COMPONENT 2B - Project 2B1

Setting up of pilot sites (Fiji and Tuvalu)

CRISP

Coral Reef Initiative for the South Pacific

Initiative Corail pour le Pacifique Sud

December 2006

MONITORING REPORT

MOTORIKI RESTORATION SITE (FIJI)

SPI INFRA

FSPI

PARTNERS IN COMMUNITY DEVELOPMENT FIJI

CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

SPREP/PROE

The CRISP programme is implemented as part of the policy developped by the Secretariat of the Pacific Regional Environment Programme for a contribution to conservation and sustainable development of coral reefs in the Pacific

The Initiative for the Protection and Management of Coral Reefs in the Pacific (CRISP), sponsored by France and prepared by the French Development Agency (AFD) as part of an inter-ministerial project from 2002 onwards, aims to develop a vision for the future of these unique eco-systems and the communities that depend on them and to introduce strategies and projects to conserve their biodiversity, while developing the economic and environmental services that they provide both locally and globally. Also, it is designed as a factor for integration between developed countries (Australia, New Zealand, Japan, USA), French overseas territories and Pacific Island developing countries.

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Component 1A: Integrated Coastal Management and watershed management
- 1A1: Marine biodiversity conservation planning
- 1A2: Marine Protected Areas
- 1A3: Institutional strengthening and networking
- 1A4: Integrated coastal reef zone and watershed management

Component 2: Development of Coral Ecosystems
- 2A: Knowledge, beneficial use and management of coral ecosytems
- 2B: Reef rehabilitation
- 2C: Development of active marine substances
- 2D: Development of regional data base (ReefBase Pacific)

Component 3: Programme Coordination and Development
- 3A: Capitalisation, value-adding and extension of CRISP Programme activities
- 3B: Coordination, promotion and development of CRISP Programme

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COMPONENT 2B
REEF REHABILITATION

■ **PROJET 2B-1 :**
Implementation of pilot sites (Fiji and Tuvalu)
■ **PROJET 2B-2:**
Edition of a Reef Restoration manual

CRISP COMPONENT 2B is funded by the following agency :

CORAL REEF INITIATIVE FOR THE SOUTH PACIFIC

MONITORING REPORT ON RESTORATION WORK

1, 3, 6, and 9 months surveys

Moturiki District, Fiji Islands

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1 Introduction

The background details of the restoration experiment including the initial establishment of the trials conducted at Moturiki are included in an earlier report (Job et al, 2005). The aim of the project was to test low cost restoration methods for use in shallow low-energy reef areas, with an emphasis on local community involvement.

A map showing the main physical features of the study area that are referred to in the text is shown in Figure 1.

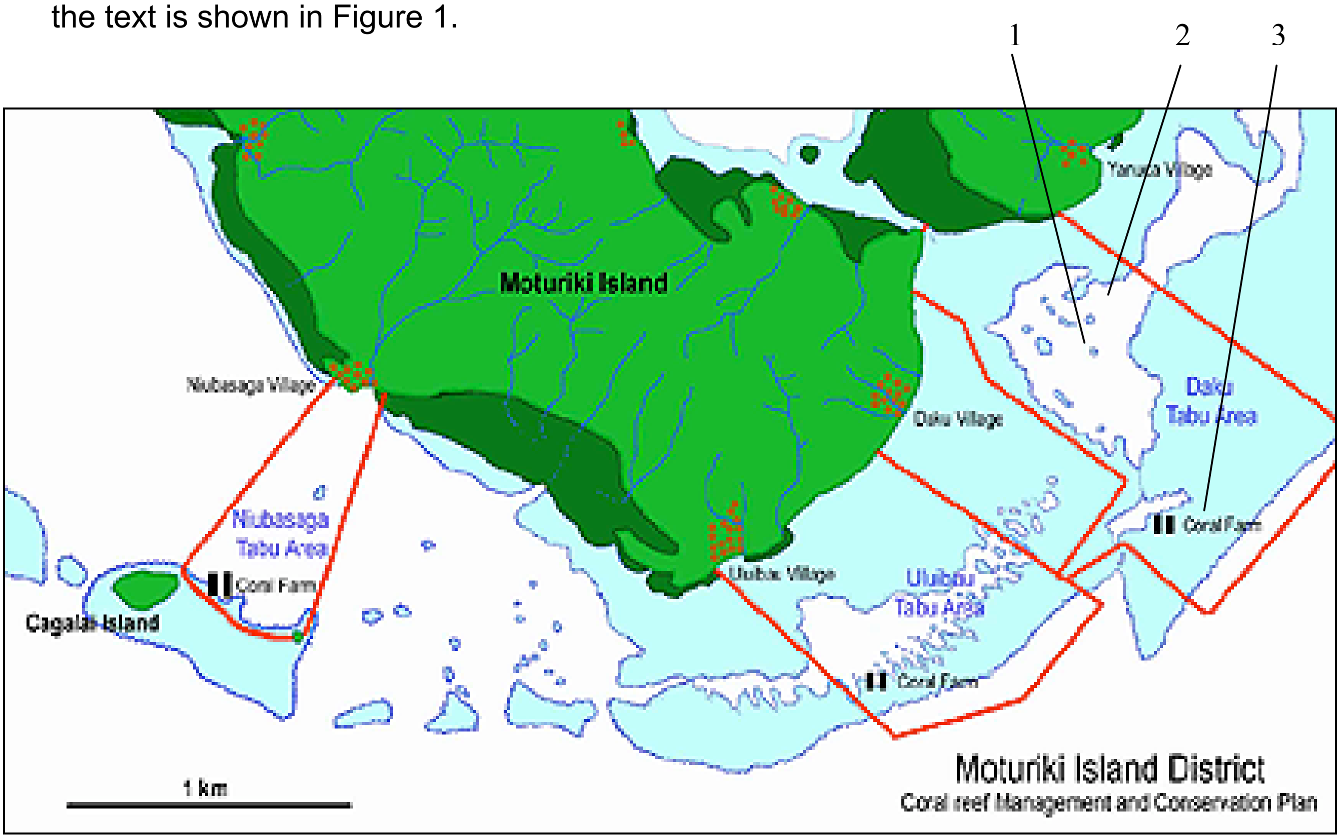


Figure 1**. Map showing main features of the study area. Line #1 indicates the restoration reef (Ucuiledi Reef); Line #2 indicates the control reef; and Line #3 indicates the main donor site. Some farmed corals set in concrete bases were also transplanted from the Coral Farm on Cagalei Island (LHS of map).**

Corals are quite fragile and highly sensitive to environmental extremes and changes. Based on previous studies, we expected the transplanted colonies to show some initial stress during the first few weeks after transplantation. This stress might be related to changes in environmental conditions between donor and transplantation sites (water quality, hydrodynamics, light, etc.), or to transplantation itself (breakage or abrasion while handling the colonies, drying, etc.). The initial site assessment recorded a few sizable coral colonies present on the experimental reef (50+ years old), indicating good potential for long-term survival of corals at the site. However, the Ucuiledi Reef experimental site (referred to in the following text as the restoration reef) is somewhat different from the original environment of the coral transplants, particularly in terms of water flow and water clarity, and potentially in terms of salinity and temperature regimes as well. Regular monitoring will help determine whether or not this new environment is adequate for the healthy growth of the transplanted corals, while helping to identify the possible impact of any seasonal or episodic affects, such as temperature and salinity extremes, or possible problems with disease and predation.

During the period between the 6-month and 9-month monitoring periods, a massive mortality of transplanted colonies occurred that meant the remaining projected project activities were terminated early. A brief discussion of a number of possible follow up on minor projects is included in Appendix 1 at the end of the report. These suggestions of additional activities for the remainder of the allocated time and resources left in this project are intended to be used as a basis for discussion with the community only.

1.1 Objectives of monitoring activities

Monitoring of changes over time in coral cover and health and fish abundance between restoration and control plots should allow an objective assessment of the efficiency and effectiveness of the restoration methods used in this study, and will provide lessons to improve procedures in future projects.

The objectives of the monitoring activities in this project are to:

- Assess the adaptability of the transplanted corals to the new environment,
- Assess the efficiency and suitability of the transplant methods used in this project,
- Record mortality, health, stability, and self-attachment of the transplants in the new environment,
- Monitor fish and invertebrate recruitment by comparing trends in restored and non-restored reef plots,
- Undertake maintenance of plot markers, and
- Undertake maintenance on transplanted corals to ensure their maximum potential for survival.

2 Monitoring methodology

The main objective of the study was to determine whether transplanting corals into a degraded reef area would allow fish to come back on the restored site. The monitoring design also included an assessment of coral transplant survival, mortality and partial mortality, incidence of disease or bleaching, colony stability, and basal overgrowth onto the new substratum (self-attachment). The methods are described under a number of different headings that include:

- Timing of monitoring periods;
- Substrate composition and cover of benthic organisms;
- Health and status of coral transplants;
- Changes in fish and invertebrate populations; and,
- Maintenance of plot markers and transplant colonies.

2.1 Timing

Monitoring of the restoration trial on the experimental reef and on the control reef was scheduled for every three months during the 18-month study period from the establishment date in August 2005. An additional monitoring period was conducted one month after the establishment of the experiment to identify:

- possible mortality associated with initial moving of the coral transplants (handling, air exposure, changes in light exposure, etc),
- potential methodological weaknesses, and changes that may be needed to fine tune the transplant methods.

The 1-month monitoring period also helped to ensure that the data collection methods were clearly understood and agreed upon by the scientists and field assistants at the beginning of the study, while all were present together in the field. The 3- and 6-month monitoring surveys were conducted by the FSPI/PCDF team. The 9-month monitoring was delayed by a month and was carried out with a team comprising the same staff from FSPI/PCDF/SPI Infra, but with new staff from IAS (USP) and a private consultant, Dr. Dave Fisk.

2.2 Substrate Composition and Cover of Benthic Organisms

The line-intercept transect method was used to assess substrate composition and cover of sessile benthic community of coral reef in the restoration and control plots. The coral community is characterized using life-form categories, which provide a morphological description of the reef community.

The method involves the use of a meter tape laid close to the reef contours with corals and substrata underneath the tape recorded. At each point where the benthic cover changed, the observer recorded the transition point in centimetres as well as the type of the specific substratum/coral form. Five permanent transects were surveyed at each of the restoration and control plots, with transects laid parallel to the reef edge.

Transects were 19 to 31m in length (see Table 1 for variations in length). The variation in lengths was due to the variation in plot dimensions and the permanent markers employed to relocate each transect (in this case the minimum transect length was 19.5m).

The line transect data are presented here using the variations in transect lengths, however, a standard length that would be more useful for statistical analyses can be adjusted with respect to the minimum transect length among all transects.

Table 1. **Line intercept transect lengths for each replicate and plot from the restored reef. Restored plots are A3, B4, B5; Control plots are A2, A4, B3.**

	Transect lengths in meters				
Transect	**1**	**2**	**3**	**4**	**5**
Plot A3	22.8	24	27.5	29.1	31
Plot B4	19.7	19.7	19.4	20	20.8
Plot B5	20.4	22.2	23.9	25.5	27.2
Plot A2	20	19.15	18.8	18.75	19
Plot A4	20	20.6	21	22	22.5
Plot B3	20.6	21	21	21.3	21

Benthic composition and cover was assessed during the 1-month and 6-month monitoring surveys.

2.3 Health and Status of Coral Transplants

The assessment of success of planting technique, transplant mortality and partial mortality, presence of colony attachment versus non-attachment to the substrate, incidence of bleaching or disease, and presence of predators were conducted by use of 2m wide belt transects along the same permanent transects as described above

The total surface surveyed during each monitoring period is about one third of the total restored area (see Results section, Table 6). Four surveyors in teams of two conducted the monitoring surveys, with one person directly assessing each transplant colony and then relaying the information to the other person who recorded these observations on an underwater slate.

Two broad experimental variables relating to the coral transplants were tested in this project. These are, the effect of three coral planting techniques on survivorship, and the response of different coral growth forms to transplantation.

2.4 Coral Planting Techniques

The manner in which a coral transplant is placed on the substrate can improve its acclimatization to the new environment and consequently its survival rate. Higher survival is expected if the degree of movement of the colony is minimized, thereby helping the coral to grow over and attached to the substrate, or to grow in a manner that increases stability of the colony without it being attached. The planting techniques tested in this project range from no assistance in attachment (colonies placed onto the substrate surface), to medium and high assistance in attachment (colonies placed tightly in crevices, and colonies cemented to the substrate, respectively, Table 2).

Basal attachment to the substratum is critical to the long-term survival of coral transplants from many species. Even though the experimental reef is a relatively low energy site, unattached fragments will still be vulnerable to minor displacement, resulting in abrasion or displacement into areas where healthy colony portions would be smothered by sand. Two of the transplantation methods (fragments plugged into holes and colonies placed directly onto rocky areas) were done specifically to encourage the contact of planted coral tissue with solid substrata so that the corals would have a chance to attach and grow onto the substratum. A "plug in" method was also employed to encourage colony attachment to the substratum with special care taken to choose appropriate sized holes for the transplants. Monitoring includes data on self-attachment rates and will reveal any potential differences between the various methods, species, or growth forms, establishing the efficiency of the methods used for the various coral species and growth forms. Observation of basal overgrowth and attachment will also indicate that the transplanted corals are growing and adapting to the new environment

Table 2. **Coral planting methods.**

Code	Categories	Remarks
PI	Plugged In	Planted into crevices in dead coral rocks without attachment
PO	Placed On	Planted on top of rock, rubble, or sand without attachment
C	Cemented	Planted by cementing colonies onto dead coral rocks

2.5 Coral Growth Forms

Corals species can be categorized into distinctive and functional growth forms without relying heavily on taxonomy. It is hypothesized that transplant colony survival, as well as the ability to attach and grow may be highly variable between coral species and growth forms. Coral growth form was therefore recorded as an experimental variable in order to get comparative information on differences in attachment and mortality of coral colonies relating to this factor. The different growth forms used in the survey are described in Table 3.

Table 3. **Transplanted coral growth-form categories.**

Code	Categories	Typical Genera and Species Used
ST	Staghorn	*Acropora formosa, A.aspera, etc.*
T	Table coral	*Acropora hyacinthus, A. millepora, etc.*
C	Cushion coral	*Pocillopora,* branching *Porites*, *Stylophora, Acropora digitifera*
BB	Bottle brush	*Acropora echinita* and related species

2.6 Transplant Health

Transplant health is an indicator of adaptation and transplantation success as it is recording the degree of stress the transplant is experiencing at the time of monitoring. Here, transplant health was monitored by recording the degree of complete or partial mortality of each transplanted colony in permanent belt transects, as well as the degree of bleaching that is observed on each colony.

A number of variables were used to measure the behaviour of transplanted corals to a new environment. These variables included:

- Complete transplant mortality,
- Partial mortality,
- Incidence of bleaching,
- Transplant attachment to the substratum (tissue overgrowth onto the substratum), and,
- Coral disease or tissue necrosis.

The initial data recorded for each individual on the transects was whether the transplant was alive or dead. Dead transplants (noted as "M" in the datasheet), were then assessed for probable causes of mortality, i.e., mechanical breakage, bleaching, smothering by sand, predation, etc. Additional notes were made of whether the mortality occurred some time in the past ('old mortality', coral skeleton covered with algae) or whether it was recent mortality (skeleton appearing clean or white, or lightly coated with new turf algae).

2.6.1 Partial or Complete Mortality

The degree of partial mortality was ranked into 5 categories (see Table 4), with each category corresponding to the proportion of dead surface coral tissue.

Table 4. **Partial mortality categories of coral transplants.**

Categories	Percent dead	*Remarks*
0	0%	No mortality
1	1-5%	Minor mortality
2	6-25%	Minor to moderate mortality
3	26-50%	Moderate mortality
4	51-75%	Moderate to major death
5	76-99%	Major death
M	100%	Completely dead

2.6.2 Incidence of Bleaching

The incidence of bleaching in transplant colonies was recorded each monitoring period for colonies that were present in the permanent belt transects. Bleaching is described in terms of the intensity of bleaching in the colony. These categories include slight bleaching (paler colour than usual), partial bleaching (usually only upper surfaces are white), or major bleaching (complete white colour).

2.7 Transplant Attachment

Obvious attachment of transplants to the substrate surface is a good indicator of colony adaptation to the new environment, as it shows that growth occurs. The attachment of coral fragments and colonies was carried out by observing the growth of new tissues onto adjacent rocky substratum. If there was no such obvious overgrowth, the surveyor waved its hands in a strong motion over the coral colony and watched for movement or instability. If the fragment was unstable during any monitoring survey, the coral was either stabilized by a rock or a piece of rubble or replanted in the immediate vicinity. Table 5 shows the attachment criteria used. Note that this is a conservative measure, as recently attached corals would likely be categorized as unattached until overgrowth is well developed.

Table 5: **Self-attachment criteria for coral fragments and colonies.**

Codes	Categories	Remarks
A	Attached	Obvious basal overgrowth visible New polyps and new tissue spreading onto the adjacent rock or cement
NA	Not Attached	Stable or unstable If unstable either stabilized *in-situ* or replanted

2.8 Changes in Fish and Invertebrate Populations

Fish visual censes were conducted along permanent belt transect lines diagonally bisecting each plot, between one inner and one outer corner stake. Belt transect dimensions varied in length from 25 to 48m, and all were 5m in width. The same two field officers carried out all the fish surveys so as to reduce the sampling bias due to different observer.

Fish counts were conducted at each monitoring period (every 3 months), while invertebrates were counted every six months due to their expected lower recruitment rates compared to fish. All 12 restoration and non-restoration plots within the restoration reef, as well as 3 plots on the control reef, were monitored for fish at each monitoring period. Invertebrates were monitored in the 3 restoration and 3 non-restoration plots on the restoration reef in addition to the same 3 plots on the control reef.

2.9 Maintenance of Plot Markers and Coral Transplants

Equipment used in the experiments such as ropes, cable ties, and metal stakes used for marking the plots and for attaching transect tapes for monitoring needed to be inspected, repaired, or replaced as required during the study. Maintenance also includes activities that are aiming to maximise the survival of the transplanted colonies. These actions are listed below:

- Maintaining the position of permanent stakes required for identification of restored and control plots, and for indicating the precise location of permanent transects,
- Replacing or realigning ropes that mark plot boundaries if they are damaged or dislodged,
- Replace old or missing cable ties used to mark the position of permanent points along the plot boundaries
- Replanting of loose coral fragments that have moved into a position where they were likely to die,
- Remove and destroy or relocate predators of corals, including crown of thorns *Acanthaster planci* starfish, *Drupella* snails, and *Culcita* sea stars, and
- Cleaning of plots and transplanted corals of any rubbish or loose seaweed.

3 Results

The monitoring data on growth form, mortality, partial mortality and attachment are based on quantitative data collected in the restored plots within 5 permanent belt transects per plot. This data represents a sub-sample of one third of the total surface area of the restoration plots (Table 6).

Table 6. **Surface area (m^2) surveyed within each restoration plot.**

Plot	Total surface area per plot	Surface surveyed per belt transects	Percentage of plots surveyed
A3	805.35	262.8	32.6 %
B4	654.82	199.2	30.4 %
B5	685.38	238.2	34.8 %

The figure below represents a schematic view of monitoring methodology that was used for the survey.

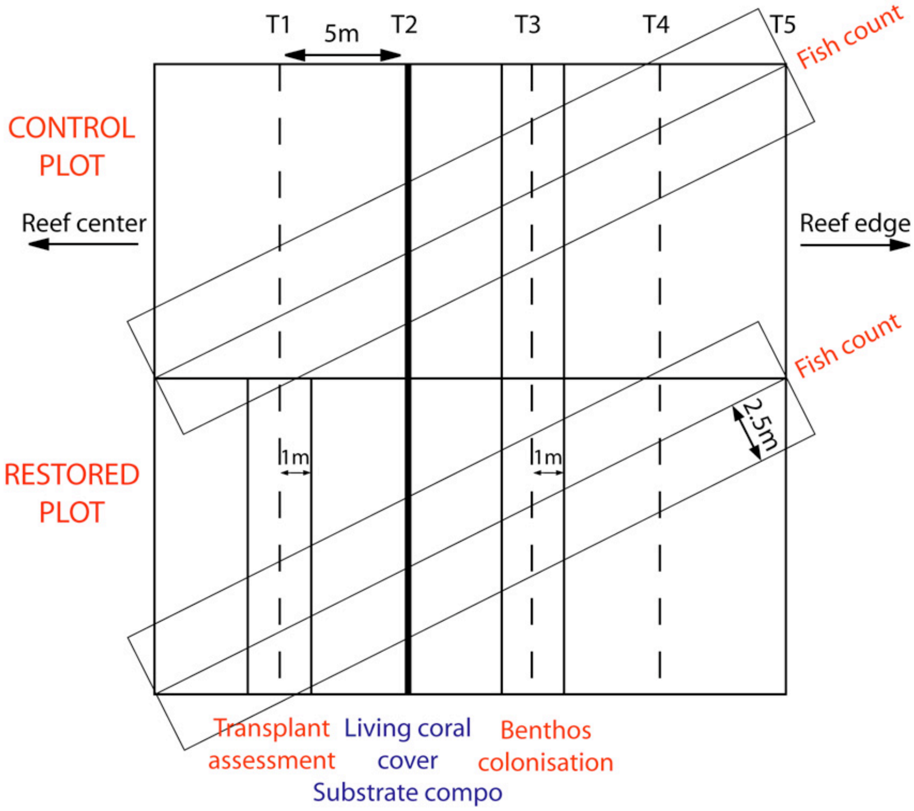


Figure 2. **Methodology used to monitor the effect of restoration action through time, on restored and control plots.**

3.1 Substrate composition and cover of benthic organisms

The changes in composition of the substrate was recorded at 1-month and 6-month monitoring periods only for the three restored plots (plots A3, B4, B5) (Figure 2). Percent cover of rubble and sand showed large increases in plots A3 and B4 (rubble) and in plot B5 (sand). Cover of dead coral with algae on the skeleton remained low in the three plots for both monitoring periods, yet the cover of live coral generally decreased by a high amount between the 1-month and the 6-month census. Planted live coral (compared to wild or natural coral cover) appears to have shown the greatest reduction in cover in the 6-month census (Plot A3 : 12.8% to 4.9%; Plot B4 : 10.8% to 6%; and Plot B5 : 13.4% to 4.9%).

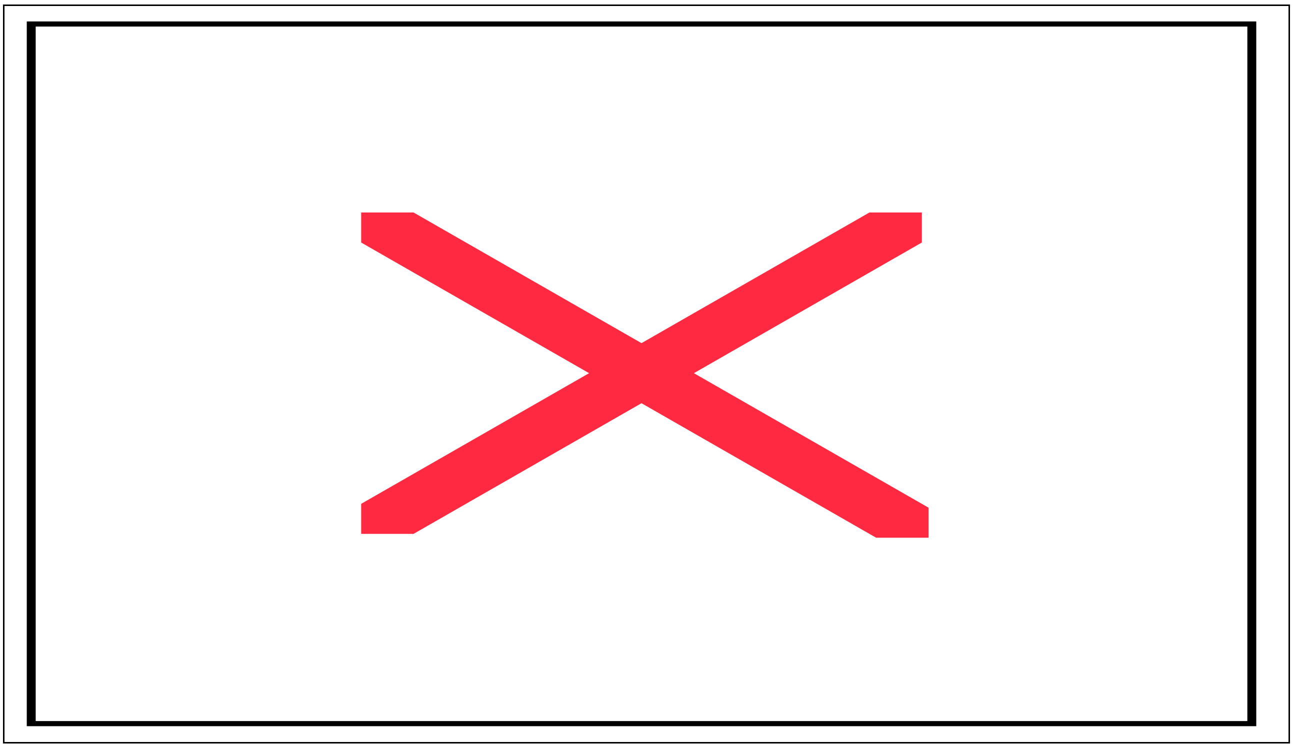


Figure 3. **Percent cover of substrate composition at the restoration plots at 1-month following transplantation, and at the 6-month census. Plot ID's refer to the plot name and initial census at the 1-month monitoring period and at the 6-month period. Key to substrate and benthic codes : RCK = Rock, RB = Rubble, S = Sand, DCA = Dead coral with algae, WC = Wild (or natural) live coral, PC = Planted live coral, SP = Sponge, SC = Soft coral, ZO = Zoanthid, AM = Anemone, MA = Macro algae, CR = Coral recruit.**

3.2 Mortality and partial mortality

Table 7 below presents a summary of the data on transplanted colony mortality and partial mortality as determined by the 1-, 3-, 6- and 9-month monitoring and Figure 3 shows the mortality graph of data from Table 7.

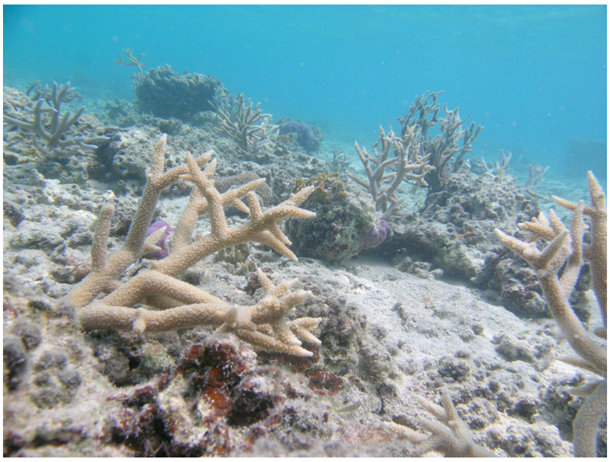
	Partial mortality rate	**Number of colonies**			**Percentage of colonies**			
Data Code	**1-Month**	**A3**	**B4**	**B5**	**A3**	**B4**	**B5**	**Mean**
0	0%	85	95	77	*51.2*	*60.1*	*56.2*	***55.8***
1	1 - 5 %	50	43	35	*30.1*	*27.2*	*25.5*	***27.6***
2	6 - 25 %	17	13	18	*10.2*	*8.2*	*13.1*	***10.5***
3	26 - 50 %	8	5	6	*4.8*	*3.2*	*4.4*	***4.1***
4	51 - 75 %	1	2	1	*0.6*	*1.3*	*0.7*	***0.9***
5	76 - 99 %	2	0	0	*1.2*	*0.0*	*0.0*	***0.4***
M	100%	3	0	0	*1.8*	*0.0*	*00*	***0.6***
Total		166	158	137	*100*	*100*	*100*	***100***
	3-Month							
0	0%	102	90	88	*58.3*	*57.3*	*59.5*	***58.4***
1	1 - 5 %	29	47	37	*16.6*	*29.9*	*25.0*	***23.8***
2	6 - 25 %	26	14	17	*14.9*	*8.9*	*11.5*	***11.8***
3	26 - 50 %	14	3	5	*8.0*	*1.9*	*3.4*	***4.4***
4	51 - 75 %	4	2	1	*2.3*	*1.3*	*0.7*	***1.4***
5	76 - 99 %	0	1	0	*0.0*	*0.6*	*0.0*	***0.2***
M	100%	0	0	0	*0.0*	*0.0*	*0.0*	***0.0***
Total		175	157	148	*100*	*100*	*100*	***100***
	6-Month							
0	0%	122	104	56	*56.6*	*58.8*	*49.6*	***55.1***
1	1 - 5 %	63	42	37	*29.7*	*23.7*	*32.7*	***28.6***
2	6 - 25 %	13	14	10	*6.1*	*7.9*	*8.8*	***7.6***
3	26 - 50 %	8	7	6	*3.8*	*4.0*	*5.3*	***4.3***
4	51 - 75 %	2	6	3	*0.9*	*3.4*	*2.7*	***2.3***
5	76 - 99 %	3	2	0	*1.4*	*1.1*	*0.0*	***0.8***
M	100%	3	2	1	*1.4*	*1.1*	*0.9*	***1.1***
Total		212	177	113	*100*	*100*	*100*	***100***
	9-Month							
0	0%	7	3	4	3.9	1.8	2.5	**2.7**
1	1 - 5 %	4	3	3	2.2	1.8	1.9	**2.0**
2	6 - 25 %	4	4	3	2.2	2.4	1.9	**2.2**
3	26 - 50 %	1	8	2	0.6	4.8	1.3	**2.2**
4	51 - 75 %	5	0	2	2.8	0	1.3	**1.4**
5	76 - 99 %	39	21	15	21.8	12.5	9.5	**14.6**
M	100%	119	129	129	66.5	76.8	81.6	**75.0**
Total		**179**	**168**	**158**	**100**	**100**	**100**	100

Table 7. **Partial mortality rate of transplanted coral colonies.**

One month after the initial transplantation, the mortality rate for the transplanted corals was only 0.6 % (3 colonies), and no additional dead colonies were found in the restored plots at the 3-month monitoring. The original dead colonies were not recorded again, as they were either buried in the sand, covered with seaweeds, displaced by fish, or incorporated into the rubble. Complete mortality rates for the 6-month monitoring period was 1.1%. More than 80% of the transplanted colonies were in very good health after the first month post-transplantation (defined as having less than 5% of their living tissue surface dead), this percentage being similar for the 3- and 6-month surveys. These results were suggesting that transplanted corals were adapting well to their new environment.

In the 1-, 3-, and 6-month monitoring periods, a more or less constant proportion of colonies had medium levels of partial mortality (i.e. with 6 to 50% of the tissue surface dead). That is, for the 1-, 3-, and 6-month periods, the proportion of colonies with medium partial mortality was 14.6%, 16.2%, and 11.9%, respectively. It is important to note that this initial partial mortality data is not only the result of handling and initial stress, but is in part a record of dead colony portions present at the start of the experiment, as several of the corals were partially dead due to exposure, predation, or overgrowth at the time of collection and transplantation. As shown on the histogram (Figure 3), data on mortality and partial mortality did not vary greatly between the 1-, 3-, and 6-month monitoring periods. As the monitoring design meant that more or less the same colonies were re-surveyed each period, an approximate similar result for mortality and partial mortality rates in the first three monitoring periods indicates that the initial transplantation was relatively successful after an initial reaction of colonies to transplantation.

After 9 months, 75% of the transplanted colonies were completely dead, about 20% were severely damaged, while the remaining 5% seemed to have resisted to heat stress.



Transplanted colonies "placed on" (picture 1) and "plugged in" (picture 2) in good health (1 mo survey)

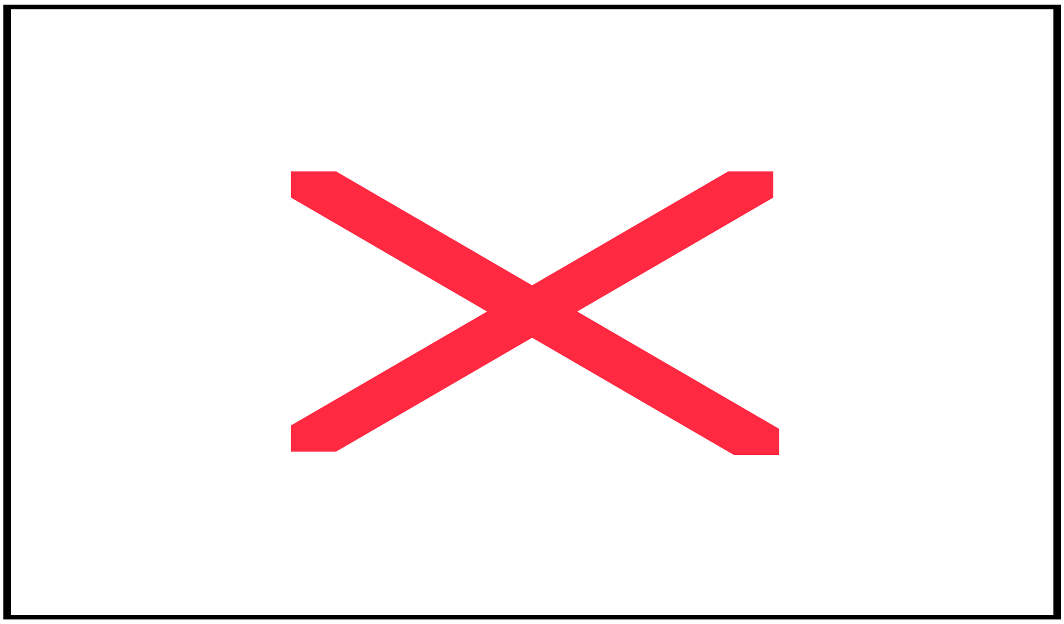


Figure 4. **Partial mortality (% of dead tissue) and complete mortality rates for transplanted corals for the first 9 months of monitoring. Data are pooled for the three restoration plots from permanent belt transects.**

Figure 3 (above) shows that most partial mortality rates were more or less similar for the first 6 months but were strongly skewed towards the total mortality category in the 9 month monitoring period. The graph also illustrates the relatively similar proportions of each of the partial mortality codes among the 3 restoration plots for each census period other than the 9 month period. This suggests that there was a similar response of all the transplants to relocation and that the plots probably did not differ substantially in terms of localised environmental conditions.

Additionally, at 9 month survey, alive natural colonies were counted in order to have an idea of the resilience of natural reef compare to the restored one (Table 8). It is worthwhile noting that some alive natural recruits (referred as being colonies from 1 to 5 cm long or diameter depending on growth form) and adult colonies were counted on the restored surface areas and were predominately in good conditions (more than 95% of natural colonies did not show any sign of degradation, whereas the remaining colonies showed minor mortality). Most of the alive natural colonies were massive and sub-massive growth forms, whereas almost all alive coral recruits were from the genus *Acropora*.

Growth forms	A3	B4	B5
Adult bottle-brush	8		
Adult cushion	2	4	
Adult massive	10	6	4
Adult encrusting			2
Coral recruits	5	12	3

Table 8. **Total number of natural colonies per restored plots**

3.3 Transplant attachment to the substratum

Table 9 presents data on attachment rates of transplanted colonies, recorded as tissue overgrowth onto rocky substratum. Coral colonies placed on fine rubble and sand (19.7% of colonies) are not expected to attach, however they are expected to become increasingly stable over time.

Table 9. **Proportion of transplanted coral colonies attached to the substratum.**

	Restored Plots			Mean
One Month Data	**A3**	**B4**	**B5**	
Number of attached colonies	43	61	16	40
Number of unattached colonies	123	97	121	113.7
% attached colonies	*25.9*	*38.6*	*11.7*	*25.4*
% unattached colonies	*74.1*	*61.4*	*88.3*	*74.6*
Three Month Data				
Number of attached colonies	84	77	47	69.3
Number of unattached colonies	91	80	101	90.7
% attached colonies	*48.0*	*49.0*	*31.8*	*42.9*
% unattached colonies	*52.0*	*51.0*	*68.2*	*57.1*
Six Month Data				
Number of attached colonies	131	80	73	94.7
Number of unattached colonies	83	97	40	73.3
% attached colonies	*61.2*	*45.2*	*64.6*	*57*
% unattached colonies	*38.6*	*54.8*	*35.4*	*43*
Nine Month Data				
Number of attached colonies	96	82	67	81.7
Number of unattached colonies	83	74	100	85.7
% attached colonies	*53.6*	*52.6*	*40*	*48.7*
% unattached colonies	*46.4*	*47.4*	*60*	*51.3*

One month after their transplantation, one quarter of the colonies were already attached to the substratum, producing some living tissue and skeletal material at the base of the transplant and overgrowing the hard substratum at points of contact (Figure 4).

Three month after transplantation, almost half (43%) of the transplants showed tissue expansion on to the adjacent rocky substrate, nearly doubling the attachment rate from the 1-month period (25%, Figure 4). Attachment rates only increased slightly by the 6-month period (57% of colonies attached).

These initial results suggested that the environmental conditions have been favourable for coral growth and that the transplanted colonies have recovered well from the initial stress of being transplanted. However there was a fairly high degree of attachment variability among the three plots, assumed to be related to differences in the substratum characteristics.

Of the transplants attached to and overgrowing the substratum, those cemented to dead reef rock were the most rapid to overgrow the substratum: 88.9% of cemented colonies showed considerable overgrowth after one month (Table 10). This result was expected due to the stability of the transplant, allowing for quicker tissue expansion. Transplants that were fixed using the two other methods (plugging in or placed on) were in the process of attaching themselves, with 20% strongly attached after one month.

After 3 months the strong overgrowth of cemented colonies decreased from 88.9% at the 1-month period to 57.4% (Table 10). It is thought that cemented colonies may be highly vulnerable to coral predators and grazers. Cemented colonies were sometimes eaten, damaged, or broken away by parrotfish and perhaps damselfish and butterfly fish. By the 9-month period all cemented colonies that remained alive were firmly attached.

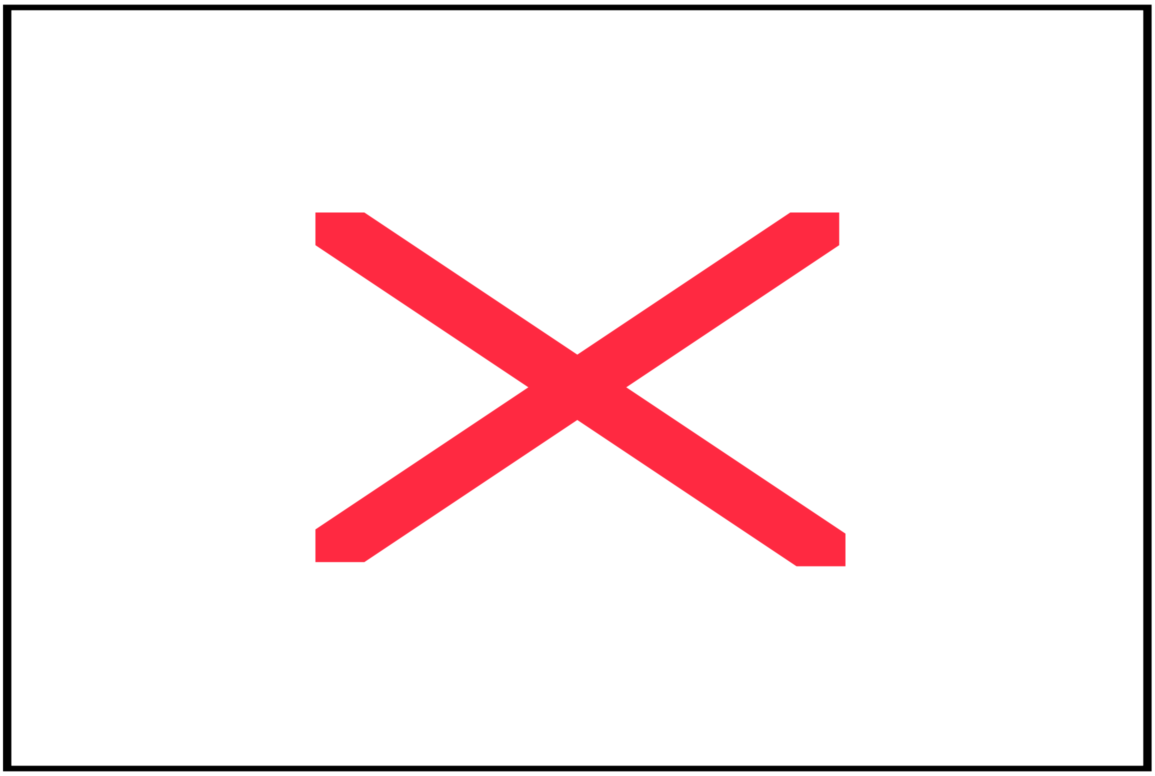


Figure 5**. Proportion of transplant colonies attached to the substratum at 1-, 3-, 6- & 9-month monitoring periods.**

Attachment rates of corals inserted into crevices more than doubled at 3 months compared to the 1-month period, i.e., from 21.1% to 46.7%. By the 6-month period, that cumulative percentage of plugged-in colonies had increased to 62.3%, highlighting the efficiency of such method of attachment (without using any kind of glue) in a low energy site. Attachment of corals placed onto the substratum increased from 20.5% to 32.9% between 1-month and 6-month periods.

At 9-month monitoring survey, 49% of colonies were recorded as attached, a lower percentage compared to 6 month. It could be possible that transplants that were 80 – 90% attached in 6 month did not attach 100% during 6 and 9month. The number of unattached colonies was greater in 9month, simply due to the fact that dead colonies did not have living tissue at their bases to attach to the substratum.

Table 10. **Percentage of coral transplants that were attached to the substrate as a function of the planting method.**

1-Month	**A3**	**B4**	**B5**	**Mean**
Cementation	91.7%	75.0%	100.0%	88.9%
Insertion into crevices	19.8%	36.1%	7.5%	21.1%
Placement	23.3%	22.7%	15.4%	20.5%
3-Month				
Cementation	88.9%	83.3%	0.0%	57.4%
Insertion into crevices	48.9%	53.2%	37.9%	46.7%
Placement	33.3%	22.2%	16.7%	24.1%
6-Month				
Cementation	100.0%	91.7%	100.0%	97.2%
Insertion into crevices	65.0%	48.5%	73.4%	62.3%
Placement	42.6%	13.8%	42.4%	32.9%
9-Month				
Cementation	100%	100%	100%	100%
Insertion into crevices	55.4%	47%	67%	56.3%
Placement	47.1%	32%	21%	33.5%

3.4 Coral growth forms

As stated in the baseline report, transplant collection and planting efforts focused on staghorn *Acropora* species, mainly *A. Formosa* (more than 80 % of the surveyed transplants at the 1-month monitoring period were staghorn corals, Table 12). Cushion colonies (*Pocillopora*, branching *Porites*, *Stylophora,* and *A. digitifera*) are the second most dominant growth forms (11.3%). Finally, bottle-brush and table colonies represented a small amount of the transplanted corals (total of 6.5%). There were slight changes in the proportion of each growth form between the monitoring periods, attributed to differences between surveyors in categorising the different growth forms, shifts of coral fragments by currents or fish out of the belt transects, or movement of the belt transect.

Table 12. **Growth forms of the transplanted colonies.**

Growth Form	A3	B4	B5	Means for the 3 plots
1 – Month Period				
Bottle-brush colonies	1	12	1	3%
Cushion colonies	27	19	6	11.3%
Staghorn colonies	127	123	129	82.2%
Table colonies	11	4	1	3.5%
3 – Month Period				
Bottle-brush colonies	5	15	2	4.6%
Cushion colonies	37	14	8	12.3%
Staghorn colonies	132	126	138	83%
Table colonies	1	2	0	0.1%
6 – Month Period				
Bottle-brush colonies	15	24	2	7.4%
Cushion colonies	53	11	5	11.8%
Staghorn colonies	143	140	106	79.9%
Table colonies	3	2	0	0.8%
9 – Month Period				
Bottle-brush colonies	7	8	4	3.8%
Cushion colonies	13	3	8	4.7%
Staghorn colonies	144	142	154	88.3%
Table colonies	11	4	1	3.1%

3.5 Fish monitoring data

The 1-month fish monitoring results show a mean of 33 fishes per restored plot while the 3-month survey shows an increase in fish abundance within transplant plots to 39 fish. However, the initial results at three months shows that control plots have mean fish densities greater that that of the restoration plots (Table 13).

Table 13. **Comparisons of mean fish numbers in the transplant and non-transplant plots on Ucuiledi Reef, and adjacent control reef plots. All fish densities are standardised and expressed as the number per 100 m^2.**

	Reef	Plot	Mean all Fish	Mean No. Adults	Mean No. Juv.
1 month survey	Restoration Reef	R-A3	40.6	20.4	20.2
		R-B4	23.3	6.9	16.5
		R-B5	34.5	13.3	21.5
		C-A2	37.8	18.9	19
		C-A4	45.2	18.7	27
		C-B3	23.2	8.1	15.0
	Control Reef	1	66.8	25.5	41.3
		2	43.0	23.0	20.0
		3	73.3	19.6	53.7
3 month survey	Restoration Reef	R-A3	76.7	31.9	44.8
		R-B4	51.6	11.1	40.5
		R-B5	35.0	13.0	22.0
		C-A2	63.1	23.6	39.0
		C-A4	101.2	52.7	48.0
		C-B3	26.2	4.9	21.0
	Control Reef	1	142.2	23.2	118.9
		2	116.3	33.7	82.7
		3	65.2	32.6	32.6
6 month survey	Restoration Reef	R-A3	103.0	37.0	66.0
		R-B4	142.0	119.0	23.0
		R-B5	141.0	109.0	33.0
		C-A2	63.0	28.0	35.0
		C-A4	51.0	23.0	28.0
		C-B3	65.0	35.0	30.0
		C-A6	21.0	9.0	12.0
		C-A5	46.0	15.0	31.0
		C-A1	310.0	70.0	240.0
		C-B6	36.0	31.0	5.0
		C-B1	32.0	21.0	11.0
		C-B2	59.0	15.0	44.0
	Control Reef	1	111.0	73.0	38.0
		2	78.0	51.0	27.0
		3	163.0	67.0	96.0
9 month survey	Restoration Reef	R-A3	176.0	119.0	57.0
		R-B4	77.0	20.0	57.0
		R-B5	69.0	20.0	49.0
		C-A2	108.0	80.0	28.0
		C-A4	38.0	34.0	4.0
		C-B3	54.0	25.0	29.0
		C-A6	23.0	9.0	14.0
		C-A5	30.0	14.0	16.0
		C-A1	171.0	110.0	61.0
		C-B6	21.0	9.0	12.0
		C-B1	52.0	24.0	28.0
		C-B2	49.0	13.0	36.0
	Control Reef	1	96.0	49.0	47.0
		2	55.0	34.0	21.0
		3	83.0	73.0	10.0

Mean fish totals in the restored plots showed an increase till 6 months and then a decrease in 9 months, for two of the three plots (Figure 5). At the same time the three control plots on the restoration reef were quite variable (Figure 6). The control reef plots showed a general decline over the 9 month period after increasing in either the 3-month or 6-month period (Figure 7). There are a number of problems with the design of the fish surveys due to their relatively high mobility and the low sample size area used in this project, so very little can be concluded from these data. An expanded discussion of the limitations of the current monitoring design is presented in the Discussion.

On a larger scale, the total monitoring period was too short and the area surveyed was too small for conclusions to be drawn on the impact of the MPA closure to fishing. The presence of the MPA was a reason put forward in the baseline report (Job et al, 2005) as to why the extra control reef was included in the study.

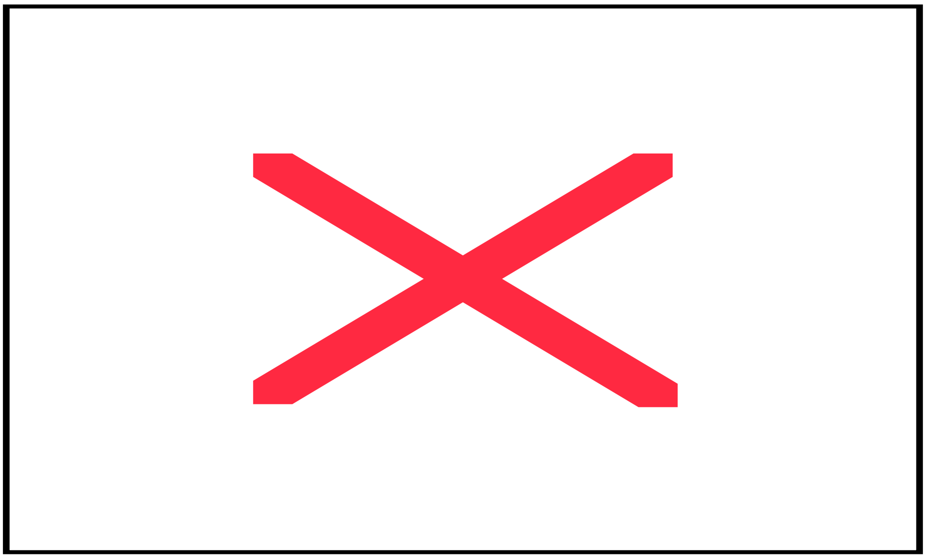


Figure 6. **Total number of fish at restored plots on the restoration reef over 9 month monitoring period.**

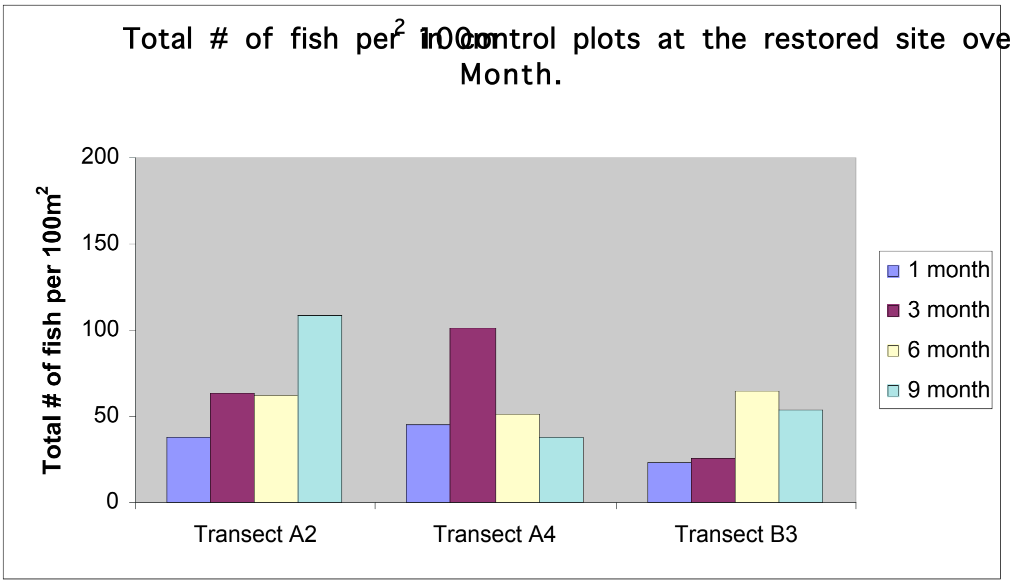


Figure 7. **Total number of fish at control plots on the restoration reef over 9 month monitoring period.**

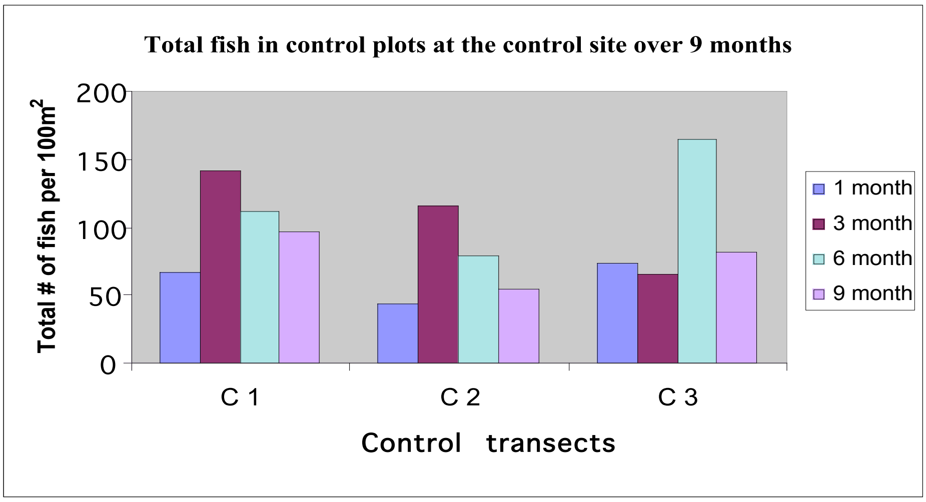


Figure 8. **Total number of fish at control reef over 9 month monitoring period**

3.6 Monitoring coral predation and disease on the restoration and control reefs

During the initial site establishment, one Crown-Of-Thorns starfish was killed from the restoration plot A1. During the one-month monitoring, a second COT was found, also in plot A1, and this was also killed.

During transplantation, coral-eating *Drupella* snails were observed on several of the corals and in the bottom of the boat, having fallen out of the coral during transport. Some of the snails were quite small. During the three-month monitoring period, a coral colony with a large recently killed white portion was observed in plot A3 and six *Drupella* snails were removed. However, *Drupella* predation was considered not to be the cause of the high mortality recorded at 9 month census though they were present in low numbers at all monitoring periods. *Stegastes* sp. damselfishes (farmer fish) were not a major problem for the corals at the restoration plots though many juveniles are present on the restoration reef.

Coral disease was seen in plot A3 on 3 coral colonies during the 1-month monitoring, all within a single 2m area and on the cushion-shaped growth form, and these corals were completely dead by the 3-month monitoring period. In Plot B5 one staghorn *Acropora* coral appeared to be diseased in the lower portions at the 1-month census, but had recovered by the 3-month census. No additional incidences of disease were recorded at the 3-month monitoring. No coral predators or disease were noted on the control reef during the initial experimental set up or subsequent monitoring visits.

A high proportion of naturally occurring colonies of *Acropora* and other genera were observed in a bleached condition in June 2006 at the restoration reef, the control reef, and on adjacent reefs. Almost all of the transplant colony remnants that were still alive in June 2006 were severely bleached as well. The small number of coral recruits at the restoration site did not generally show signs of bleaching, nor did a number of naturally occurring coral colonies from a several genera. Large branching *Acropora* spp colonies on the relatively deeper margins of the restoration reef and nearby control reef, as well as some cushion *Acropora* spp, were partially bleached (slight pale colouring or upper branches only bleached).

More patchy (selected species only showing bleaching symptoms) and less intense bleaching (i.e. corals with pale colours and/or upper colony surfaces pale) was also observed at the outer lagoon donor site. The observed bleaching was consistent with a water temperature induced stress event[1]. The observed bleaching was unexpected as it occurred in the normally cooler winter months, though sea surface temperature data from a logger stationed at Cagalei Island indicated the water

[1] Coral bleaching that is correlated with elevated sea water temperatures can vary in severity according to the time period where temperatures are maintained above local ambient levels. The bleaching effect is also caused by a synergistic interaction with high solar radiation levels (eg, when there are, clear sunny, calm conditions for an extended time period). Severe to low level bleaching is observed in corals by the degree of pale colour to the tissues and the low to high bleaching pattern in parts of a colony (eg, the relatively highest bleaching is on upper surfaces).

temperatures were above long term modelled averages for this time of the year (Figure 7). The spatial differences in the June 2006 coral bleaching distribution pattern are indicative of the likely difference in severity of such an event which may have also occurred during the intervening period between February and June 2006. That is, the mid lagoon reefs are periodically exposed to relatively more severe disturbances from elevated sea surface temperatures, than are outer lagoon and nearby offshore island reefs, as indicated by the differences in the degree of coral bleaching observed in June.

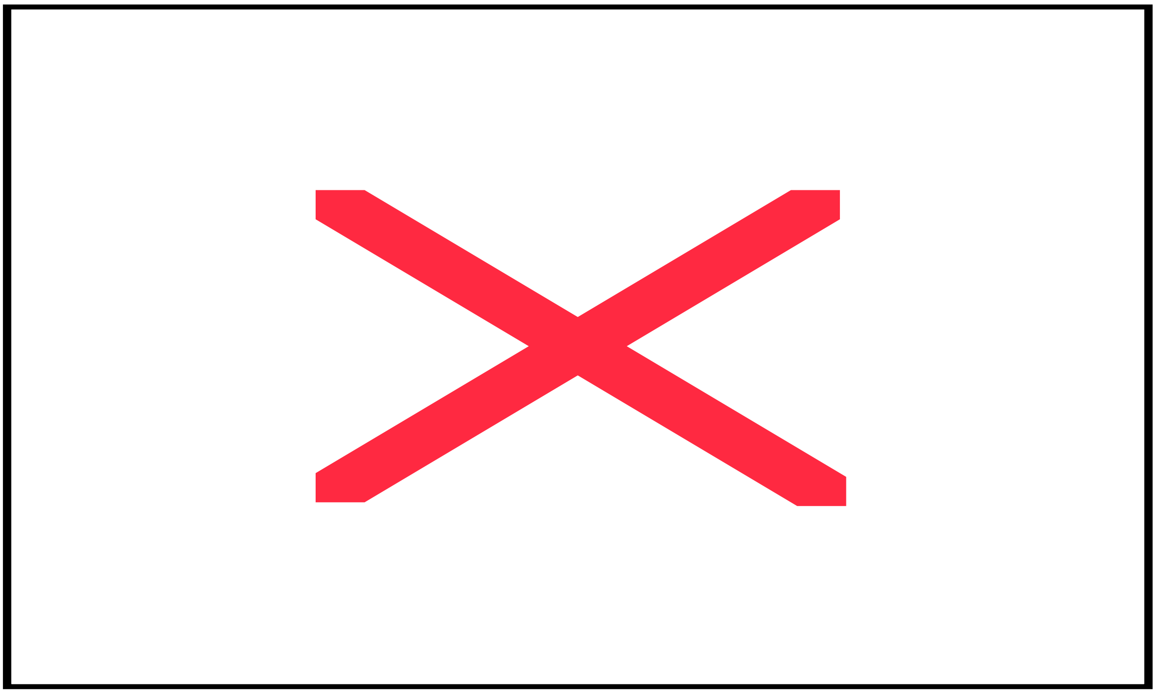


Figure 9. **Graph of daily mean sea surface temperature (SST) from a temperature logger at nearby Cagalei Island for the period of December 2005- June 2006 compared to the long term (49 yr) average of SST for Fiji for the period 1951-1999 (from modelled data by Hadley Centre Meteorological Office UK).**

3.7 Invertebrate Surveys

Counts of macro invertebrates were carried out at the 1-month and 6-month monitoring periods (Table 14) during which very little change had occurred between surveys. Most invertebrates recorded in transects were molluscs, particularly cone shells. The time period between surveys was probably too short to detect any changes in macro invertebrate fauna as many are relatively slow growing and would not be detected over a one year survey period.

Table 14. **Summary of invertebrate counts in permanent belt transects at the restoration reef for restored and control plots. Census data are for the 1-month and 6-month monitoring periods.**

	Restored Plots			**Control Plots**		
	A2	**A4**	**B3**	**A3**	**B4**	**B5**
1-month Invertebrate Survey						
Mean number of invertebrates per 100 m_	30	7	15	27	11	10
Mean number of invertebrate species per 100 m_	11	6	9	11	6	6
6-month Invertebrate Survey						
Mean number of invertebrates per 100 m_	5	25	13	16	15	17
Mean number of invertebrate species per 100 m_	4	9	6	7	7	6

4 Discussion

4.1 Adaptation of the transplants to their new environment

The very low mortality and partial mortality rates of the transplanted corals during the first 6 months of the trials strongly suggested adaptation of the transplanted corals to their new environment. If the new environmental conditions were not favourable for transplants, an increase in partial mortality and/or complete colony mortality rates would have been observed within the first few months following their transplantation. The initial positive results were noteworthy as they included the majority of the hot summer months up until the 17th February 2006. These early positive results also suggested that the transplantation methodology used during the initial fieldwork was effective and appropriate for the specific conditions at Moturiki. Despite the conditions under which corals were transported, i.e., entangled and stacked on top of one other, most of them recovered well with growth observed on the many broken branches during the first 6 months following the transplantation. As detailed below, the most commonly used method for planting in this project, i.e. plugging of fragments into holes and crevices, was effective given the limited amount of time and financial investment available to accomplish the work. Early transplantation success was probably also enhanced by the choice of a low energy site for transplantation.

The almost complete mortality of transplants that occurred some time between the 6-month and 9-month monitoring periods (between 17th February and 20th June 2006), was unexpected since the prior post-transplantation period indicated that successful restoration was quite likely to occur. The nature of the sudden high mortality suggests that an acute natural disturbance occurred sometime between the intervening monitoring periods. An inspection of nearby mid lagoon reef areas at the 9-month monitoring period, including the extra control reef, showed that possibly, similar coral mortality had occurred in the recent past as well. However, it was very difficult to compare the situation on the restoration reef to nearby reefs in the lagoon as very few coral growth forms to the transplant colonies were present on all the reefs, and in the same shallow positions within the central parts of these reefs. Corals at the donor site, located on the outer lagoon, showed some signs of similar mortality characteristics to the transplanted corals, though mortality was more limited than on the transplantation site, demonstrating that the disturbance caused more damage to the transplanted corals than the natural ones. However extensive bleaching stress was seen at Cagalai Reef (a donor site). The temperature logger data collected from Cagalai reef showed the maximum temperatures in March and April.

It may be that in contrast to the outer lagoon habitat, the middle lagoon habitat experiences significant disturbances with a longer periodicity, or that there are more extreme inter-annual environmental conditions. Reef community abundance and composition would be expected to show different responses to the differences in environmental regimes between the two habitats. That is, in a significant longer term disturbance regime, reef communities would show dramatic changes in response to those disturbances, probably in terms of species dominance. In shorter term environmental extreme conditions, mid and outer lagoon reef communities will vary in their ability to survive such regimes.

Most of the few remaining fragments or parts of transplant colonies that were alive in June 2006 were showing varying degrees of bleaching with most having major bleaching symptoms on the upper branches of the live portions of colonies only. This indicates a recent symptom of temperature and solar radiation stress that is unusual to observe at this time of the year (mid-winter). Observations of coral communities at the donor reef on the outer lagoon and at nearby Cagalei Island during the 9-month monitoring period, confirmed that a similar pattern of bleaching was occurring in the same suite of coral species (predominantly *Acropora* spp and some massive species). This indicates that a broad regional stress factor was present in this part of Fiji which is unrelated to the coral transplant mortality event.

This report includes a discussion of a number of factors which may have contributed to the observed mortality of transplant corals. In summary they are :

- Use of coral colonies for transplantation from relatively different habitats (from an outer lagoon habitat to a mid-lagoon habitat), instead of using colonies from the same habitat, which would have been most adapted to the localized conditions at the restoration reef.
- The placement of transplant colonies to the middle and shallowest part of the transplantation reef, instead of in the relatively deeper margins of the patch reef, thereby reducing the exposure of transplants to the more extreme conditions at the restoration reef.
- Placement of transplant corals without consideration of the differences in environmental conditions between the upstream (seaward) and down stream sides of the patch reef especially with respect to the area where waves and relatively nutrient richer water first arrives at the patch reef.
- The choice for transplantation of predominantly branching *Acropora* spp growth forms which were not common on the patch reef tops, and the limited use of other growth forms and genera of coral that may be more suited to the mid-lagoon habitat.
- The choice of species that would be more adapted to the turbid environment of transplantation site through a closer observation of surrounding alive patch reefs.

4.1.1 Recommendations for maximising survival of transplants

The lessons learnt from this exercise at Moturiki include a number of fundamental essential prerequisites for all coral transplant work. The prerequisites include the following:

(1) The donor and transplant sites should be in the same habitat with respect to most environmental conditions (wave, current, depth, temperature, light, and disturbance regimes);

(2) Coral growth forms used for transplanting should be adapted to the prevailing environmental conditions at the restoration site;

(3) Donor coral fragments should be from the most healthy colonies available; and,

(4) Donor colonies should represent the full range of colony growth forms that are suitable for a restoration site so as to maximise habitat diversity of the restored reef.

4.1.2 Possible environmental causes of the mass mortality of transplants

Possible explanations for the high mortality that occurred at an undetermined time period between February and June include the possible presence of:

(a) A major flood event that would result in lowered salinity and increased turbidity due to terrestrial run-offs causing mortality to shallow water organisms and to corals in particular. This is unlikely as natural recruits and corals were not affected. An alternative explanation is that the transplanted colonies were still weaker than natural ones, even 9 months after their transplantation.

(b) A major infestation of coral predators (e.g., Crown Of Thorns starfish or *Drupella* snails) that would kill the majority of corals in the mid lagoon area. This is unlikely as natural corals were still alive and as we only observed very low number of these predators within the previous visits to Moturiki reefs.

Possibilities (a) and (b) are less plausible than others based on observations by the team in June 2006. No major floods on the adjacent islands and no infestation of coral predators were reported during the period when the majority of transplant corals died (eliminating possible causes (a) and (b)).

(c) A major tremor in the vicinity that caused the release of anoxic gases and/or anoxic interstitial water that floated to the surface and caused mortality to organisms in areas where there was minimal mixing of this water with oceanic water. Only rare literature exists on this topic, it should be looked in more details.

The Moturiki area frequently experiences earth tremors that could feasibly cause the release of toxic gasses or subsurface water held in sediments. A large tremor was recorded during the period in question by the US Geological Service website on the 26th February 2006. The tremor was located 630km SSE of Fiji Islands and measured 6.4 on the Richter scale. However, no observations by local communities of unusual sea conditions have been recorded, so this possible explanation for the transplant coral mortality cannot be confirmed (possible cause (c)).

(d) A major or minor bleaching event due to abnormally high sea surface temperatures, or another unknown factor like disease, that was confined to the mid lagoon corals. This is the most likely event that occurred.

(e) A minor stress event with conditions that would cause high mortality to the transplanted corals due to their being under stress associated with their relocation from another habitat. This was probably combined with an environmental stress.

It is feasible that a minor stress event during the period between surveys could have disadvantaged the transplanted corals but not other naturally occurring similar corals. However, this is very hard to substantiate without a meaningful comparison with the same suite of species / growth forms that would have to be occurring in the same habitat and depth range as the transplanted corals (possible cause (d)).

The possibility of a stress related event which could possibly be heat induced bleaching or another unknown factor, is the only remaining explanation for the sudden mortality of the transplanted colonies (possible cause (e)). Furthermore, it appears that such a stress event was restricted to the middle (and possibly inner) lagoon areas of Moturiki[2]. The observed mortality suggests that the stress event was mainly confined to the transplanted corals, which would indicate that the transplant colonies were not as healthy as they appeared to be, and were susceptible to such levels of stress. This would be a significant finding if it can be confirmed, as it would mean that the currently used indicators for stress are not adequate for health monitoring purposes.

4.2 Coral planting methods

4.2.1 Plugged-in method

Initial observations indicate that this method works very well, especially for smaller branching coral fragments. This method is not suitable for larger colonies or massive corals. The main limitation on this method is that it greatly depends on the availability of natural holes and fissures in the rocks, so it is very site-specific. The main challenge is to find an appropriately-sized hole to tightly hold the fragment being planted, and this can be time consuming. Even so, this method takes considerably less effort than does the cementation method. Regular follow-up maintenance is needed with this method as fragments can sometimes be dislodged before they can cement themselves firmly in place. Causes of dislodgement of the coral fragments include water currents and waves, fish feeding, and small fish or crabs sheltering in the hole that push the fragment back out. In the this study, corals fragments that were dislodged were re-plugged into the dead reef rock each monitoring period, often by using a small piece of coral rubble wedged into the hole with the coral to secure the fragment more tightly. No record was kept of the amount of follow up maintenance that was required to re-establish dislodged colonies. However, it is an additional factor that should be included in calculations of the amount of effort required to establish an area of reef.

[2] Other similar lagoon areas some distance from Moturiki and the transplant site were not investigated so as to ascertain the extent of the mortality event.

The ideal planting method that resulted in very little dislodgement occurred coral fragments were plugged into small dead branching corals, particularly branching *Porites* and cushion-shaped *Acropora* colonies. Fragments planted with only dead lower portions in contact with the rock needed to be replanted during the one-month monitoring in a way that live tissue was in contact with the adjacent rock. Some of the smaller coral colonies, although remaining stable at one month, had come into contact with sand or were very close to sand patches. Any strong water movements or disturbances caused by animals would likely suspend this sand and affect these particular corals, so these corals were relocated to better locations nearby, further from the sandy bottom.

4.2.2 Plugged-in method: recommendations

(1) The plug-in method is the most efficient way to plant coral fragments with little maintenance. It is most appropriate for restoring coral reef areas dominated by dead colonies of small branching corals, assuming that natural coral larval recruitment and reef recovery is inhibited.
(2) Similar sized holes to fit the fragment should be chosen for planting fragments and to maximize their subsequent attachment to the substratum.
(3) Fragments should be stabilized or wedged in with a piece of rubble if the hole is too big for the fragment.
(4) The ability of coral fragments to self-attach to reef rock requires living tissue of the fragment to be in direct contact with the rocky substrate. To ensure that as much live tissue as possible touches the substratum, all dead portions should be broken off before planting.
(5) Identify holes and cracks for planting corals >1m from sand patches if possible, to ensure that the fragments will not be affected by the movement of sand, or will not fall into and be smothered by the sand should they become dislodged.
(6) The outer edges of coral colonies should be planted at least 50cm away from each other, so that they won't compete for space and light. Smaller fragments can be planted closer together, but consideration should be made for potential crowding effects over time. Competing corals can be trimmed and replanted at the restoration site later on, should competition become a factor, and adjustments made in planting density at future sites if this is indicated.
(7) Records should be kept of the amount of maintenance time that is required for re-plugging dislodged colonies.

4.2.3 Placed-on method

This method is only appropriate for low-energy environments, where colonies are placed on rock, rubble, or sandy rubble substrates. Here the colony weight alone is sufficient to stabilize the coral until it can either self-attach or settle into the sand substratum. Because colony weight is important, only larger cushion-shaped colonies and multi-branched staghorn colonies were planted with this method during the study. Most cushion shaped colonies and massive colonies will maintain their position on mobile substrata until a sufficiently large force moves it. However, it is unlikely that these coral forms will ever self-attach on these surfaces so their long term survival is unlikely.

4.2.4 Placed-on method: recommendations

(1) If possible, coral colonies should be positioned behind larger boulders and in depressions where they will be sheltered from expected storm current and wave directions.
(2) Coral colonies can also be positioned into rows facing the predicted current direction, so that collectively they will present less resistance to strong water motion and hopefully protecting each other during storms.
(3) Medium-sized rocks (30-40cm) can be wedged around the bases of the coral colonies, giving them something to attach to even if on sandy substrata, increasing their overall weight and stability, and providing added insurance against potential future storms.

4.2.5 Cementing method

The advantage of planting corals using cement is that it ensures the corals will be attached and therefore completely stable and protected from any sort of dislodgement, giving a better chance of survival. On the other hand, as observed at the 3-month monitoring period, this stability might also be a disadvantage in that it seems to make the corals more vulnerable to breakage from fish feeding activities, as compared to loose corals that were placed on the substratum or plugged into rocks. Cementation of farmed corals with cement bases is the most time consuming of the three methods, however it was the best planting method for the farmed corals because they were already firmly attached to the 5cm cement disks, and this prevented them from being wedged into small holes and cracks in the rock. The method was also most suitable for small table colonies and branched *Porites* and *Pocillopora* species. However, small branches of *Pocillopora* and *Porites* should be amenable to plug-in methods as well

4.2.6 Cementing method: recommendations

(1) This method should be preferentially used for any coral that cannot be easily plugged into holes and that are too small and lightweight to be placed on the substratum directly without attachment (small to medium sized rounded colonies, massive colonies, and farmed corals attached to cement disks).
(2) This method should be used in cases of coral transplantation in areas of high to moderate wave and current energy, including calm areas when the transplantation takes place just before or during the cyclone season.
(3) Extreme care should be taken while pouring the cement onto the substratum to prevent cement being poured onto other living organisms (other corals, sponge, shells, sea urchins, etc).

4.3 Monitoring surveys and design

A more detailed assessment of the monitoring design and methods employed in this project are presented in a review submitted to FSPI (Fiji) (Fisk, 2006). Only a brief summary of the major findings are given here.

The frequency and scope of monitoring surveys generally reflected the expected variations in responses of the transplant corals and their associated reef communities. Comprehensive before and after transplantation monitoring is expected to give the necessary information to judge the impact of the exercise. However, it should be decided *a priori*, what is the purpose of the monitoring, which will be framed by the overall aims of the project.

More frequent surveys concentrating on coral transplant health were conducted at the early stages following transplantation. Indicators that were showing the adaptation and health of the transplants up to and including the 6-month monitoring period included increasing numbers of colonies overgrowing and attaching to the substrate, and the lack of disease or bleaching symptoms. Additional tools that would have assisted in interpreting the mass mortality of transplants after the 6-month monitoring period include water temperature data (a temperature logger on the restoration site), and regular, careful observations on other natural phenomena in the adjacent area that could have an influence on the transplant site. A range of relevant observations should be explained to the MPA wardens in the community for this purpose. The observations should include the occurrence of dead reef organisms that do not normally occur in the area, the presence of discoloured water, unusual strong odours from the nearby water, high seas, rainfall with associated flooding and other unusual phenomena.

Monitoring methods used in this project were appropriate for some purposes, eg, data recorded from belt transects (fish, invertebrates, transplant characteristics), though the variable length of each replicate transect made it impossible to conduct reliable statistical analyses on the data. Most data were useful to follow trends over time but not for statistically assessing changes in most parameters.

The design of the experimental plots within the restoration reef is an example of an approach that was partly scientific and partly for demonstration purposes to the local community. That is, some plots were used for enhancing coral communities and others were left to develop naturally. The choice of plots for either treatment was not done principally with best or similar environmental conditions present for transplant adaptation. It would have been more appropriate to use a patch reef as a single experimental treatment replicate with a perhaps a mosaic of transplant areas within each patch reef. Unequal numbers of replicate plots for transplantation and for comparison against natural trends, made monitoring of success difficult to assess. The use of a separate reef as a comparison for natural changes in reef communities was probably appropriate if whole patch reefs were used as single experimental transplant sites, but was not necessary for the design used here ,i.e., plots within a single patch reef were used for restoration trials and other plots used for comparison with the restored plots).

That is, several patch reefs would have had to be used for transplantation to make use of a comparative naturally changing patch reef.

4.3.1 General recommendations for the monitoring surveys

(1) To avoid unnecessary coral breakage the team should be thoroughly briefed on the specific methods and handling precautions before going into the site.
(2) It is recommended that working during low tides should be avoided as this increases the chance of breaking corals close to the water surface.
(3) Care must be taken with using fins and it is recommended that those inexperienced in snorkelling must take a responsible snorkelling lesson to prevent or minimize damage on the reef. Short fins or no fins at all are recommended over long fins.
(4) It is recommended that community consultation personnel make special notes and observations of the effects of extreme rainfall and high surf events in the area, based on weather reports, or any exceptional event, and if possible have contact with the community when extreme conditions occur in order to deduce some of the positive or negative changes that might occur at the coral restoration site. These changes should be recorded on calendars and log books.
(5) Fish count transects at all experimental and control plots should be permanently marked with stakes, lines and cable ties to avoid having to deploy the transect tape each time. This approach will prevent damaging contact with the transplants and will minimise adverse fish responses to the presence of divers prior to a census.

4.3.2 Specific recommendations for monitoring surveys and design

(1) To maximise the scientific assessment of the effect of transplantation on reef communities at Moturiki, a more structured design with equal number of replicates in transplant and non-transplant sites would have to be adopted. Standardisation of replicate monitoring transect dimensions is also required for full statistical analyses of trends over time.
(2) If the aim was solely to demonstrate to the community the potential of restoring a reef (a stated claim of this project), a different approach to the one adopted here is recommended. This could include the abandonment of the use of plots and control areas (which are used for comparisons with natural changes). The approach would require transplantation to all or many of the most suitable locations and positions within a number of patch reefs within the same habitat, and by adhering to all the essential requirements for transplantation (like transplanting from within very similar habitats and with appropriate coral growth forms). This would mean that most of the monitoring techniques adopted in the Moturiki project would not be used as they are based on a treatment – control design. The monitoring protocol would be replaced by a few simple monitoring methods that would vary in different locations or patch reefs. The comparison over time would entirely be on the basis of comparisons of changes before and after the transplantation effort was completed for each site or patch reef separately (that is, data would not be pooled over sites), but by using the same monitoring format within each site.

5 References Cited

Job S, Bowden-Kerby A, Govan H, Khan Z, Nainoca F, (SPI INFRA / FSPI) (2005). Field Work Report on Restoration Work, Moturiki District, Fiji Islands. pp. 31.