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REPORT

A Study Investigating The Effect Of Marine Protected Areas On Reef Health And Fisheries In Small Island Communities

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A Study Investigating The Effect Of Marine Protected Areas On Reef Health And Fisheries In Small Island Communities

Gillis, L. G., Steer, M. D. and Fanning E. (eds.)

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Abstract

The island of Gau in the south of the Fiji archipelago, has suffered from decreasing fish stocks over the last decade. Marine protected areas (MPA’s) were introduced in front of all coastal villages to try and preserve essential marine resources. The study investigated important aspects of coral reef health over a one year period. Each specific monitored variable was chosen so that conclusions could be drawn regarding the overall health of the ecosystem. Three regions were chosen, each site was monitored every three months over a one year period. The MPA's for each village were not introduced in one year but over several, therefore it was expected that sites which held older protected areas would have greater hard coral coverage and diversity as well as a larger abundance of fish species. It was also predicted that all sites would show a general increase in entire ecosystem health over the year period. There was no evidence that fish biomass and coral health were higher in areas with longer serving MPA’s. However, the second hypothesis was supported by the data; a general increase in reef health was observed. These overall results were unexpected, further analysis of the data and conditions of the sites suggests that there was a bias caused by independent factors such as human activity. These are the preliminary results; further research is required in Gau for the improvements of fisheries are to develop effective marine management. The use of marine protected areas for coastal management is important for regions like Fiji where many islands rely on the marine resources for their livelihood.

Key words: Coral reefs, marine protected area, fish biodiversity, fish biomass, coral growth, and coral diversity

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.Introduction

1.1 Environmental and Anthropogenic Stressors of Coral Reefs

Coral reefs are diverse ecosystems that are second only to tropical rainforests in terms of productivity and complexity (Carr et al 2001). They amount to less than one percent of the world's marine ecosystems and yet are estimated to provide food and shelter for up to 25% of all marine life (Carr et al 2001). They are particularly delicate ecosystems which survive within a narrow range of temperatures and salinities; with a low tolerance to change (Souter and Linden 2000). With encroaching human populations and cyclical events such as El Nino, there are a great many pressures on coral reefs (Lindahl *et al* 2001). Many developing countries rely upon reefs for income, coastal defense and as a food source (Gomez 1997). A vital part of some economies is bought in by tourism from the marine environment (Souter & Linden 2000). This has allowed a greater level of protective measures for coral reefs to be introduced (Gomez 1997).

Scleratinian corals (hard corals) have a narrow range of water temperatures for optimum growth, within 25 - 29 °C corals are able to grow and reproduce (Brown & Ogden 1993). Temperatures above this range can cause the coral to become stressed and can result in bleaching, where the coral will expel the zooxanthellae (Jones *et al* 2000). Fiji suffered a bleaching event in March-April 2000; 80% of reefs were effected (Vieux et al 2004).

Corals require clear water to allow sufficient sunlight for the algae (zooxanthellae) within the tissues to generate necessary nutrients to support coral growth (McLaughlin, C. J. *et* *al* 2003). Influx of substances from agricultural run-off, pollution or untreated sewage can damage reefs. A phase shift may occur where coral is outgrown by algae; which competes with the coral for space and light (McManus & Polsenberg 2004). This change can occur quickly and result in a sudden drop in productivity in the form of fish and invertebrate populations (McManus & Polsenberg 2004). Changes in fisheries can have impacts on local human populations dependent on the reef for income (Koop *et al* 2001).

Other negative impacts on coral reefs include sedimentation, which reduces light levels in addition to preventing recruitment of new corals by smothering the rocky surfaces required for settlement (McLaughlin *et al* 2003). Furthermore, over-fishing or overexploitation of the reef resources can cause problems within trophic levels which have strong implications for the entire ecosystem. Top down fishing of large predatory fish from a reef community has a cascade effect resulting in colonization by benthic algae and consequently a reduction in hard coral cover. This can result in an increased number of herbivore fish which feed on the algae and normally are kept in check by the predatory fish species (Dulvy *et al* 2004). Removal of key herbivores, such as parrot fish, can result in overgrowth of macroalgae due to the reduced herbivores herbivorysMcManus & Polsenberg 2004).

1.2 Marine Management

Marine protected areas have nave been implemented in many coastal areas to protect regions of threatened species and habitats; ensuring they are not degraded by human influences (Botsford *et al* 2003). They are also used as a management tool to protect areas of high biodiversity and value and to support the structure and functioning of the wider marine ecosystem (Sala *et al* 1993). Marine protected areas which have involved the community from inception have been shown to be very successful (Russ & Alcala 1999). Fiji has embraced the concept of marine protected areas and has developed various methods to implement them.

The Locally Managed Marine Area network Fiji (LMMA) has taken management back to the community with the setup of a network of reserves that are administered by the local community. These reserves are established with the help of partner research organizations to provide research expertise and knowledge in the form of training and workshops in the manner of adaptive management.

The foundation of the Customary Marine Tenure Act is the traditional *Qoliqoli* method of marine management whereby all the waters from the mean high tide line out to the reef wall edge are under the authority of the regions chief (Veitayaki *et al* 1995). This traditional method of management when supported by the Fijian government has been proved successful in protecting the fishing stocks and improving local fish stocks and reef health (Veitayaki *et al* 2003).

2. Area Description

Gau is part of the Lomai'Viti chain of islands and is situated 90 km east of Fiji's capital Suva, on the island of Viti Levu. Figure 1 shows a map of Gau, which is composed of a variety of terrestrial and coastal ecosystems for example rainforests, grasslands, mangroves and coral reefs (Veitayaki *et al* 1995). The island of Gau has little coastal development (Veitayaki *et al* 1995). On the western side of Gau, a barrier reef extends northwards from the southern tip, approximately two thirds of the way north of the island. Between the barrier reef and the land there is a deep lagoon, with fringing reefs also extending up the western coastline. The islands remoteness means that there is little tourism with a currently unoccupied resort at Nukuyaweni representing the only development on the island.

Figure 1: Map of Gau Island

2.1 Integrated Coastal Management of Gau

All the lagoonal waters on Gau come under the jurisdiction of the High Chief and the *mataqali*. Gau's chief allows no commercial fishing within its waters for non-residents of Gau. However there were concerns within the community for the islands fish stocks and coral reef health (Veitayaki personal communication).

With the assistance of partner organizations such as the International Ocean Institute – Pacific Islands (IOI-PI) and World Wildlife Fund (WWF) Fiji, Gau has become part of the Locally-Managed Marine Area (LMMA) network in Fiji (Veitayaki *et al* 1995). Gau's communities have adopted the LMMA with all of the islands coastal communities declaring at least one no-take zone. These protected areas were established with the intention of improving fish stocks by providing a refuge and to allow recovery of local reefs through seeding. Frontier-Fiji was requested to join the various agencies to provide research on the state of the coral reefs of Gau in order to develop the management of the island's resources.

2.2 Rationale of the Program

For this paper we wanted to investigate the potential success of marine protected areas on Gau. It was decided to choose three regions which had MPA's for different periods of time. We then took data from phases 064(2006) and 074(2007) which would give us an indication of changes in each ecosystem health over a period of one year, each monitoring period was completed at the same time; October to November. None of the specific transects that we analyzed data from were in the MPA's for each region, however it was felt that the protected areas should contribute to the overall health of the ecosystem in each area. The regions of Nawaikama, Somosomo and Nukuyaweni where chosen, each of these have protected areas of seven, three and two years respectively. Three full transects were chosen from each site per monitoring phase to compare changes. A transect covers a distance of 45 m running along the contours of the reef at a constant depth. Depth ranges covered are 10-12m (reef bottom) and 6-8m (reef slope).

Each variable which was chosen to be monitored was important in understanding the health of the ecosystem. The coral percentage cover and diversity were recorded; this is the most important aspect of estimating health of the reef areas. Hard corals are the architecture of the ecosystem; they support huge levels of biomass of fish species as well as large numbers of invertebrates. Combining hard coral coverage with algae coverage from each region allows the investigation of changes in phase shifts from coral to algae which have severe effects on biodiversity thus fisheries. The main reason for developing MPA’s in each region was to improve fish stocks for the adjacent villages. To analyse this we used data collected on invertebrate number, fish biomass, biodiversity and trophic group. These are all vital components of monitoring fish stocks hence if the marine protected areas are providing protection for important species.

3. Objectives for investigating the impact of marine protected areas on ecosystem health

The main purpose of this study was to observe coral reef health in regard to the effect of the marine protected area. Previous studies have shown MPA´s can positively influence adjacent ecosystems (Walters *et al* 1999).

Prior to the study it was expected that regions should show a significant difference in fisheries as well as better overall reef health over a period of one year. Regions which have had protected areas for the longer periods would be expected to have improved reef ecosystems which would include components such as increased biomass and biodiversity in fisheries, larger numbers of invertebrates, greater percentage hard coral cover and lower algae cover. As such it was expected to see Nawaikama to have the most recovered ecosystems with greatest fish biomass and biodiversity, Somosomo should show the second greatest reef health. Lastly Nukuyaweni which has held a marine protected area for 2 years would show the lowest levels of hard coral cover and fishery health.

3.1 Methodology

All data was collected using the Baseline Survey Protocol (BSP) which provides information on benthic coverage, fish data, invertebrate species and environmental conditions of the site. It allows many aspects of the marine environment to be documented and used to determine whether there is any relationship within this environment. These relationships can provide potential explanations for reef health status. Three transects were monitored from each site per phase; each transect was surveyed at two separate depths 6-8m and 10-12m. It was found to be difficult to monitor specific transects per phase due to the nature of the monitoring completed in the past.

Therefore on occasions transects were chosen in close proximity to each other. Monitoring was completed using a four man diving baseline survey team; each person held a specific role in surveying the reef. To fully survey one transect, a team completed a survey within 1-2 hours using 1 tank.

3.2 Materials

The four surveyors monitored different aspects such as physical, fish, substrate, algae and invertebrates. The Physical surveyor recorded the physical and environmental factors. This surveyor took a campus bearing and placed a tape measure transect along a given depth contour, parallel to the shore. Environmental factors were recorded including depth, temperature and visibility at 0 m, 20 m, 25 m, and 45 m. The fish surveyor monitored the size and frequency of fish encountered along the transect in a hypothetical 5 m^3 box extending 2.5 m either side of the tape measure and 5 m above it. The size of any fish entering this space was estimated to the nearest 5 cm. Fish surveyed were limited to 18 families, belonging to six trophic groups. The Benthic surveyor noted the benthic substratum which is found directly underneath the 1 transect and recorded the length against the tape measure (in cms) of each new substrate or coral genera. Additionally the surveyor was trained to identify hard coral and soft coral to genus level so that a measure of biodiversity at sites could be taken. The algae and invertebrate surveyor investigated invertebrates within a 5 m wide corridor above the transect.

Any invertebrate was recorded to genus or family level, with some notable indicators as exceptions being recorded to species level. Such as those which are protected and particular organisms which are indicators of over fishing or low reef health.

3.3 Data Analysis

All data analysis was carried out using Microsoft Excel 2003 and Past version 1.91 (2009). Fish abundances were converted to biomass (kg) using published length weight relationships from FishBase (Froese and Pauly 2004) using the following equation:

$$W = bL^{b}$$

Where *W* is fish biomass (kg), *L* is the length of fish and *b* a published allometric scaling value specific to each species (Froese and Pauly 2004).

The Shanon-Weiner diversity index (*H'*) was used to calculate fish diversity each transects. The following equation was used with biomass of each species encountered on each transect.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where p_i (the proportional abundance of the *i*th species) = n_i/N; *N* being the total number of fish caught and n_i the number of individuals in species *i*. *S* is the total number of species caught.

To determine whether there was significant difference analysis of variance was used with replication (ANOVA) using phase and region as factors. This is a suitable statistical test when there are more than two independent ways of assigning the observations into groups and there is more than one observation per factor combination. In specific sections ANOVA one factor was used. Because of the form of the invertebrate data it was