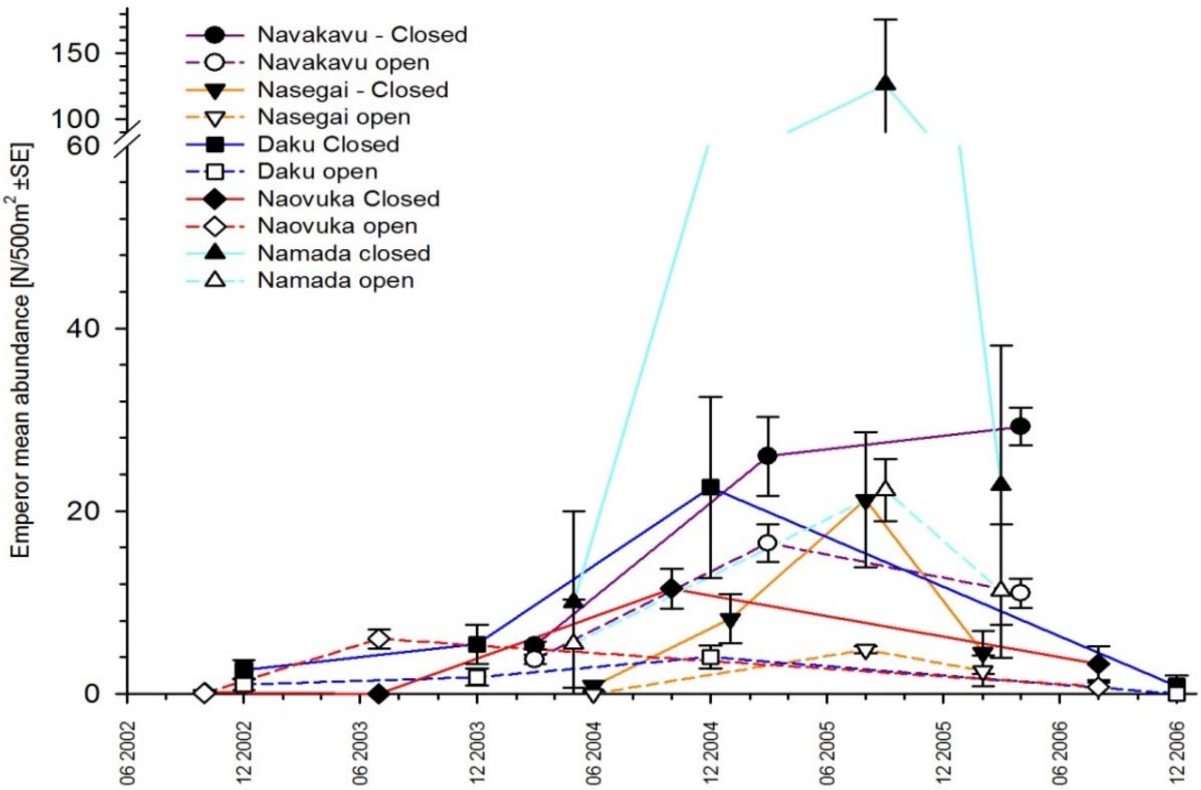

Figure 12. Emperor mean abundance

Quantitative information on community monitoring

Table 9 provides quantitative evidence from SLO interviews (N=7) on the frequency of communication & interpretation of the data, self-sufficiency and potential management adaptation from survey results for all monitoring sites (N=27). The extent of community interpretation of the data was said to be rather basic and in many cases wouldn't differ much from the presentation of the results.

Table 9. Quantitative results from SLO interviews

Question asked	Answer
Number of self-sufficient monitoring sites	22
Frequency of communication of monitoring results	27
Frequency of interpretation of monitoring results	21
Frequency of management response to survey results	4

Qualitative information on community monitoring

The list below indicates the four incidences in which communities were said to have responded to the survey results by adapting their management strategy:

1. Licensing issuing was reduced in Votua (Ba province) after realising that abundance of fish was decreasing.
2. Due to vast decreases of sea cucumbers in a collectively managed tabu area in Navakavu (Rewa province) its location was changed because villagers had the impression that the community adjacent to the tabu area was poaching.
3. Communities in Daku, Kadavu found an increase in fish in the tabu area during monitoring and decided to open it temporarily for harvesting.
4. The community of Namuana, Kadavu established an additional area for temporary opening to the initial permanently closed one because the data indicated increasing resources within the tabu area.

Answers from SLO interviews on their perception towards the utility of community-based biological monitoring and related questions regarding drivers behind community decision making and perception on the monitoring were summarised according to four broader questions. This provided important information when analysing the overall usefulness of community based bio-monitoring (see Table 10).

In general, SLOs named social or socio-economic reasons to be the main driver behind decision making with regard to management related issues. Also, experiences from Fijian women who reported to catch the same amount in less time after the tabu area was set up are real life observations that communities can relate to easier compared to abstract data (reported by community members from communication and interviews in Kadavu and other FLMMA meetings). Perceived benefits from monitoring were similar to the FLMMA objectives and one SLO specified that the process would fascinate community members. It was generally indicated that communities enjoyed the monitoring and take pride in being selected for the monitoring at least in the beginning. Alifereti Tawake associated monitoring with having a psychologically positive effect to add more credibility to the process and engage communities in management and monitoring. “If there was no monitoring, preaching awareness would be the sole action. Communities are interested in monitoring as it also shows them that there is an ongoing interest from IAS!” However, it was also reported that community monitoring is not always requested by the communities (especially by new applicants).

Another comment made by an SLO, was that currently no more new monitoring sites are encouraged. Due to limited capacity to supervise the monitoring the aim is now to improve the quality of existing monitoring sites. In Cakaudrove province (see Figure 1) 153 villages are being supervised by IAS and the Cakaudrove Yabula Management Support Team but at present only one of these communities has started with biological monitoring. Furthermore, to minimise financial resource needs, monitoring efforts will be restricted to one community per district representing each of the 15 districts. The lessons learned are then planned to be extrapolated (pers. comm. Semisi Meo, SLO for Cakaudrove province and Senior Scientific Officer at IAS). Another remark was that most communities decided to decrease monitoring from biannually to annually and were not believed to be willing to increase the number of transects (pers. comm. Semisi Meo, Alifereti Tawake). From interview answers it was noted that the interpretation of monitoring results differed widely between SLOs. While some SLOs reported only an increase of resources in the control site (potential spillover effect) as a management success, others reported any increase as a management success to the communities. Especially, the increase within the protected area would be presented as a sign that the tabu is working whereas a decrease would be a reminder to be more attentive towards the tabu area.

The inconsistency in timing and methodology of monitoring events was ranked highest as current limitation to maximise interpretation and application of survey data. Particularly, inconsistency in sampled indicators, replication, and absence of a control site was frequently encountered during database examination. SLOs indicated that a change in the initial monitoring team members was a frequent cause in change of monitoring protocols, or the chosen indicators were not observed at the monitoring event and therefore not recorded or replaced by whatever was encountered. This was observed or reported at several sites (pers. comm. Alifereti Tawake, Semisi Meo). Out of the 53 sites with survey data 12 sites initially chose to monitor only the tabu area (see Appendix III). Key informants said this was due to a primary interest in seeing whether the tabu area is actually “working” in accumulating resources or time constraints at the monitoring events.

Table 10. Qualitative results from SLO interviews

Question	Answer
Most common reason to adapt the tabu area or other resource management strategies	Social or socio-economic reasons (e.g. the relocation of the tabu area due to poaching)
Community content with monitoring	Communities are content with the monitoring but interest slowly comes to an end in some sites were monitoring has been going on for several years
Benefits of monitoring (ranking of answers)	1. It increases their project ownership and involvement 2. It is a reality check for the communities 3. Communities learn about dynamics within tabu areas 4. Data collection and presentation fascinates communities
Limitations of monitoring (ranking of answers)	1. Monitoring often not consistent 2. Costly and time consuming, effort should concentrate more on livelihoods 3. Transect length not adequate 4. Not all communities want/ like to monitor, no incentives 5. Women are not included

Challenges of community-based biological monitoring in the FLMMA approach

Since little reliable measures of impact were found to date within the FLMMA biological monitoring data sets (Govan et al., 2008b), the question arose what confounding factors could potentially be responsible for this. From participant observation at two monitoring events, semi-structured interviews with key informants, and consultation of secondary data, issues with the monitoring design and implementation thereof were summarised. Design issues reflect an inappropriate monitoring design as has been taught to communities. Sampling issues relate to differences in what is being applied at the monitoring event from what was communicated. These are based on observations from site visits (refer to Appendix V).

Biases which are inherent to UVC methods (e.g. Edgar et al., 2004) are likely to influence the outcome as well and have to be kept in mind; the most common biases are listed in Appendix VI. A general inconsistency at the monitoring event but also in terms of monitoring design and sampled indicators was identified as the biggest challenge to current monitoring efforts.

Design issues

1. A clear experimental monitoring design to test a certain objective is missing, thus experimental designs and objectives vary across sites
2. Current sampling is often not robust enough to detect density-dependant spillover (only once a year with limited replication, no stratified sampling design and no use of CPUE information)
3. Design not adapted to bio-geographical properties of reef (e.g. no adaptation for sampling patch reefs, sampling of several different habitats in a transect)
4. Different sampling efforts and techniques make it difficult to compare results across sites
5. Pseudoreplication (sampling left and right of the tabu area)
6. Different biophysical attributes & habitat requirements of indicator species imply temporal and spatial variability or absence/ presence of species at the monitoring event
7. Little or no facilitation for the indicator choice, often too many and/or inappropriate ones are chosen by the communities (e.g. anemone fish, Crown of Thorns, “rarely seen”, barracudas, sharks, giant clams etc.)
8. Difficulties in translating Fijian indicators to scientific names (vast regional differences & Fijian names are often given at species, guild, genus or family level)
9. Sampling of entire genus, families or guilds instead of clearly defined species

Sampling issues

1. Not sampled during same tidal phase
2. Sampling during bad weather conditions and medium to low visibility
3. Counting fish outside the sampling range
4. Regular changes in the monitoring team might introduce additional bias
5. Frequent changes in the list of indicators from year to year
6. Not observed indicators are not recorded at all or are replaced with another indicator
7. Not consistent in monitoring the open (control) site concurrently
8. Sites not clearly identified or marked, inconsistency in transect locations

4.4 Discussion

Statistical analysis of IAS monitoring data

The analysis of the data did not yield sufficient prove to support any long-term changes in indicator abundances. This might be due to two main reasons: first of all, the current design and implementation of the tabu areas at the sites looked at did not produce a management success, e.g. they were too small or too frequently harvested. The second reason might be that the current monitoring design is not robust enough to detect any management effects that have potentially occurred. The relatively low quality and large variance of the data in combination with current sampling and design issues suggest that the second reason plays an important role. Although there is a number of near-significant results in some of the indicators looked at, the sampling is still not accurate enough to show statistically significant differences. Hence, it seems unlikely with minor exceptions that management effects on sampled indicator abundance can be statistically detected with the current sampling effort and design. However, there were differences in indicators looked at. Giant clams did not show any significant changes over a 4 year survey period which can be explained by an unsuitable life history (e.g. long population doubling time) to be able to show short to medium term changes in abundance. Emperors on the other hand seemed to hold more potential showing several significant or near-significant changes over time within and between tabu and control sites. This was also the case to a lesser extend for surgeonfish, sea cucumber, rabbitfish and parrotfish which shows that there are indicators with a varying degree of suitability for community-based monitoring.

The variance of the data resulted from a combination of many different factors from natural variation to biases from sampling and design issues to comparing results from different sampling regimes. In addition, most species are not “normally distributed” in nature but occur in clusters (Poisson distribution), several reef species aggregate for feeding, reproduction etc. Also, results will vary according to sampling season, temperature, tidal phase, and time of day therefore the likelihood of encountering the indicator species will change along with these abiotic factors. Johannes (1998) suggested that natural fluctuations are too big to attribute stock decline or increase clearly to changes in fishing pressure and management in appropriate timeframes. Since according to the LF, all biological changes are attributed to human behaviour, all these factors have not been considered so far. This is further compromised by differences in habitat complexity and quality and degree of protection. Comparisons between sites were also difficult due to higher initial abundances in the tabu areas which were statistically significant in a fourth of all sites. Further significant increases in abundances within the tabu areas compared to the control sites may be explained by these initial differences. Some general trends have become apparent which shall be discussed here. However, these could not be conclusively linked to the degree and duration of protection and design of the tabu areas looked at. The most apparent trend was the occurrence of intermediate peaks in abundance detected at the second or third survey, roughly after 3 years of tabu area establishment. These peaks with a drop to initial abundance levels seem to indicate opening events of the tabu areas. A study by Cinner et al. (2005) of community-managed periodically opened reserves in Papua New Guinea showed overall increase in biomass and size inside the protected area despite the periodic openings . Since the intensity of these openings in Fiji is not known only prudent predictions can be made towards the time scale after which a temporary opening can be compensated. The data indicate that harvesting after two to three years after a first increase in numbers has been detected, does not seem to be a sustainable option. Although, this cannot be generalised since the intensity of harvesting events may be crucial. Extreme outliers have been encountered with unrealistically high abundances for emperors, parrotfish and surgeonfish. Although some surgeonfishes have short population doubling times of less than 14 months (Froese and Pauly, 2000), these numbers are unrealistically high even if a feeding aggregation would have been sampled. In contrast, several time lines showed no change whatsoever. Especially, initial values in control sites were generally very low and showed little to no recovery. Although a significant increase would not be expected in an open harvest area, the initial abundance might have been too low from the beginning. However, there is one village (Nasau) with the most frequently significant (although mostly negative) changes over time. While the data from the graphs did not display much change, detection of statistical difference can be explained trough a very low variance and a comparatively high replication of six transects within the tabu area. In contrast, the Wilcoxon tests failed for the control area which has a replication of only three transects. This is an interesting finding since six transects are generally still conceivable to be carried out by communities. A power analysis could help to verify this finding. Since the inherent variance of the data made a meaningful analysis very difficult, it is questionable whether the method and data collected at present is adequate for communities to measure progress and base management decisions on the results. Before major efforts are undertaken to modify the design, it is imperative to discuss how the monitoring results are currently interpreted and used.

The role of monitoring in decision making/ adaptive management

Although six out of seven SLOs reported that communities do interpret the monitoring results, they also said that the interpretation was generally very simplistic (i.e. did not go beyond graphing numbers on a sheet of paper). More consistent scientific support and training is needed to ensure that communities are enabled to interpret the data with the necessary biological and ecological background. This would requires a basic knowledge on life history characteristics like growth rates, reproduction, recruitment, habitat needs, larval transport and ecological interactions of the species of interest. This will prevent drawing false conclusions or none at all which both could lead to questionable management decisions. The Community Biological Marine Monitoring Training Video which is supposed to assist the communities does not provide an adequate support. While the video states that data interpretation is crucial, no further advice or examples are given on how to interpret or respond to the monitoring results. Interpretation from UVC surveys is rarely straight forward, hence how should a community without adequate training or support know when a result is biologically relevant or not. It should be investigated which effect size is significant to the communities and might even convince them to lift the tabu status. A more focused approach would be needed that shows communities how to respond to data with adequate management decisions. The project partners involved in the supervision of the monitoring also need to be more consistent in the future on how results are presented and what is interpreted as a management success. It seemed that the presentation of the data was used to advertise the concept of the tabu area- more fish inside equals tabu area success and more fish outside shows a spillover effect.

In terms of management response to the data, only few examples were found in which communities have used the data at least to some extent for decision making processes. This is mainly linked to a higher importance of socio-economic factors for decision making but may also be due to the limited experience in data analysis and a general loss in community interest in monitoring. Even within the few examples in which communities did use the data for adaptive management purposes, the rational for management adaptations were in most cases not directly attributable to the monitoring results. In the case of Navakavu, supposed poaching from one of the adjacent villages resulted in a relocation of the area to a location that allowed better enforcement. This occurred regardless of any biological reasons, with the initial area formerly hosting lots of sea cucumbers (pers. comm. Semisi Meo). Therefore, socio-economic considerations appeared to be of higher priority. What is important to note is that even if communities use the data in any way for decision making, e.g. to open a tabu area, it has not necessarily helped them to improve their management capacity. Even if the opening event is regulated in advance (e.g. IAS has recently given out recommendations to restrict the harvest to one day, pers. comm. Ron Vave, Database Manager at IAS), several examples exist where communities overexploited the whole area and made full use of their resources. Data exist for the Biausevu community where harvesting from an opening event was recorded and showed incredible amounts of resources taken out in only 1 day (pers. comm. Alifereti Tawake, Semisi Meo). A lack of general increase in abundance of indicator species across all locations suggests that only drastic changes with regards to the selection of the sites, size and opening regime is likely to improve the food security and provide a successful management tool. At present the management intervention stops after making the decision to open the tabu so the monitoring results are not even utilised to limit the harvest. Although many communities may be still at the beginning of a learning process it seems that until today, community-based biological monitoring has not met its needs for the CBAM approach in Fiji.

For community-based biological monitoring to persist in the future, a long-term commitment by the community is required to carry on with the process even after project partner support has ceased. Since communities are not paid or do not receive other forms of compensation to carry on with their efforts, this needs to come from an insight within the community. A general perception is required that monitoring is beneficial to them and supports decision making for future management efforts. Although responses from community members regarding whether they felt that monitoring was beneficial to them or not were consistently positive, none of the interviewees were able to specify particular benefits. Even greater confusion arose when asked for which purpose the monitoring was carried out. One SLO reported that communities wanted to know how the data can help them to catch more fish, which demonstrates shortcomings in explaining potential benefits and limitations of UVC monitoring. Moller et al. (2004) suggested that traditional communities should not be expected to invest valuable time on monitoring their fishing grounds and that they might not actually be interested in the monitoring. Community members from Buliya, Kadavu for example reported to go snorkelling in the tabu area once a month to get an impression on how the reef and the fish were doing to report back to the chief. Based on their observations the chief made the decision to keep the area closed for another 5 years. This example illustrates that respective community members have adapted a tool to better suit their needs for management and decision making. In general, communities are still more likely to place a greater significance on their perception than on generated scientific data (Fisk, 2007). The findings discussed imply an adaptation of current biological monitoring efforts. Apart from more and continuous scientific support, realistic expectations are needed on what this kind of monitoring could or should provide.

Ways forward

Although the FLMMA Community Based Biological Monitoring Guide promotes a consistent monitoring design as the “golden rule” to make results comparable within and between sites, changes in the protocol are said to be acceptable as well. Similarly, while some SLOs named the primary importance of monitoring as an involvement tool to increase project ownership, others named the potential to provide a “reality check” to the communities for adaptive management purposes as primary target. Both are important and conceivable objectives but cannot be realised by the same monitoring design hence imply different adaptation of future efforts. These differences in objectives and expectations towards what the monitoring could or should provide need to be addressed. Additionally, the degree of change or the effect size which is expected to occur as a management result also needs to be defined. Giving the limitations in data quality, lack of use thereof, and a set of various different objectives there are essentially three different options which might be applied independently or combined to improve the current situation:

1. An improvement of current efforts, addressing inconsistency and design issues, main-streaming, and adequate support functions
2. Ceasing UVC completely and opting for more perceptive, data-less approaches
3. Implementing scientific surveys in representative project sites to address specific stakeholder questions and to find generalised responses that can be used as guidance for management; potentially with participation of interested community members

In the first case, the monitoring should be ideally restructured, with a clear objective and a specific monitoring design according to which appropriate tabu & control site(s) need to be chosen. Specifically, these need to display similar bio-physical qualities. Also, higher replication with bi-annual surveys to account for seasonal differences would be advisable. To reduce natural variation in species distribution between habitats a stratified experimental design needs to be adapted which adjusts the transect location to habitat preferences of respective indicators. Process issues need to be addressed through additional training and increased facilitation, also in regard to the choice of appropriate indicators. To improve the potential to compare between different sites and examine the generality of effects the design would have to be main-streamed with a minimum set of standardised indicators that are monitored at each site. More so, to make meaningful statistical comparisons possible, a sampling design would need to be chosen according to an objective, a null-hypothesis that could be tested. Also, the database would need to be improved with a standardised data entry of all data. However, these improvements could not be implemented for all sites because it would require too much of human and financial capacity. Thus, up-scaling of scientifically relatively sound monitoring procedures as part of a low-cost management model for Fiji or the wider Pacific cannot be achieved. Therefore, only a couple of sites should be chosen, as planned in Cakaudrove, or continue with sites where bio-monitoring has had reasonable success with ongoing community interest. However, since it was reported by several informants that communities tend to lose interest in monitoring over the years and commonly reduce the frequency of sampling events or transects, it seems unlikely that monitoring design will be improved to yield sensible results for most of the communities. More importantly, communities can only carry out monitoring self-sufficiently if they are provided with enough training on data analysis and necessary biological and ecological concepts of management responses of resources. If this cannot be achieved, monitoring as a tool becomes pointless.

These aspects suggest reconsidering a data-less approach as the standard procedure. Additionally, from a community involvement point of view bio-monitoring is unlikely to be the best strategy since it is only carried out by a limited number of the same people. While this is a reasonable approach to minimise observer bias it does not engage as many community members as the revision of the management plan does. A more consistent revision would also keep management issues in people's heads and although it is again perceptive, monitoring efforts have to date not succeeded in quantifying management responses in stocks. Furthermore, it does not require any initial investments into gear/technical equipment and maintenance or additional staff time and transportation cost for monitoring training and follow up visits. Lessons learned from data-less management initiatives in the Pacific e.g. from Vanuatu communities suggest that their approach is highly successful and provides a truly low cost model (pers. comm. Etika Rupeni, Programme Manager at FSPI). Also, real life observations like catching fish in less time are still more powerful than abstract data since they are easy to relate to and part of community reality. This demonstrates that non-quantitative monitoring can involve communities and provide useful results. Additionally, where communities see their tabu area as an easy accessible storage area it is questionable whether monitoring project success is actually necessary.

The third suggestion is to carry out a more scientifically rigorous monitoring design in some key sites which looks more thoroughly at priority questions from stakeholders (as identified in

Chapter 3). This would have the potential to generate knowledge which can feed back into the communities but also serves for network learning and even the academic public. Different management tools (e.g. permanent vs. temporary no-take zones and differently sized tabu areas) should be compared to detect general trends of various designs on marine resources. Especially, tabu area openings should be monitored through before-after comparisons and additional listing of extracted resources to calculate a CPUE. Spatial CPUE data from the national CPUE survey should also be triangulated with monitoring results to create a more comprehensive picture. This would most likely give better advice on outcomes of different management options.

Another way forward might also be to conduct regular surveys at appropriate frequencies on the status of marine reserves rather than continuous monitoring. FLMMA should trial the measurement of alternative indicators at the site level in cooperation with the communities which can be used to develop simple guidelines for further decision support. Sampling the size or biomass distribution and trophic structure of caught fish might be particularly useful as rapid appraisal methods to gain insights on current stock status (this is further discussed in Chapter 5).

To conclude, community-based biological monitoring cannot provide the data to address priorities and information needs by communities, project partners, and higher level management. Therefore, FLMMA should reconsider their priorities, objectives, and expectations as well as the level of change (the effect size) that is acceptable in the project. Taking all considerations discussed into account, a data-less approach should be chosen and scientifically more rigorous surveys in some sites to explore certain question.

Thus, the actual role of science in the FLMMA approach at the site level is still limited and might require adaptation. Therefore the potential role of science needs to be looked into also in regard to mid and national efforts.

Chapter 5

The potential role of science in CBAM at different levels of governance

5.1 Introduction

Although CBAM is mainly focused on community management it is strongly linked to the wider regional and national management framework and functions within government legislations. Science can and should play a crucial role at all levels but needs to be adapted to the target audience and their needs. It is necessary that any management effort is well coordinated and that regular communication between the different governance levels is established and maintained. Additionally, scientific projects that aim at testing management effects to optimise strategies will be important and have the potential to feed back information to the community level. To improve the supporting role of science it has to provide management relevant information in the right format and taking account of stakeholder needs and priorities. Currently local priorities in Fiji are strongly focused on food security, therefore research and management have to collaborate to achieve their common goals and measure progress of management measures. Information gained has to be communicated in such a way that stakeholders can understand and implement it. This requires a certain level of education and training. Therefore, the potential for science to support CBAM in Fiji will depend to a large extent on capacity building, communication, and how well science addresses the Fijian context. Present efforts under the FLMMA approach have been mainly focused on community-based biological monitoring to measure success of management strategies. While these ongoing efforts currently have substantial limitations to provide scientifically sound information on general effects of resources under novel management strategies, it should be assessed whether improved and/or additional science can help the adaptive management process at all governance levels. Fiji receives scientific attention by international NGOs, USP, and international research teams who have carried out a number of natural science projects. Such projects cover a wide range from purely research to strongly management orientated topics. More recent projects with a long-term interest have attempted to combine empirical science and community based management. For example, the Ecosystem Based Management

(EBM) project by WCS, WWF, and Wetlands International is attempting to implement a more holistic approach crossing the separation of land and sea management in two coastal areas of Fiji with the intent to upscale outcomes to a national level. However, there is a tendency that analysis of generated data often lags behind. Alternatively, results are not made available in an appropriate form to be used locally at the community level. Currently many organisations in Fiji are not fully aware of the outcomes of other projects and no comprehensive index exists on detailed data outputs of past and ongoing research. A more coordinated and focused approach would largely improve the situation and ensure project information is adequately distributed and effectively implemented in coastal resource management. This would also prevent potential replication of past and ongoing efforts and improve the use of existing information.

Given the scarcity of comprehensive and conclusive analysis of existing data, novel analysis and tools need to be explored to fully utilise its potential. Often research efforts have discontinued after entering the data in databases that are not easily accessible. This has often been a result from not properly defining the objectives, sampling design or the data needs of the respective statistical analysis method in addition to a lack of a larger ongoing framework. Additionally, there is a lack of alternative monitoring and evaluation methods. Looking into these issues can be utilised to assess the need for and guide future empirical research work.

On the other hand several modelling approaches could have potential to be used. They have the merit, in some cases, of enabling a range of scenarios to be examined and extrapolated in a very short period of time in comparison to additional empirical surveys. Although modelling is a fairly new concept in Fiji, it may be a low-cost, rapid way of addressing stakeholder priorities if data requirements can be met. Models are mostly numerical analysis tools that simulate or predict natural processes in time and or space, based on mathematical equations and estimated parameters or rules. It is important to note however, that models remain hypothetical, based on certain (at times unrealistic) assumptions which ultimately are a simplification of the real world and can create great uncertainties. In the context of Fiji less complex models with lower data requirements and relevant output would be appropriate. Still, the quality of data used and whether assumptions and rules are based on empirical evidence will ultimately decide the usefulness of the model.

As identified in Chapter 3 stakeholder priorities in Fiji are centred on design, function, and management of the tabu areas. In particular, sustainable harvest levels, relevance of tabu area size, as well as the establishment of a national network of marine reserves are common questions. Potential for natural science applications should therefore concentrate on these priorities were appropriate, e.g. guiding the establishment of such a network. Until recently individual FLMMA sites have been looked at as single entities. However, stakeholders are interested in knowing whether the many protected areas in Fiji's near shore waters are providing cumulative benefits to local and national interests in terms of sustainable use and resource protection. With the advent of highly sophisticated and versatile digital spatial analysis tools the use of management scenario modelling to find optimal solutions has become popular. GIS (Geographic Information System) tools can be adapted to various purposes e.g. to function as gap analysis tool for the government and planners to identify current conservation gaps and priority areas but also areas facing higher threats. A number of spatial decision support software or tools have been developed to facilitate the design process and support decision making; the most commonly used being MARXAN (Ball and Possingham, 2000; Ardon et al, 2008). MARXAN uses criteria and information layers to calculate spatially optimal network solutions for protected area networks. Several guidelines are proposed for the design criteria (e.g. Roberts, 1998; Robert et al, 2001), that acknowledge ecosystem functionality and connectivity of populations (e.g. Murray et al., 1999; Roberts et al., 2003) but incongruity exists towards the prioritisation of socio-economic over ecological design criteria and vice versa.

In general external stakeholders and project partners in Fiji are also inclined to provide communities with quantitative guidelines on sustainable resource use. Local communities are particularly interested in quotas to increase the benefit of their management plans. The FAO Strategy for Improving the Status and Trends of Capture Fisheries (FAO, 2003) highlights the need for improving data and information for the small-scale fisheries sector. Stock assessment requiring estimates of growth and mortality parameters would allow to advice on adequate exploitation levels (Sparre and Venema, 1998; Hoggarth et al., 2006). But in tropical developing countries institutions are mostly lacking capacities to undergo required research and institutional frameworks to implement any recommendations. This might also hold true for Fiji, although stock assessment has been identified as a priority of the Fisheries Department. Additionally, in Fiji multi-species multi-gear subsistence and artisanal fisheries are making it considerably more complex to model stock dynamics (Sainsbury, 1988; Medley et al., 1993). In the absence of previous work on the potential role of science in CBAM, this thesis is summarising exiting information and then evaluating the practicality of using modelling and alternative survey methods to address identified information needs.

5.2 Methods

Review of existing projects & data from coastal areas in Fiji

Semi-structured interviews were conducted with practitioners from relevant NGOs (N= 16), USP (N=12) and the Fisheries Department (N=8) and experts (N=6), identified though snowball and purposive sampling (refer to Chapter 3). This information was utilised to compile existing and ongoing natural science efforts and generated data. Additionally, unpublished and published documents were reviewed to supplement the information gained from the interviews. These mainly consisted of reviews and project reports from NGOs, USP, and the Fisheries Department. On the basis of this information a data table was created to provide a comprehensive overview on existing biophysical data in Fiji. This provides the first attempt to synthesis past and ongoing empirical science projects in Fiji that are to coastal resource management. Survey methods were recorded as well as methods of data analysis if available.

Potential use of data and analysis

Relevant literature was consulted on applications and data needs of model types which could potentially be used with existing data in Fiji. Main focus for potential models was on marine reserve and network design as well as stock assessments and harvest levels to support CBAM at different levels of governance. For that purpose the identified existing data was compared with model input requirements to assess the utility of several model types. Peer-reviewed literature was also consulted on additional monitoring and evaluation methods for the support of CBAM, to suggest additional survey techniques and a suite of simple progress measures.

5.3 Results

Existing data

A wealth of past and present marine survey projects were identified which created data potentially relevant to coastal management in Fiji. Most of the project results are not readily available and have not been published or put online for easy access. These projects are spanning a period from 1995 – 2008 and have been summarised according to the nature of the data, organisation, location and time span, survey and analysis method.

Species abundance

Abundance of finfish and invertebrate data are amongst the most frequent data generated. They were mostly derived from UVC from various monitoring designs which vary greatly in detail and precision (some sampled to the species others to the family level). In most cases those data are comparisons between marine reserves or tabu areas and open access areas.

Length frequencies

Length-frequency data have been collected simultaneously with abundance during UVC surveys by all organisations, with exception of Coral Cay Conservation and Resort Support. Only length data from one community biological monitoring site on mud clams were directly measured. In total, seven data sets from locations across Fiji have been collected with length-frequency data.

CPUE/Catch

Information on total catch of the subsistence and artisanal/ small-scale commercial inshore fishery in Fiji as well as effort data (CPUE data) is sparse. Only two catch and consumption surveys were carried out since 1995. Only during the past two years catch landing surveys have been carried out by the Research Division in the major market outlets. To date, none of the information covers the potentially large subsistence part of the inshore fishery. This gap is currently addressed by the national CPUE survey supervised by IAS-USP.

Benthic habitat cover

Available information on benthic cover has been mostly focussing on percentage live hard-coral cover, although sea grass has been included in some surveys. Coral cover has been estimated as percentage with life forms of the corals. No survey has consistently identified corals to the species level, but depending on the survey dead coral, rubble and sand as well as soft coral and sponges were included. Most of the community biological monitoring of FLMMA sites only estimate percent hard coral cover.

Bathymetry

Bathymetric information from navigation charts is provided by the Ministry of Transportation. The Pacific Islands Applied Geoscience Commission (SOPAC) also undertook multi-beam sounder surveys around the Yasawa group and along the Coral Coast and generated high resolution data of benthic topography for small nearshore areas.

Benthic/geomorphologic maps

Accurate, remotely sensed benthic habitat maps only exist for very few areas in Fiji. With the exception of the maps generated by Chris Roelfsema (Roelfsema et al., 2007), they are neither ground-thruthed nor very detailed. More recent projects are currently addressing these issues and are also starting to build up local GIS capacity. Geomorphologic maps of all coral reef types from the Millennium Mapping project (Andréfouët et al., 2006) exist for all of Fiji but they are of relatively coarse resolution and not useful for modelling at a *qoliqoli*-scale (pers. comm. Serge Andréfouët).

Land use/ resource use maps
Resource use maps are developed by the communities with help of the FLMMA partners, while WCS and WWF have geo-referenced the resource maps from their project sites, most of the maps are kept on paper and are very crude. Nationwide land use maps are provided by the Fijian Department of Land and Service e.g. on sugar cane plantations and population distribution.

The data table (Table 11) was compiled to get an overview of the nature and quantity of biophysical data from coastal areas in Fiji. To know what scientific information is available in Fiji is a prerequisite to improve communication and information flow and also to improve collaborations between organisations. The table also serves as matrix to assess whether the data requirements are met for various kinds of models or software that may be able to address some of the community and stakeholder priorities. It indicated that data on catch landing and fishing effort as well as benthic habitat maps are still scarce in Fiji and need to be collected to complement existing efforts. While the oldest data sets presented date back to 1995, the bulk of the data has been collected more recently. The only information with a Fiji-wide or near Fiji-wide coverage is geomorphologic maps of all coral reef types from the Millennium Mapping project. Sea Surface Temperature (SST), species abundance, benthic cover, coral health, and community resource use maps are also available for many places across Fiji but vary greatly in data quality and precision. The table also shows that the majority of the data was generated using the same methodology (UVC) and that the data analysis did not extend beyond preliminary, descriptive statistics in most cases.
Not included in the table are data available from various global data bases. NASA’s Monthly Mean Global Surface Ocean Variables data set (Halpern, 2001) provides global low resolution data on monthly mean averages of bio-physical oceanographic parameters. Despite all the efforts undertaken to find all available data and project information it might be possible that some projects have not been included. Also much of the data described will not be publicly available or published in any form.

Table 11. Biophysical data Fiji

Data	Org	Data specification	Area	Time scale	Source	Data analysis
Species abundance	IAS-USP	Finfish and Invertebrate Indicator species inside and outside tabu area, (community monitoring)	About 80 sites Fiji wide	varying, from 1998 ongoing	UVC	Meta analysis, regressions, SMD statistical
	WCS	Finfish and invertebrates to the species level inside and outside marine reserves (all non-cryptic species); monitoring	4 sites in Kubulau	from 2004 ongoing	UVC	Preliminary statistical analysis
	WWF	Finfish and invertebrates to the species level inside and outside marine reserves (all non-cryptic species); monitoring	7 sites in Macuata	from 2004 ongoing	UVC	Preliminary statistical analysis
	Green Force	Finfish and invertebrates to the species level	2 sites in Yadua & Kubulau	from 2001 ongoing	UVC	n.a.
	Coral Cay Conservation	Finfish and invertebrates	Coral Coast, Yasawas, Mamanucas	from 2002 until 2006	UVC	Descriptive statistics
	Frontier	Finfish and invertebrates to the species level, (initial assessment)	11 sites in Gau	2006	UVC	Species diversity, descriptive stats PCA with benthic cover
	Resort Support	Finfish and Invertebrate Indicator species inside and outside tabu area (all non-cryptic species); long-term monitoring once a yr	1 site (Waitabu, Taveuni)	from 1998 ongoing	UVC	Descriptive statistics
	Fisheries Department	Finfish and invertebrates to the species level, (initial assessment)	currently 40 qoliqolis	2002 ongoing	UVC	Descriptive statistics
	SPC	Finfish and invertebrates at the family level (2 monitoring events)	6 communities across Fiji	2001-2002; 2003	UVC	Pasgear
	GCRMN	Finfish and invertebrates at the family level	12 sites across Fiji	2002-2006	UVC	Descriptive statistics
Length-frequency	IAS-USP	Size classes for mud clams (community monitoring)	2 sites (Ucunivanu & Kumi)	from 1998 until 2006	Direct measure ment	Descriptive statistics

Data	Org	Data specification	Area	Time scale	Source	Data analysis
Length-frequency	Green Force	size classes	2 sites in Yadua & Kubulau	From 2001-04; ongoing	UVC	-
	WWF	size classes	7 sites in Macuata	from 2004 ongoing	UVC	Preliminary statistical analysis
	SPC	size classes	6 communities across Fiji	2001-2002; 2003	UVC	Pasgear
	Frontier	size classes	11 sites in Gau	2006	UVC	Biomass estimates
	Fisheries Department	size classes	currently 40 qoliqolis	2002 ongoing	UVC	Descriptive statistics
	WCS	size classes	4 sites in Kubulau	from 2004 ongoing	UVC	Preliminary statistical analysis
Benthic habitat cover	IAS-USP	Hard coral cover, Benthic cover for some sites	Several communities Fiji wide	varying, from 1998 ongoing	UVC	Descriptive statistics
	Resort Support	Algal, hard and soft coral, sand, rubble and sea grass cover inside & outside tabu area	1 site (Waitabu, Taveuni)	from 1998 ongoing	UVC	Descriptive statistics
	SPC	soft bottom, life coral, rubble& boulders, hard bottom, soft coral	4 sites (Dromuna, Lakeba, Mali, Maivus)	2001-2002, 2003	UVC	Pasgear
	GCRMN	benthic cover, depth stratified coral health & recovery from bleaching	various regions in Fiji	from 1998 ongoing	UVC	Descriptive statistics
	Green Force	benthic cover	2 sites in Yadua & Kubulau	from 2001 ongoing	UVC	n.a.
	Coral Cay Conservation	benthic cover	Coral Coast, Yasawas, Mamanucas	from 2002 until 2006	UVC	Descriptive statistics
	Frontier	hard coral, soft coral, algae, anemone, rock, rubble, sand, silt, recently killed coral, sponge	11 sites in Gau	2006	UVC	PCA with benthic cover
	WWF	Life forms, benthic cover	Macuata	from 2004 ongoing	UVC	Preliminary statistical analysis
	WCS	Life forms, benthic cover	Kubulau	from 2004 ongoing	UVC	Preliminary statistical analysis
CPUE/catch	Fisheries Department	catch statistics	Six main market outlets	from 2006 ongoing	Market surveys reports from middle men	-
	SPC	Catch consumption	n.a	n.a	Household interviews	n.a.

Data	Org	Data specification	Area	Time scale	Source	Data analysis
CPUE/catch	IAS-USP	National CPUE survey (incl. fishing pressure grids)	whole of FIJI	from 2007 ongoing	Log book Community survey	ongoing
	IAS-USP	Creel survey, catch consumption	Viti Levu	1995	Interviews catch surveys	Descriptive statistics
bathymetry	SOPAC	High resolution	Nadi to Suva; Yasawas	n.a.	Multibeam echo sounder	n.a.
	Tokyo Institute of Technology	n.a.	1 site (Votua, Coral Coast)	ongoing	Site scan sonar	n.a.
	Ministry of Transportation	British Admiralty Charts	Fiji wide	n.a.	n.a.	-
	Fiji Hydrographic Survey	n.a.	Kadavu, (?)	n.a.	n.a.	-
Benthic habitat maps	Coral Cay Conservation	n.a.	Mamanucas Yasawas	n.a.	Satellite imagery	-
	WCS	Not ground-truthed	Kubulau	2006	Satellite imagery	-
	USP- Chris Roelfsema	n.a.	3 sites (Suva habour , Navacavu, Soso reef)	2007	Satellite imagery& ground truthing	
Geo-morphological maps	S. Andrefouet-NOAA	coral reefs	whole of FIJI	2006	Satellite imagery	-
	National Trust of Fiji	coral reefs	whole of FIJI			-
Resource use maps	IAS-USP		FLMMA sites	from 2001	Comm. Interviews	-
	WCS		Kubulau	from 2004 ongoing	Comm. Interviews	-
Land use maps	Department of Land and Service	E.g. sugar cane plantations, population distribution	All of Fiji	n.a.	n.a.	-
SST	GCRMN (Resort Support+ Lovell)	n.a.	across Fiji	ongoing	Temperature loggers	-

Potential models for Fiji

Stakeholder priorities are centred on design and management of the tabu areas, sustainable harvest levels as well as the establishment of a national network of marine reserves. Based on these priorities and because certain models address a range of needs from fisheries to network functionality they were grouped into the two following categories:

1. Stock assessment and fisheries models/ software
2. Spatially explicit models and Decision Support Software (DSS)

Table 12 summarises some model types commonly used to generate reference points for stock assessment and fisheries management based on estimated parameters. They have evolved from holistic to analytical single species to multi-species stock assessment to ecosystem based models that place the object in a more realistic ecosystem context. Agent based models (ABM) have also been developed which are based on a set of behavioural responses observed from nature according to a set of rules and are referred to in the next section. The function and respective data needs are indicated and whether the models may be used on the background of the presented data (see Table 11). To date, modelling approaches have had very limited applications in Fiji (see Appendix VII for a list with applied models).

Table 12. General types of stock assessment and fisheries models/ software

Model type	Function	Data needs	Application in Fiji
Holistic models: Surplus production models (SPM) or Climate combined models	Calculating a (maximum) sustainable yield (MSY) & virgin biomass (B) (environmental conditions can be included)	Timelines of catch (C) and effort (f) data (time series of environmental conditions)	Only with software that does not require timelines (e.g. ParFish)
Analytical models: (Yield per recruit models; Catch at age models)	MSY, allow forward prediction of stock size	Data on growth (G) and natural & fishing mortality (M&F); data on size/age at first capture; catch at age, catchability coefficient (q), M/F at age, fecundity at age	Yield per recruit models only with length-frequency data (from direct measurements or UVC) as a substitute for age
Ecosystem-based trophic model (EwE)	Explore ecosystem effects of fishing & management policy options (e.g. from MPAs)	Biomass estimates of all compartments, consumption, production, diet, catches	No, data not available

Ecosystem based models like Ecopath with Ecosim (EwE) are far too data intensive and require general information about the dynamics of exploited stocks as well as all other compartments of the examined system (Table 12). Although the ecosystem based approach seems likely to be the way for future modelling since its much more realistic (Medley et al., 1993; Christensen et al. 2000) and is increasingly used also in tropical countries, the model shows great uncertainties around estimates and is often too complex to be used as a tool for management. Yield per recruit and catch at age models require the aging of the species looked at, which is technically very demanding for tropical species and has never been done in Fiji. Length-frequency multi-year time series however are available for some sites and can serve under certain conditions as substitute to give information on the respective age of caught fish by plotting the length against the abundance (see Gulland and Rosenberg, 1992). For a review on this method refer to Hoggarth et al. (2006).

Describing the models and software presented in further detail is beyond the scope of the thesis. However, Pasgear and ParFish are briefly discussed here, because they use CPUE data and length-frequency-data respectively which are both available in Fiji to a certain extent. The Pasgear 2 software (Kolding, 2000) is based on a multi-species population dynamics model and is one of the very few models that has been used in Fiji (see Appendix VII). The Fisheries Division is trialling Pasgear 2 using length-frequencies and annual catch data from interview surveys both provided by the Secretariat of the Pacific Community's (SPC) PROCfish survey (SPC, 2001). The scope is to test the software as a tool for future analysis of the MRIS data. Pasgear 2 allows exploitation rates for the most important food fishes to be calculated. A further advantage of Pasgear is that it can be adapted for the use of experimental UVC generated data which is the most commonly applied survey method in Fiji. The software can also be used to estimate effects of tabu areas on fish populations via comparison of biomass differences inside vs. outside the area. It therefore has potential application to answer some of the questions of harvesting strategies of tabu area openings.

At the moment time series of CPUE data are not available thus traditional SPMs can currently not be applied. However, the ParFish software (Walmsley et al., 2004) might be used for stock assessments since a lack in long-term CPUE data is complemented with additional information from interviews with fishermen. Additionally, the national CPUE survey could provide a baseline for future modelling. ParFish aims at providing a framework for participatory stock assessment and co-management and was developed to involve fishers in the development of management strategies for small-scale fisheries in developing countries. It combines the conventional SPM with expert knowledge and past experience using a Bayesian approach (calculating probability density functions) to account for variation in data limited situations (Medley, 2006). Software outputs are standard fisheries management parameters such as MSY, stock status, and the level of control (e.g. effort or quota) that would be most supported by involved fishers.

In contrast to more conventional fisheries models, spatially explicit models may be helpful for the establishment of a network of marine reserves and the placing of individual tabu areas as well as examining system connectivity. These topics are particularly important to practitioners in order to assess whether preconditions are met for the grouping of individual FLMMA sites to a regional decentralised network. As in the previous table, Table 13 indicates the function and respective data needs for spatially explicit models and Decision Support Software (DSS) and potential to be used based on existing data in Fiji.

Table 13. Spatially explicit models and Decision Support Software (DSS)

Model type	Function	Data needs	Application in Fiji
Network design models & Decision support software (e.g. MARXAN)	Identify networks of reserve sites that would meet defined objectives while minimizing “costs” to resource users	Benthic habitat maps, information on spatial patterns of conservation targets, threats (major settlement, industry etc.) & opportunities (areas with higher probability of success)	Yes, but still a lack of benthic habitat maps
Ecosystem based spatially explicit trophic model (Ecospace with EwE)	Establishes species-habitat associations, rates of dispersal & migration; examines how MPAs affect biomasses through time.	Biomass estimates of all compartments, consumption, production, diet, catches + benthic habitat maps	No, data not available
GIS based plume model for major watershed areas	Models dispersal distances of plumes, coastal run-off	Slope, water discharge, land cover, soil type, rain fall etc	Yes, information on land cover and soil type exist, other data inputs can be estimated
Hydrographic models (larval dispersal)	Predicting larval dispersal rates to elucidate recruitment under passive or active swimming behaviour	wind records, current records, information on tides, salinity, temperature + larval behaviour optional, location of spawning sites	Only under extremely simplified assumptions
Agent based models (ABM)	Understanding & prediction of agent behaviour (fleets, fish, fishermen etc.)	Definition of agents and decision rules for agent behaviour, grid	Does not run on presented data, grids are available, but little empirical evidence for rules

Ecosystem based management tools like Ecospace in combination with EwE are theoretically addressing a couple of the stakeholder priorities such as testing marine reserve effects on fished stocks. However, they are more useful for general management strategy testing at larger scales rather than specific management regimes (Christensen and Walters, 2004). Also, important benthic habitat maps of coastal areas in Fiji for Ecospace are mostly lacking.

Fish movement as response to spatial closures might be modelled with an ABM that would need empirical data such as a current research project at the Coral Coast and an ongoing tagging study by WCS.

There is a suite of more or less specific network decision support software and other GIS-based tools. As the most widely used, MARXAN could be tested in Fiji, similar to the example in Kimbe Bay, PNG (Green et al., 2007) and Palau (Hinchley et al., 2007) both commissioned by The Nature Conservancy (TNC). At present, MARXAN is planned to be used in Fiji by WCS and IAS-USP (see Appendix VII). Priority areas for the network are generally identified by dividing the planning region into a number of user-defined planning units, and selecting portfolios of units that meet these targets by calculating the amount of each conservation feature in each planning unit. Identifying these portfolios can be done manually but it is generally much more efficient to use software. However, benthic habitat maps and the scarcity of other remotely sensed data are currently a limiting factor and are being addressed.

Potential of other scientific methods for monitoring and progress evaluation

Surveys in Fiji for monitoring and progress evaluation of management interventions are relatively limited in their spectrum. As Table 11 shows, a range of biophysical data exist but with limited utility. Therefore coordinating and improving monitoring and evaluation methods seems promising especially with regard to connectivity studies. In most of the surveys UVC is used to assess the state of reef communities or to compare protected with unprotected sites. This method is often limited in the taxonomic resolution, lacks sound size estimates and is susceptible to high natural variability (e.g. Edgar et al., 2004). This suggests that other methods need to be explored which might be more appropriate and/or more cost-effective to evaluate management success. Further effort should go into the exploration of alternative scientific methods to generate more robust and consistent information that addresses stakeholder priorities. One such method that has been successfully used to obtain reliable data is baited underwater video (BUV). This method would also provide information of sufficient quality for international comparisons and publications in scientific peer-reviewed journals.

The use of BUV has also grown internationally (e.g. Willis and Babcock, 2000; Willis et al, 2000; Harvey et al, 2004). WCS is planning to use BUV for the EBM project and presentations of videos at their study site generated interest within the community (pers. comm. Daniel Egli, research fellow at WCS). It may therefore also be a good advocating tool. Although alternative methods may be more resource intensive, depending on the objectives, they may be justified by more accurate and valuable results.

Alternative indicators

Information that is missing in Fiji is a general understanding of stock dynamics and species interactions of tropical fish. Also, the state of fished stocks and their response patterns to exploitation are largely unknown. Several low-tech indicators are therefore proposed which can be measured at all governance levels. Assessment of the mean trophic level in catch landings can be used as a proxy to determine the current status of the fishery since overexploited fisheries largely lack apex predators (Pauly et al, 1998). Thus, the higher the mean trophic level the healthier the ecosystem and fishery can be assumed to be. Also known as the Marine Trophic Index (MTI), it is estimated by multiplying the landings by the trophic levels of the individual species groups, then taking a weighted mean. Reference structures from healthy environments would however be required for comparison. At the site level, project partners could evaluate the trophic level together with the communities by examining the general structure of landed fish. This could serve as a proxy for the status of fished resources and could be easily integrated as a participatory method during awareness sessions. This would also fit in well with the food pyramid explanation during the initial FLMMA workshop. Size structure of catch landing data can also be used for other relatively simple measures. Graham et al. (2005) have investigated the relationships between abundance and body-size and calculated size-spectra from simple size-abundance data under a gradient of different fisheries pressure in Fiji. Their results suggest that the slope and height of the size-spectrum appear to be a good indicator of fishing effects on reef fish assemblages. Alternatively, Froese (2004) proposed three easy to measure indicators, which can also be used as rapid appraisal methods at the site level: percentage of mature fish in catch, percent of specimens with optimum length in catch and percentage of ‘mega-spawners’ in catch.

Due to exponentially increased fecundity in bigger, mature females it should be avoided to catch these mega-spawners since they can provide substantial numbers of eggs and may have a disproportional high influence on recruitment. Also, it is undesirable to catch fish that have not had the chance to reproduce yet, thus only mature fish which have contributed to the brood stock should be caught. When length is correlated to the respective age of a species, an optimum length range can be calculated which excludes immature and highly fecund development stages. This can be done with the length-frequency wizard in FishBase (Froese and Pauly, 2000). The wizard will also calculate a percentage of how many fish are caught below/ above or within the optimum size range and gives indications on the condition of the stock due to the size distribution. This might give more reliable information to communities and other stakeholders than repeated UVC monitoring.

5.4 Discussion

Challenges and opportunities

It should be mentioned first that existing results and data should be better communicated and made accessible to improve information dissemination across Fiji. This also implies that reports and grey literature are published and made readily available so future research builds on information from different projects. One explanation for the recent shortcoming in published reports is the delayed analysis of survey data. It seemed that completing the surveys was placed with greater importance than the actual analysis and interpretation of generated data. A greater emphasis needs to be put on data analysis using more sophisticated methods and improved meta-analysis of existing data.

Fisheries stock assessment (SA) projects have been carried out throughout the South Pacific during the 1980s and early 1990s (see Dalzell, 1996) particularly by SPC focusing on single-stock assessment of target species but the results generated found very limited applications for management strategies. Even if funds were available to establish a quota system with a MSY and a maximum sustainable effort, governance structures and legal frameworks are not in place to control input and output effort (especially the artisanal fishery). Additional challenges are posed by the community tenure in which assets are shared and there is generally little interest in maximising benefits (Foale and Manele, 2003). Gillett (pers. comm., consultant and expert for South Pacific fisheries) compares sophisticated stock assessment for community purposes to calculating the optimum length of individual blades of grass before cutting the lawn. The kind of precision provided by SA is in most cases not needed to answer the rather crude objective of preventing stock collapses. Co-management projects rarely involve modelling and other Western fisheries management concepts but rather go for easy to communicate and easy to enforce measures. Rules of thumb should be established which also focus on community needs, e.g. to attempt to establish a sustainable yield based on some of the following factors: fish consumption (amount of protein needed), the fishing area (qoliqoli/ LMMA), the population, the effort level (how many people are fishing within the qoliqoli for how many days/hrs), how much is caught and which gear do they use. But also rather easy analysis methods should be considered like using CPUE data to plot fishing pressure along the Fijian coast to address questions such as where the current exploitation levels are very high and what kind of management is really needed.

Nevertheless, the ParFish software looks promising for Fiji. However, limitations of CPUE are that it assumes a constant catchability coefficient (q) which in most fisheries is hardly the case. Additionally, declining stock abundance can be masked and only shows with retarded effects due to schooling behaviour of fish or improvements in gear etc. (Maunder et al., 2006). Also SPMs are highly debated in the scientific community and it has been suggested to discard this model from "the fisheries toolbox" (Maunder, 2003). Length-frequency data have had many applications especially in the tropics (Sparre, 1998) since they are comparatively easy to obtain. Although a couple of projects in Fiji have included length-frequencies in their surveys (see Table 11), they are rarely analysed and should be collected more. Some limitations of length-frequencies of tropical fish are their life history traits, relatively long-lived and slow growing, with highly variable individual growth trajectories and protracted spawning periods (Manooch, 1987) which often makes the distinction of cohorts difficult.

At the community level a "common sense" data- and knowledge-based approach to management with the adaption of a precautionary approach to fisheries seems most appropriate in the short term. Guiding community fishing efforts away from times of peak spawning for the targeted marine species is one conceivable common sense low-tech measure which doesn't involve quotas or needs to be based on yields or yield modelling.

While the attempt was to explore better use of existing data by means of modelling approaches it has to be acknowledged that in most cases additional data would have to be gathered. Also a major effort would have to be undertaken to build up necessary capacities and support functions. Pasgear for example is the first software to be used for a more comprehensive data analysis by the Fisheries Department and still requires substantial outside support (pers. comm. Milika Sobey, Professor in Biology USP). But even if models in general were to be successfully used, the difficulty lies in translating modelling results into management action because the capacities are currently lacking. Interpretation and transformation of data into a management output that can be used and communicated may be very hard due to its theoretical and highly technical nature. This applies not only to communities but also to managers, fisheries extension officers, and other people who are dealing with enforcement. From interviews with key informants and personal communication with fisheries research personnel these issues were often mentioned. Furthermore, significant levels of uncertainty have to be kept in mind because only very little model outputs account for model uncertainty (Hill, 2007). Interpretation will often be very different from modeller to modeller since parameters might be estimated or weighed differently due to a different understanding of the system represented. For example model outputs from ABMs are only as good as the understanding of agent characteristics. If empirical evidence is scarce or absent, they will rather remain intellectual toys. Nevertheless, both the Pasgear and ParFish software that rely on rather simple fisheries models might be useful in determining rules of thumb to establish a sustainable yield for certain focal inshore fisheries. Most importantly, it will be crucial in the future to readjust the current fisheries development driven approach and increase the capacity in fisheries research and biology/ecology to generate a general knowledge of the fishery. Rapid appraisal methods and easy to measure indicators seem currently more promising to be used at all levels and should receive more attention in the future to gain a better knowledge of the stocks and the impact of the fishery.

While specific fisheries models seem to have a certain yet limited applicability to support CBAM in Fiji, spatially explicit models such as MARXAN that work at larger scales and which can be used for planning purposes at mid and national levels seem to hold more potential for future support. A spatially explicit approach will be inevitable for the planning of a national marine reserve network. The conservation targets for the network amongst other factors will dependent on the specific objectives according to which design criteria are formulated. As discussed in Chapter 3, these are not clearly defined but the focus will likely be on fisheries enhancement and protection of productivity of the inshore coastal areas. However, MARXAN is primarily designed for biodiversity conservation planning and not as a means to design spatial management measures for resource exploitation (although it has potential to be adapted for resource management purposes). To serve the purpose of resource exploitation it will have to be especially important to collate ecologically optimum sites with community needs. High priority fishing spots from fishing pressure grids could be used to create valuation indices for important fishing areas (Ardon, 2005), to indicate reef areas that communities are highly dependent on. Local knowledge data on spawning aggregations and nursery grounds may be collected and geo-referenced. Some observations on the location of spawning areas made by community members are published by the Society for the Conservation of Reef Fish Aggregations (SCRFA). Some of the more accurate community resource maps might be geo-referenced or new ones could be drafted in collaboration with the communities based on aerial photography or Google earth images for habitat distribution and resource use. This participatory method was used successfully in the Solomon Islands as a substitute for resource intensive ground-truthing for habitat map production (Aswani and Lauer, 2006a; Aswani and Lauer, 2006b; Lauer and Aswani, 2008) and was also trialled in Fiji by Roelfsema et al. (2007). These methods would involve communities from the beginning on to make them familiar with underlying scientific concepts and to increase compliance. Other input data that might substitute benthic habitat maps are coral reef type distribution maps and bathymetry charts. Very simple hydrological modelling might also be used. Since most of the coastal communities rely on healthy, productive reefs for their daily needs, it is vital to have information on reef areas which are more prone to disturbance and would affect communities negatively. MARXAN can generate a human footprint, a corridor, from demographic information, maps on land use practices and logging activities as well as air borne and industrial pollution sources which put additional pressure on reefs. For these coastal run-off scenarios a suite of watershed models are also available. SST and reef resilience to bleaching data can also be used. This could also be the basis from which to calculate a threat index for Fijian communities similar to the Reef at risk study (Bryant et al., 1998) to be used by FLMMA/ the government to coordinate future interventions. However, data gaps for network models are apparent; particularly the lack of benthic habitat maps, high resolution remotely sensed data and species distribution data would need to be addressed first if an ecologically meaningful analysis is required. Another challenge will be faced by the difference in ecologically sensible management units and the traditional governance and *qoliqoli* boundaries.

The problem of scale

The problem of scale will pose the biggest challenge for a national network establishment because ecologically viable scales will have be to consolidated with traditional boundaries which are generally much smaller. While the mean size of a *qoliqoli* is about 22 km^2, some are not bigger than 1 km^2 and are thus too small to have a continuum of ecological systems within the modelling environment. After all, larval disperse at a much larger areas than the scale at which CMT operates (Foale and Manele, 2004). Any network design output is likely to generate a scenario of trans-*qoliqoli* marine reserves which may not find the acceptance by the communities. This information is not available but might significantly decrease opportunities for areas with higher ecological connectedness. Reserves stretching over socio-political/ traditional boundaries imply that resource management has to be up-scaled which could on the other hand foster collaborations between communities and facilitate ecologically more effective resource management and protection. Generally MARXAN has some design constraints which make it difficult to adapt it to a South Pacific environment. While planning units can be chosen in any size and resolution of data, MARXAN is not designed to have local (small) scale goals being entered with larger scale targets. Experiences from TNC work in Kimbe Bay, PNG are mixed. While traditional boundaries were overlaid some traditional areas didn't have MARXAN polygons in them and were left outside whilst their neighbours got workshops which resulted in governance issues and lack in compliance (pers. comm. James Comley). Since applications from PNG are recent, it is difficult to predict to what degree the software output will be implemented. A concern which has been raised by community members at a FLMMA meeting was that MARXAN and other ecosystem based management tools coming from a strictly scientific background would focus on biodiversity rather than resource management. Their concern was that this might neglect local or traditional knowledge and the priorities of communities (pers. comm. James Comley). In many of these locations, management is only likely to be sustainable if communities have ownership over the project- and food security not biodiversity conservation is their main focus. Additionally, there will have to be a clear distinction about who will be responsible and enforcing which areas of marine reserves. It also has to be considered whether the traditional tabu areas should be kept out of a national marine reserve network. Most importantly a clear definition of objectives and questions in combination with the resulting data needs and current data availability is essential to be led by objectives and not the tool.

Increasing scientific research in Fiji is likely to yield data that will be more appropriate to serve as a model input and could also be utilised by a range of different models. However, making full use of existing scientific and fisheries management related information should be the first priority.

Chapter 6

General discussion

The purpose of the presented thesis was to examine the current and the potential use of natural science to be integrated into the CBAM process and support sustainable management at various levels of governance in Fiji. Additionally, the CBAM approach was examined and respective information needs and stakeholder priorities were looked into.

Fiji has experienced vast changes during the past century (especially through the introduction of the cash economy). Traditional governance structures are being weakened in some places as a consequence of western influence. However, traditional communal structures still persists in most rural places and need to be integrated in any management efforts. As a consequence, in the Pacific the novel CBAM approach has proven to be very influential and successful in engaging local communities. Nevertheless, this approach also poses additional challenges to a more conventional approach, especially in terms of time requirements and capacity building. Although, intentions and expectations might differ between communities, challenges and managed resources are essentially the same. Therefore it is important to find successful management strategies that can be up-scaled to a broader planning level and enhance coordination and support without eroding the importance of the individual community. Successful management however is not just a question of scale but will ultimately depend on the individual communities' capacity, commitment, and interest to adapt to the changes that are occurring and on the mid/national government's capacity to provide an adequate framework and support functions to sustain the process.

Although community interest has become a high priority in Fiji, to date little focused effort has been carried out to identify and address stakeholder requests. Challenges for effective coastal resource management, however, are often linked to lacking stakeholder buy-inn and implementation and enforcement of proposed management strategies rather than a lack of scientific information (Risk, 1999). Additionally, growing economic needs, limited alternative livelihood opportunities and weakened governance structures are considerable obstacles for conservation and management. These issues are not likely to improve with only an un-coordinated increase in scientific surveys. Even having the best possible information is unlikely to induce a change in the behaviour and improve the management of local resource owners. Especially, in a situation where support structures, enforcing capacity, and local interest are lacking. In Fiji, existing knowledge is not used and applied to its full potential. Nevertheless, community interest in management in Fiji is apparent due to the large number of participating communities in the FLMMA network. Community members and key informants also formulated a range of different information needs that would require additional scientific information. However, how much and which kind of scientific data is appropriate is not always straightforward and viewpoints vary greatly on this topic.

"Once we free ourselves from the illusion that science or technology, if lavishly funded, can provide a solution to resource or conservation problems, appropriate action becomes possible" (Hilborn and Walters, 1993).

Following on from this citation several authors argue that nature especially tropical nearshore fisheries are too complex and variable to understand or even predict their dynamics (Sainsbury, 1988; Medley et al, 1993; Johannes, 1998). Especially in tropical developing countries too little human capacity exists and science is mostly carried out by outside projects which tend to primarily answer to donor requirements while often ignoring local priorities and the value of existing indigenous knowledge (Johannes, 1998). After all, CBAM can be mostly based on common sense, attributing a minor role to natural science. Often, environmental education coupled with simple development measures will be much more effective because they are site specific, targeting direct problems, and are easy to communicate. Although it should be mentioned that information for environmental education also results from scientific surveys documenting the progress in scientifically provided knowledge. Advocating the protection of spawning aggregations and educating communities about effects of destructive fishing practises will simply require socially skilled and respected facilitators. However, if marine reserves and fisheries related management strategies are being implemented, additional scientific information and surveys are required. Most importantly it is imperative for any adaptive management strategy to use some form of progress measure that can evaluate their success. Obviously, these can range widely from simple perception based to highly sophisticated and expensive scientific surveys.

There are two primary aspects of natural science use in CBAM which were examined in this thesis. The first was to assess the actual and potential benefits of ongoing monitoring and evaluation methods required for adaptive management. The second aspect was to appraise whether information needs and stakeholder priorities can be best addressed by using additional strictly scientific methods.

The main questions asked by stakeholders were regarding sustainable harvesting levels and optimal management strategies for their tabu areas. These information needs are very difficult to quantify and predict. Walters and Hilborn (1993) even claim that science has repeatedly failed to provide enough knowledge to give any kind of optimum yield predictions for a fishery. The very limited number of stock assessment models carried out in Fiji was not used for any evident management purposes either. Therefore, at present robust rules of thumbs and recommendations based on live history information of the most important food resources that are already available from the region should be developed at the site level. To address the above mentioned stakeholder information needs, quantitative studies to compare various management tools (different designs, degrees and durations of protection of tabu areas) will still be required. Even Johannes (1998) argues that quantitative research is essential, especially on the functioning and effects of marine reserves. Therefore, basic research and relevant scientific monitoring of management measures need to be continued in the Pacific. However, a more effective way needs to be found to integrate and communicate science in a CBAM setting. At present scientific efforts focused on CBAM needs in Fiji are very limited in scope and often duplicate other projects.

While participatory science such as community-based monitoring is perceived as an integral part of the CBAM approach, analysis has shown that it has had only limited value for capacity building and as a management success measure. Therefore, the findings of this thesis suggest that it does not meet its required needs for CBAM. Communities have proven that in principal they can conduct biological monitoring but more attention should be paid towards whether they actually perceive this as beneficial and can truly utilise the results. Additionally, it should be acknowledged that communities cannot be expected to grasp and fully integrate novel management strategies after only a couple of awareness raising and training sessions. This applies especially to the biological monitoring. How are communities supposed to self-sufficiently use the data with no background in data analysis? Traditional or local knowledge cannot assist the process. Most importantly, more and continuous training and management support is needed. As has been shown, scientific examination of the community data has not yielded any conclusive proof of the long-term effectiveness of the tabu area. Only limited significant increase in abundance over time was detected. This was largely due to data of statistically poor quality reflecting a lack in robustness of the current monitoring design to detect management effects. From exploring the data and observed inconsistency in sampling it is questionable to what degree it might be possible to use inferential statistics to provide any management advice based on the monitoring data. However, purely statistical analysis is mostly irrelevant for communities. Of greater interest would be to known which effect size would convince the community members that the tabu is working or not and influence their adaptive management strategies. Results from SLO interviews and communication with community members suggested that at present the data alone have limited influence on management interventions in Fiji. Especially, the interpretation of results poses great uncertainties. To date, little effort has been paid to analysing and responding to the monitoring data in the FLMMA network. The findings of this thesis strongly suggest an adaptation of current monitoring efforts, including a clear definition of objectives. Monitoring in the CBAM context does not need to meet stringent scientific criteria in the classical sense. Surveys for management purposes can be adequate with a relatively low precision of about 20% and to achieve higher precision could be considered a waste of time and money (Risk and Risk, 1997). Therefore, for CBAM at the site level more importantly than precision is how the results are communicated and implemented. Nevertheless, not every simplistic approach will provide a reliable and sensible outcome. While sophisticated science certainly isn't needed at every site in such an environment, even simple strategies and surveys should be implemented and carried out more carefully and focused. There is also the question whether it is most efficient or necessary to pursuit such regular monitoring of management measures that are likely operating at much longer time scales. Regular surveys at appropriate frequencies of easy to measure indicators rather than continuous monitoring seem to be more feasible (FAO, 2003).

The ideal amount of science is very difficult to determine, as well as how much of it can be realistically implemented. This will again depend on local and national capacity and interest to sustain the process and adapt to scientific information. One requirement to achieve this goal is to provide stakeholders at all levels with enough training to implement scientific information that is relevant to resource management and decision making. Currently, it seems that the perception of the community on success of management goals is placed with higher importance than the actual biological outcome measure of community management (Fisk, 2007). It is a balancing act between adapting scientific methods and procedures which are often coupled with high needs in capacity to the reality of a tropical developing country without depriving its people from best available knowledge. There is a considerable list of information gaps for Fiji that need to be addressed especially at the higher governance and planning levels. However, at present it is more realistic that ongoing efforts are reviewed and improved with better focus and appropriate objectives. Essentially, making full use of existing scientific and fisheries management related information should be the first priority. The review of community-based biological monitoring data concludes that it cannot address current priorities and information needs of communities and project partners. To improve this situation in Fiji, the FLMMA network needs to review their priorities, objectives, and methodology to address these needs and develop an adequate measure to measure management success.

In conclusion the present review suggests a twofold approach that can keep local communities involved while addressing specific information needs for CBAM. Firstly, a perception-based approach, that could include a strongly simplified community monitoring, but is largely based on perception and relevant socio-economic factors. The experience with CBAM suggests that this approach is better reflecting present structures and is more likely integrated into the adaptive management process. Additionally, presented alternative indicators should be used at the site level and simple rules of thumb need to be developed. Secondly, simultaneous scientifically more rigorous surveys in selected and representative sites should be conducted to investigate specific questions that can provide sound guidance for the CBAM approach. Although scientific efforts are still mostly instigated and carried out by external organisations and research institutions, Fiji has great potential to developing its capacities further if local organisations are well integrated and the process is nationally coordinated. Sound and relevant scientific research will also provide benefits to Fiji beyond the CBAM needs. Although it has been found that to date modelling has rarely been used as an approach in Fiji, increasing and focused scientific efforts can produce data that could serve as a model input. Therefore, future potential for science applications in resource management could include modelling, which would add valuable input to the medium to long-term regional and national planning. With regards to any scientific research to be conducted in Fiji it is crucial that commitments to inland priorities are respected, capacities are strengthened, and expectations of outcomes and its utility to resource management are realistic.

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Appendix I: List of FLMMA network partners and members

1. The communities:

- Burebasaga Confedaracy
- Tovata Confedaracy
- Kubuna Confedaracy

2. Governmental agencies:

- Fijian Affairs Board
- Ministry of Tourism
- Department of Environment
- Department of Fisheries

3. Educational institutions:

- University of the South Pacific (USP), particularly the Institute of Applied Science (IAS)
- Fiji Institute of Technology (FIT)

4. Statutory organisation:

- National Trust of Fiji

5. Local and international NGOs:

- World Wide Fund for Nature (WWF)
- World Conservation Society (WCS)
- Partners in Community Development (PCDF)
- SEAWEB
- Mamanuca Environmental Society (MES)
- Resort Support
- Laje Rotuma Initiative

Appendix II: Field notes from community interviews from Kadavu

Site	Informants	Interest/ Priority	Tabu area	Monitoring	Use of information	other comments
Dravuni	m; 45	More biological information on species (e.g. on posters): ▪ habitat requirements of species during different life stages ▪ movement and home range	▪ Established to set aside patch of reef for chief & future generation; ▪ Existing plans to establish long-term reserve due to population growths	-	▪ Location of tabu area chosen according to current directions, wind & location of spawning aggregations	▪ Fish are recovering, reported to have seen plenty of fish while spear fishing
	8 f; 18-55	-	▪ Half of the women did not know that a tabu area existed & did not know about plans of relocation	-	▪ The women were not using provided scientific information since they said they weren't part of the ongoing management process	▪ Mentioned several fishing techniques
	2 m; 25	▪ More USP support, more training on fisheries related topics ▪ Interest in movement of fish to better locate them ▪ Biological information on sea cucumber(sucuwalu)	▪ Established to tame finfish and make them easier to catch ▪ Long-term protection important but livelihood & increase in money of higher priority	-	▪ Realised that the use of duva & coral smacking was bad, resulted in change in fish behaviour, no more fish there; also destruction of reef caused change in fish assemblages	▪ They need to stay out fishing longer for the same amount of fish than they used to
Buliya	m; 30	▪ Additional awareness would be appreciated	-	▪ Repeated snorkelling in the tabu area (every month), based on results chief decided to close the tabu area for another 5 yrs	-	▪ No spillover of clams & sea cucumber noticed
	m; 30	▪ More awareness required ▪ Why do fish become poisonous?	▪ Use the spillover for ceremonies & feasts , ▪ See spillover since the tabu area establishment	-	▪ Thinks that stocks will never be depleted	-
	m; 30	▪ More awareness & information wanted on life history & size limits	-	▪ Some community members go out snorkelling in the tabu area, do perceptive monitoring to get an idea about how the resources are doing, then consult with the chief	▪ Remembered from workshop not to stand on coral to "not destroy the house of the fish"	▪ Crabs & lobster are coming back as a result of the tabu area ▪ fish get tame within the tabu area
	m; 30	-	▪ Established to preserve reef & fish, improve income & exclude poachers; hope for increased spillover to sell to build church	-	▪ Chose location & duration of tabu area after baseline study; decided for a healthy reef for 5 yrs after awareness training	-
Waimoso	m; 55	▪ Trans-qoliqoli tabu area establishment needed; ▪ Repeat awareness trainings during additional workshops	▪ Established to make stocks increase ▪ Received money to build a church	-	▪ Before awareness raising "no idea about environmental impacts on reef & didn't care about it" ▪ Well informed about connectivity, currents, winds, dispersal	▪ Bigger sized fish come back as a result of the marine reserve

	f; 25	-	-	-	-	▪ Difficult to communicate about management issues ▪ comments on how she fishes, reported that there are still plenty of fish in the inshore area
Vabea	m; 50	▪ Need for additional strategies apart from the tabu area & to manage the qoliqoli as a whole, currently management plan only for tabu area	-	-	-	▪ Has participated in lots of workshops, installed moorings for ships to not destroy the corals, ▪ They fish much quicker now
	m; 20	-	-	-	-	▪ Regular poaching for black teatfish (sucuvalu) in neighbour *qoliqoli,* knows other poachers
Lawaki	3 m; 30-40	▪ Interest in knowing more about the mangrove systems	▪ Established in 2003, opened in 2004, realised they fished too much, decided then to close it again for a long time	▪ Biological monitoring was supposed to be carried out by community but it was never conducted	-	
Nakaugasele	2m; 20	▪ More outside support required; do not know what else to do management wise apart from setting up a tabu, trust in FLMMA to provide support	▪ Established in 2004 to protect a nursery area, no current in the bay	▪ CPUE is regarded at as a good thing, but it is still unclear for what reason it is carried out; most of the rulers were lost	▪ Use very small mesh sizes	▪ Reported spillover ▪ Women see fish swimming into the tabu area to seek refuge,; sweetlips and juveniles aggregating in the tabu area, haven't seen that in a long time,
	m; 25	▪ More outside support to get "new/ more ideas on how to improve the tabu and the qoliqoli"	-	▪ Didn't fully understand concepts of CPUE, thought it is used to prove that fish grow bigger	-	▪ Mentioned idea of forest reserve
Daku	m; 45	▪ More presentations from FLMMA needed (in previous workshops many people have been away)	▪ No change inside tabu area before and after closure, so it can be opened since Daku is a small village and not everyone fishes	-	▪ Overfishing was named as the reason for decreasing catches, particularly recreational (!) spear fishing & fishing more than could be eaten	▪ Need for continuous conversation about conservation topics within family & village, tikina meetings;Now they see spillover, fish of all sizes
	m; 55	▪ "Is the tabu the only way to help fish to increase??" Need for additional fisheries management strategies	▪ In the beginning, village elders had little for the tabu area but then saw how tame fish were; chose common fishing ground with healthy reef and turtle nesting as location	▪ Started monitoring in 2002, from the results they saw that the tabu area was working	▪ After awareness training realised that decrease in abundance wasn't seasonal but due to over-fishing & use of duva; consider aquaculture, weed farming, had giant clam culture & tourism project	▪ "tuva tuva", planning for the future step by step ▪ Importance of transferring knowledge to next generation
	2m; 16-20	-	▪ opening in decrease; see fish move in and out	▪ think it helps the village, send results to IAS, no changes made; no more surveys cause no more underwater paper; also since 2004 for 3 years surveyed every months	▪ no more use of duva or small mesh size	▪ understood CPUE; increase in catch=increase in stock

Appendix III: Summary table of all FLMMA survey sites

Legend: year a: annual sampling; year b: biannual sampling; o: open; c: closed, b: both; sites in italics: listed as monitored in the database but no data entry, sites marked in grey: sites with at least 3 monitoring surveys of both open & closed sites

Location		Surveys																		Survey Frequencies		
Province	Site	1997	1998	1999	2000	2001	2002a	2002b	2003a	2003b	2004a	2004b	2005a	2005b	2006a	2006b	2007a	2007b	2008a	o	c	b
Ba	Votua						b								b					2	2	2
	Tavua district														b					1	1	1
Cakaudrove	Naboutini *1										c		c		b	?	b			1	3	2
Kadavu	Buliya												b							1	1	1
	Cevai												b	c						1	2	1
	Daku *2						b		b		b				b		b			5	5	5
	Daviqele														b					1	1	1
	Dravuni																					
	Dravuwalu														b					1	1	1
	Drue																					
	Gasele																					
	Jioma												b							1	1	1
	Kabariki												b							1	1	1
	Lawaki												c								1	
	Lewuka												b							1	1	1
	Matanuku *3												c							1	1	1
	*Matasawelevu *4*																					
	Muani												b	b						2	2	2
	Nacomoto												b							1	1	1
	Naivakarauniniu												b							1	1	1
	Nalotu																					
	Nakaugasele												b							1	1	1
	Namuana/ Namalata										b		c	b						2	3	2
	Naqalotu																					
	Narikoso																					
	Nasegai *5										b		c	b	b					3	4	3
	Nasau														b					1	1	1
	Nuku												b							1	1	1
	Nukuvou												b							1	1	1
	Solodamu												b	b						2	2	2
	Solovola																					
	Soso												b							1	1	1
	Rakiraki														b					1	1	1
	Ravitaki												b	b						2	2	2
	Tabanivonolevu																					
	Tavuki												b	b						2	2	2
	Tawava																					
	Tiliva																					
	Waisomo												b							1	1	1
	Yawe												b	b						2	2	2

Location		Surveys																		Survey Frequencies		
Province	Site	1997	1998	1999	2000	2001	2002a	2002b	2003a	2003b	2004a	2004b	2005a	2005b	2006a	2006b	2007a	2007b	2008a	o	c	b
Lomaiviti_Gau	Lamiti-Malawi								b						b					2	2	2
#	Lekanai						b		b		c				b					3	4	3
	Naovuka						b		b		c				b					3	4	3
	Vanuaso						b		b		c				b					3	4	3
Lomaiviti_Koro	Nasau												b	b	b		b			4	4	4
	Mudu																b		b	2	2	2
	Sinuvaca																b		b	2	2	2
Macuata	Druadrua												b		b					2	2	2
	Nabubu																					
	Gevo																					
Nadroga	Biausevu												b				b			2	2	2
	Komave												b				b			2	2	2
	Namatakula												b				b			2	2	2
	Navola												b				b			2	2	2
	Namada								b		b		b		b					4	4	4
	Tagaqe								b											1	1	1
	Vatu-o-lalai								b		b				b					3	3	3
	Votua								b				c		b		b			3	4	3
Rewa	Navakavu								b		b		b		b					4	4	4
Tailevu	Kumi	b	b	b	b	b	b		b						c					7	8	7
	Naloto								c												1	
	Naivuruvuru								c												1	
	Ucunivanua	b	b	b	b	b	b		b		b				b					9	9	9
	Navunimono																					
	Uluiloli																					
	Sawa																					

Appendix IV: Summary table of FLMMA monitoring sites with at least 3 surveys

Legend: o: open; c: closed, b: both (o,c) for the same year; x nr: sampling frequencies

	Site													
Province	Kadavu		Lomaiviti				Nadroga			Rewa	Tailevu		total	3b+ sampling
	Daku	Nasegai	Lekanai	Naovuka	Vanuaso	Nasau	Namada	Vatu-o-lalai	Votua	Navakavu	Kumi	Ucunivanua		
Indicators														
Anemone fish									1c				1	
Bannerfish								1b					1	
Barracuda								1o	2o,1c				2	
Bass	1c								1c				2	
Boxfish								2o,1c	2o,1c				2	
Bream							1c		1c				2	
Cowrie shell	1b												1	
Butterfly fish						4b	2b	1b	2o,3c	2b			5	1
Catfish										1b			1	
Cod	1b												1	
Conus sp.	3b									1b			2	1
Crab	1b		1b		1b								1	
Crown-of-thorns	1b			1b	2b		1o,2c	1b	1o,3c				6	
Damsel fish	1b							1o					1	
Drummer							1c	1b	1c				1	
Emperor	5b	3o, 4c	3o,4c	3o,4c	3o,4c		3o,4c	2b	3o,3c	3b			9	5
Flutemouth									1b				1	
Giant Clam	5b	2o,4c	3o,4c	3o,4c	3o,4c	4b	2b	3b	2o,2c				9	4
Goat fish	1c						2o,3c	2o,1c	2o,3c	2b			5	
Grouper	4b	3b	3o,4c	2o,3c	3o,4c	4b	1b	2b	2o,3c	3b			10	4
Hogfish	1b												1	
Kaikoso											7o,8c	9b	2	2
Live hard coral	1b								1o,2c				2	
Lobster	3b								1b				2	1
Longtom									1o				1	
Mullet							1o,2c		2o,1c				2	
Octopus	1c						1o,1c	1b	1o,2c				4	
Parrot fish	5b	3b	3o,4c	3o,4c	3o,4c	4b	3o,4c	3b	3o,4c	3b			10	8
Porcupine fish									1o				1	
Rabbit fish	5b		3b	3o,4c	3o,4c		3o,4c	2b	2o,2c	1b			8	3
Rock cod	1b	1b							1b				2	
Sandperch									1b				1	
Sea cucumber	5b	3o,4c	3o,4c	3o,4c	3o,4c	4b	2o,3c	2o,1c	2o,4c	5b			10	5
Seaperch	1b							1o,2c	1b				3	
Sea urchin							2b	1o,2c	1o,2c	5b			5	1
Sergent									1o				1	
Shark	3o,4c								1b				2	1
Snapper	1c						1b		1o,2c				3	
Soldier fish							2b						1	
Squirrel fish	1b							1b	2b				3	
Starfish	1b	1b					1b			3b			4	1
Sting ray	1c						1b		1o				3	
Surgeon fish	5b	3o,4c	3o,4c	3o,4c	3o,4c	4b	3b	2b	2o,3c	1b			10	5
Sweetlips		1b											1	
Toby									1o				1	
Trevally	1b						2b	1b	1o,2c				4	
Trigger fish	1c							1o	1b	1b			4	
Triton shell				1c									1	
Trochus	1o,1c		3b	3o,4c	3o,4c								4	2
Trumpetfish									1b	1b			2	
Turtle	3o, 4c								1o				2	1
Tuskfish	1b												1	
Unicorn fish	4b	1b					1b	1o	1o,1c				5	1
Wrasse	4b						1c	1o	1o,2c	1b			5	1
Spider shell	1b					4b							2	1

Appendix V: Observations from biological monitoring events

Locations: Silana (S), Tailevu province and Lawaki (L), Kadavu province

- Sampling outside of the sampling range (L)
- Tidal regimes differed between monitoring events (S)
- Transects were laid across several different habitats (S)
- Presentation and interpretation of results by IAS project team to the communities was not a priority (S+L)
- Staff wasn't properly equipped to draw the graphs (S)
- Results from former year were not analysed correctly (coral cover % from each sampling point within the transect were added up and reported as 400% coral cover) (S)
- Data and resulting management implications weren't discussed prior to presentation (S)
- Control site was not sampled due to time constraints (L)
- In Lawaki results weren't presented at all due to time constraints
- Sampling at high tide, fish were hiding amongst the mangroves, were not detected via belt transects in channel (L)

Appendix VI: Bias of UVC survey methods

- Observer bias (behavioural, subjective decision making, experience)
- Behavioural differences of fish inside vs. outside the tabu area (fish inside the tabu area often more tame)
- Effects of swimming speed, transect duration, how many investigators are involved and how they swim the transect
- Selectivity of method for certain species (size appearance, different visibility, behaviour of target species, proportion of population not detectable by method at time sampled) e.g. counting Emperors being one of the common indicator species has been reported to be under sampled with means of UVC in Fiji (Jennings and Polunin, 1995).
- Also aggregating, shoaling species are easily under/overrepresented e.g. surgeonfish which are frequently chosen as indicator species
- Bias due to movement of fish; fish movement / migration in and out of the tabu area thus numbers are not necessarily representative for tabu area success
- Abundance influenced by many abiotic and biotic factor reflecting natural variability

Appendix VII: Applied models & the future use of models in Fiji

Applied models in Fiji

Model	Organisation	Purpose	Used for CBAM
Pasgear software (Multi-species population dynamics model)	Fisheries Department (2007; still in test phase)	Stock assessment for all qoliqolis	Planned but approach unclear, little capacity
Hydrological modelling	SOPAC	Dredging of lagoons	n.a.
Y/R model for Emperors	Paul Dazell (1992)	Initial stock assessment	no
GIS based plume model for major watershed areas	WCS (2005)	Input into MARXAN for marine reserve network evaluation	potentially
ELEFAN software (LFDA package) for single-species stock assessment	Marine Resource Assessment Group (1998)	Assessment of current management in Fiji	no

Future use of models in Fiji

Model	Organisation	Purpose	Status
MARXAN	WCS	Evaluation/reconfiguration of marine reserves	Planned
MARXAN	IAS-USP	Testing ecological viability of existing tabu areas in Kadavu	Planned
MIDAS[2] (in development) SIMILE[3]	CI+ Boston University	Management impact on marine environnements	Planned
Customised hydrographic model	Tokyo Institute of Technology	Hydrodynamic modelling	Ongoing

[2] Decision support tool that combines ecological, socio-economic and governance variables in ArcGIS

[3] Dynamic modeling software to model ecosystem service outputs from knowledge of ecosystem and market dynamics