CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

COMPONENT 2B
Reef Restoration Project

PROJECT C2B1
Implementation of Reef Restoration Pilot sites

February 2008

MONITORING REPORT

FUNAFUTI ATOLL
(Republic of TUVALU)
CORAL REEF RESTORATION PROJECT
1-3-6 and 9 months post-trial

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CRISP

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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.

The CRISP Programme comprises three major components, which are:

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 :

1 Background

1.1 CRISP – TANGO Coral Reef Restoration Initiative

FSPI CCP program has recognized the need of applied research and capacity building to support community based activities. FSPI has been researching the development of low-tech and low-cost coral reef restoration techniques as a viable management tool for local communities in the South Pacific region. FSPI, through its affiliates, PCDF (Partners in Community Development Fiji) and SIDT (Solomon Island Development Trust), have already conducted coral reef restoration trials in Solomons and Fiji. The former project has been established in conjunction with the Darwin Initiative; the latest project has been conducted thanks to AFD (French Agency of Development) funding, as part of the CRISP program (Coral Reef Initiative for the South Pacific). The present venture is also part of the "Reef Restoration" component of the CRISP program and aims at restoring a degrading reef in Funafuti atoll (Tuvalu), through the participation of FSPI local partner, TANGO.

1.2 Objectives and aims

The general objectives are:

- To increase communities' awareness on the importance of healthy reef habitats for sustainable fisheries.
- To assess the cost-benefits of engaging local communities to carry out low-tech reef restoration efforts.
- To demonstrate that current disturbance factors (presence of high abundances of *Stegastes* spp territorial fish, macro algae overgrowth, corallivorous gastropod infestations) are major contributors to the reduction in fringing reef fisheries biomass.

The aim of the experiment is to create a suitable juvenile fish habitat in an area that is currently low in fish and is threatened by *Drupella cornus* predation and macro algae overgrowth. It is hypothesized that *Drupella* predation cause coral necroses and mortality, which in turn provides good substrate for the growth of macro algae, leading to an algae dominated system.

The specific objective of the survey is to examine the response of the dominant branching *Acropora* to the removal of threats from *Drupella* and macro algae, in order to possibly use this technique as a reef restoration tool in areas subjected to these threats.

1.3 Study Site

Lofeagai reef is situated north of the main township island of Fongafale, Tuvalu atoll (Figure 1). T he restoration site is approximately 165 m from the lagoon side beach, with a sandy substrate habitat adjacent to the fringing reef slope. The site is located at 4-5 m depth, and is at least 30 m distant from the fringing reef slope and other scattered patch reefs on the sand.

Figure 1. Satellite image from Google Earth showing the approximate location of the four established restoration patches at Lofeagai (gold circles) and the location of the high school (gold rectangle).

2 Monitoring Methods

2.1 Monitoring aims and objectives

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.

Monitoring sessions include the following activities:

- Recording of mortality, health, stability, and self-attachment of the transplants in the new environment, in order to assess their adaptability to the new environment.
- Measurements of restored patch reefs dimensions in order to assess coral growth.
- Recording of fish and invertebrate recruitment in restored patches by comparing trends in restored and non-restored reef plots.
- Maintenance of plot markers and restored patches by removing coral threats (*Drupella* and macro-algae).

The initial baseline monitoring phase included the measurement of patch reef dimensions and live/dead coral volume assessments. The measurements involve the use of 1m length measuring rulers. Subsequent ongoing 1, 3, 6 and 9 months monitoring of the patch reefs included the live/dead coral volume measurements in addition to coral health indices and fish numbers, types, and sizes. The presence of other organisms such as macro invertebrates within the patches are also to be recorded.

The pictures in Figure 2 illustrate some of the measurements that are being made as part of the monitoring activities.

2.2 Coral transplants monitoring

The condition of coral transplants is monitored using the following indices:

- Growth index: indicated by the increase in volume of live coral within each transplanted patch reef.
- Coral mortality index: indicated by the volume of dead coral within each transplanted patch reef and incidence of bleaching or diseases.
- Disturbance index: indicated by incidences of predation by *Drupella* spp, Crown Of Thorns starfishes (COTS), or macro-algae overgrowth.

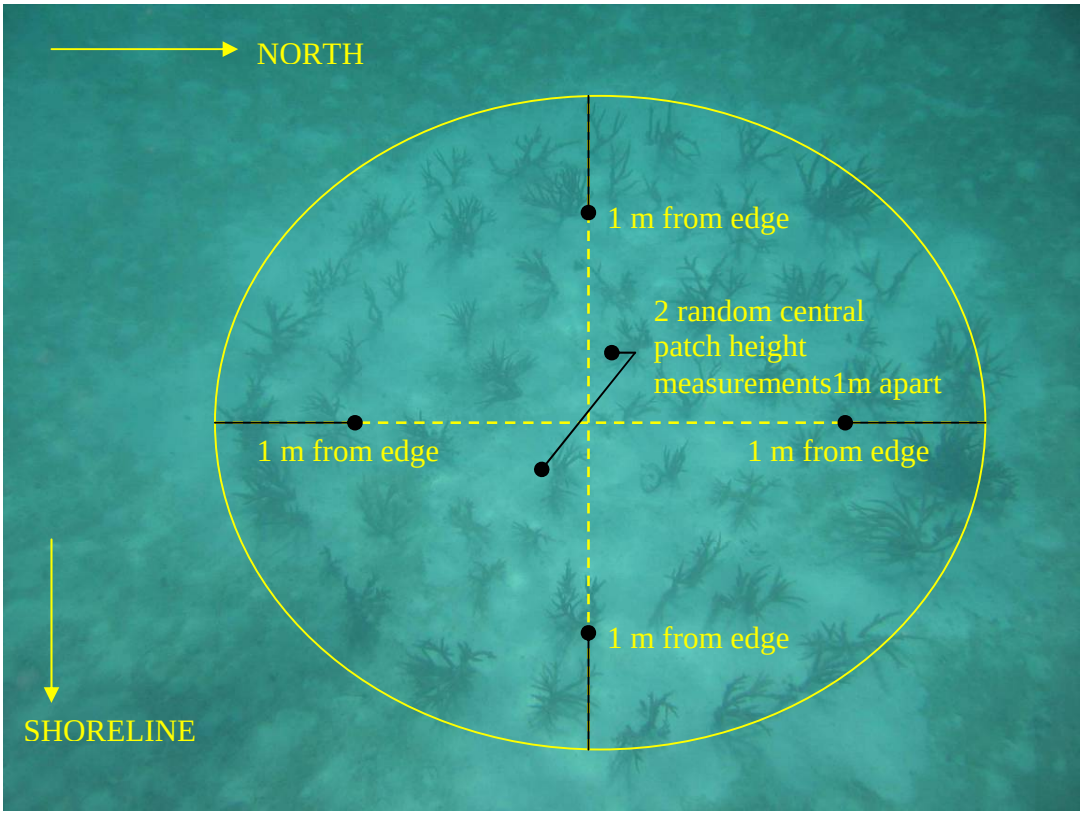


Figure 2 Photo illustrations of essential measurements that are taken as part of the monitoring protocol. Top: patch reef measurements used to calculate the volume of patch reefs. Bottom: individual measurements for live / dead coral portions.

2.2.1 Growth index

The importance of monitoring the volume of each transplanted patch reef is to assess the success of transplantation and the availability of fish habitat over time. It is essential to measure both live and dead portions of patches as fish use the patches for shelter (both the live and dead portions, with the live portion providing an increasing volume of protective area over time), and for food (herbivores graze on turf algae that grows on the dead portions whereas corallivorous fish feed on live corals).

Growth of transplanted patch reefs is followed by measuring the proportion (volume) of live and dead corals within a patch reef, and the overall size of each of the transplanted patches. The method used for measuring the volume of coral patches requires an adjustment of the volume estimates in patches where a portion of the corals might have completely died. In this situation, a visual estimate of the percentage of completely dead coral on the outer surface of the patch reef is deducted from the estimate of the volume of live coral.

Live and dead coral volume of each patch is estimated using the following measurements:

- **Maximum (Dmax) and minimum (Dmin) linear diameters** of each patch, using a standardized approach: the first value corresponds to the diameter positioned in a direction perpendicular to the shoreline (or from shoreline out to the mid lagoon), and the second value to the diameter at right angle to the first diameter, generally parallel to the shoreline.
- The **height** above the substrate of the dead colony zone ($\mathbf{H_{D\ (1\text{-}6)}}$) and the height from the substrate to the outer most coral branch ($\mathbf{H_{T\ (1\text{-}6)}}$) in that position (the live coral zone is calculated by subtracting the dead coral height from the total height at that position, ie, $\mathbf{H_{L(1\text{-}6)} = HT_{\ (1\text{-}6)} - H_{D\ (1\text{-}6)}}$.
- The **volume of live and dead zones** in a patch is calculated using a standard number of 6 height measurements scattered around the coral patch (the standard approach is to measure 4 positions within each patch that are approximately in the vicinity of a meter in from the edge of the two max/min diameter positions, and an additional 2 positions approximately a meter apart in the central zone of the patch).

The volume calculations for each patch are as follows:

Mean Radius ($\mathbf{R_M}$) of patch	**(Dmax + Dmin)/2**
Total Area ($\mathbf{A_T}$) of patch	$\mathbf{\Pi\ (R_M)^2 = 3.142\ (R_M)^2}$
Mean Total Height $\mathbf{H_{TM}}$	$\mathbf{\sum H_{T\ (1\text{-}6)}\ ) / 6}$
Mean Dead Height $\mathbf{H_{DM}}$	$\mathbf{\sum H_{D\ (1\text{-}6)}\ ) / 6}$
Mean Live Height $\mathbf{H_{LM}}$	$\mathbf{\sum H_{L\ (1\text{-}6)}\ ) / 6}$

Total volume of patch ($\mathbf{V_T}$)	$\mathbf{A_T \times H_{TM}}$
Volume Dead Coral ($\mathbf{V_D}$)	$\mathbf{A_T \times H_{DM}}$
Volume Live Coral ($\mathbf{V_L}$)	$\mathbf{A_T \times H_{LM}}$

2.2.2 Coral mortality index

The presence of bleaching is recorded using the following categories:

- Bleaching categories: none, slight (paler than normal colour), partial (upper surfaces white, lower surfaces normal), major (all surfaces white or very pale).
- Percentage of the total patch with any of the above bleaching categories.

Observations: several species of *Acropora* spp compose each restored patch reefs so there may be differential responses to bleaching that should be noted. Additionally, if coral disease symptoms are present in the patch corals, they are described and the proportion of the patch reef with symptoms is recorded. Photos are taken for verification of the symptoms.

2.2.3 Disturbance index

Disturbance indicators are recorded each monitoring period which include the presence of *Drupella* gastropods and crown of thorns starfish and the number of individuals that are removed to the adjacent fringing reef (or destroyed).

The monitoring protocol for macro algae includes an estimate of the relative amount of algae present each monitoring period using the following categories: none, low, medium, high. The high macro algae category should be comparable to what is currently present in the adjacent fringing reef, under branching *Acropora* spp colonies.

2.3 Fish monitoring

The fish monitoring data are restricted to fish found in or within a few meters of each of the patches. Fish abundances are monitored using the number of each major trophic fish group and dominant plus sub-dominant species / families, along with individual sizes grouped into five size classes:

The table below indicates the major families that can be found on coral reefs.

Family	Common Name	Family	Common Name
CARCHARHINIDAE	Requiem sharks	POMACENTRIDAE	Damselfishes
DASYATIDAE	Stingrays		Sergeantfishes
MURAENIDAE	Moray eels		Anemonefishes
OPHICHTHIDAE	Snake eels		Farmer fish
PLOTOSIDAE	Eel catfishes	LABRIDAE	Wrasses
SYNODONTIDAE	Lizardfishes	SCARIDAE	Parrotfishes
HOLOCENTRIDAE	Soldierfishes	SPHYRAENIDAE	Barracudas
	Squirrelfishes	MUGILIDAE	Mullets
AULOSTOMIDAE	Trumpetfishes	PINGUIPEDIDAE	Sandperches
FISTULARIIDAE	Cornetfishes	BLENNIDAE	Blennies
SYNGNATHIDAE	Pipefishes	GOBIIDAE	Gobies
	Seahorses	ZANCLIDAE	Moorish idol
SCORPAENIDAE	Scorpionfishes	ACANTHURIDAE	Surgeonfishes
SERRANIDAE	Anthias	SIGANIDAE	Rabbitfishes
	Groupers	BOTHIDAE	Lefteye flounders
APOGONIDAE	Cardinalfishes	SOLEIDAE	Sole
CARANGIDAE	Trevally	BALISTIDAE	Triggerfishes
LUTJANIDAE	Snappers		Picassofish
HAEMULIDAE	Sweetlips	MONACANTHIDAE	Filefishes
NEMIPTERIDAE	Spinecheecks	OSTRACIIDAE	Trunkfishes
LETHRINIDAE	Emperors		Cowfishes
MULLIDAE	Goatfishes	TETRAODONTIDAE	Puffers
CHAETODONTIDAE	Butterflyfishes		
POMACANTHIDAE	Angelfishes		

Table 1. A list of the major fish families that may be found on the coral patches. This list may not be complete.

2.4 Maintenance

The maintenance of restored patches commenced shortly after completion of the restoration to ensure its success while the initial stage is often critical for coral transplants survival. For the first 2 months, maintenance visits were conducted every two weeks. After the early stages, maintenance trips are planned every 3 months.

Description of maintenance activities?

3 Results

3.1 Coral transplant monitoring

3.1.1 Growth index

The baseline, 1, 3, 6, 9 month monitoring growth data are shown for the four coral patches in Figures 3 & 4. On the restored patch reefs, the mean patch volume of live coral decreased over the first month following transplantation, from 82% to 49% of the total patch volumes (i.e., a 30% reduction in live coral had occurred), with a subsequent increase in the mean volume of dead coral from 18% to 33% of total patch volume. This possibly indicates an initial effect of transplantation. After 3 months there was further decline in the live coral cover, with an average of 27% live and 46% dead coral within the four restored patches. This may be due to floods and big waves that occurred during this period, possibly combined with a later stress effect of transplantation.

The mean volume of live corals began to increase 6 months after restoration, from 27 to 43%. This trend was also noted at 9 month with 52% of the total volume of the restored patches being alive.

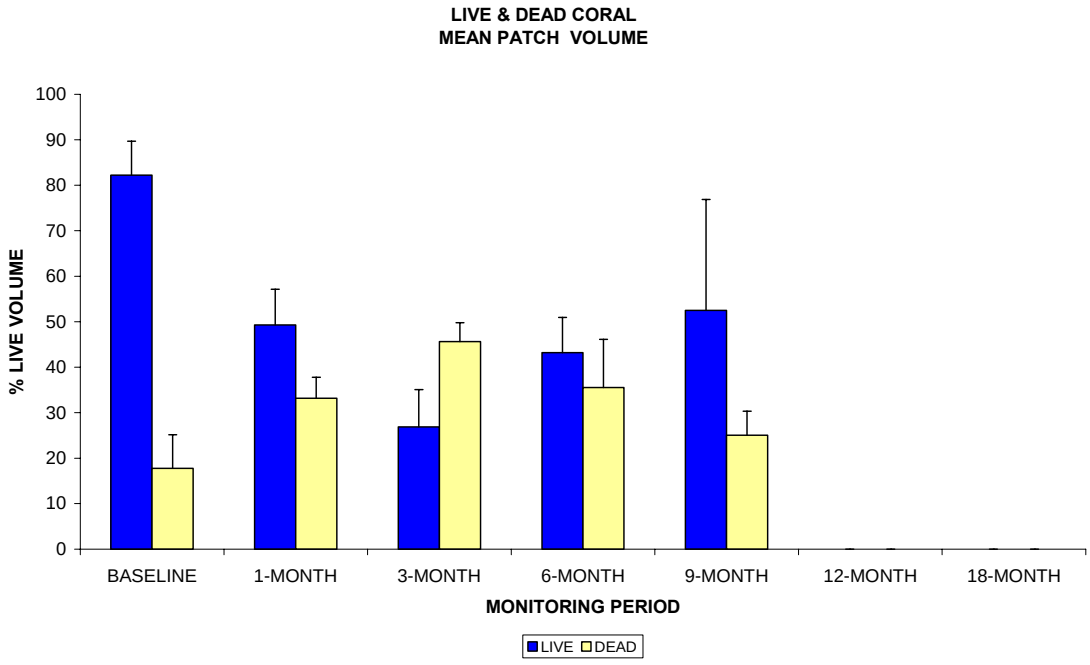


Figure 3. Mean live and dead coral volumes from all four coral patches at 1, 3, 6 and 9 months following transplantation.

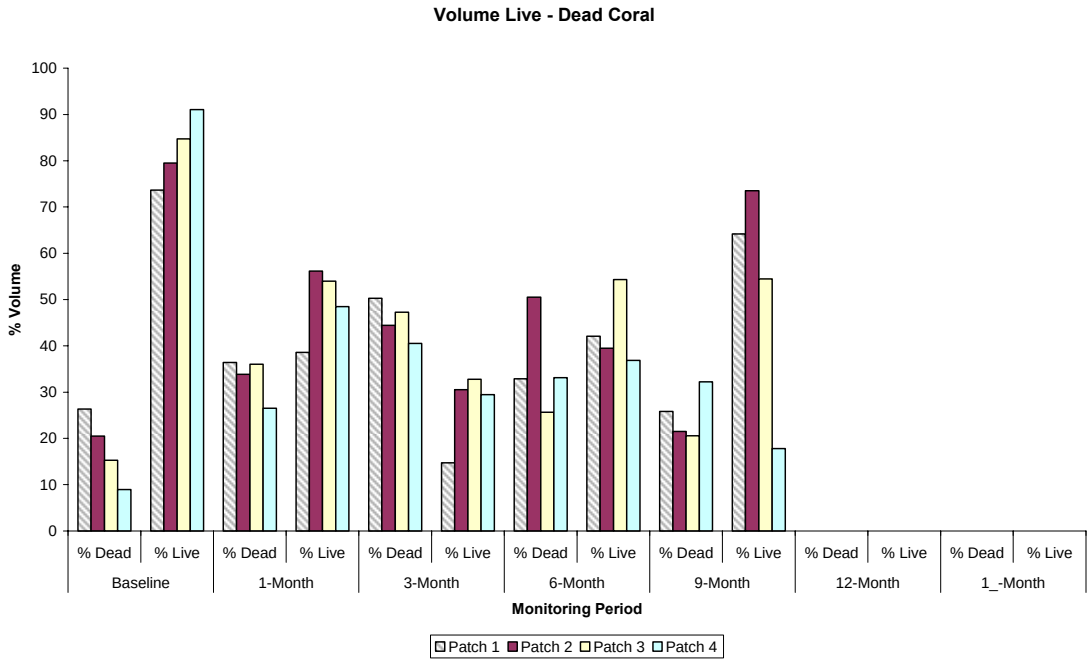


Figure 4. Volume of live and dead coral in each of the patch reefs at 1, 3, 6 and 9 months following transplantation.

3.1.2 Coral mortality index

To be completed

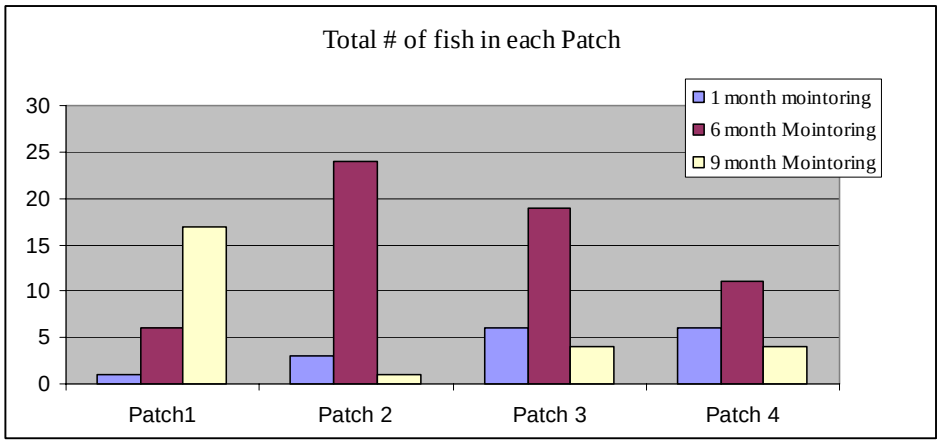
3.1.3 Disturbance index

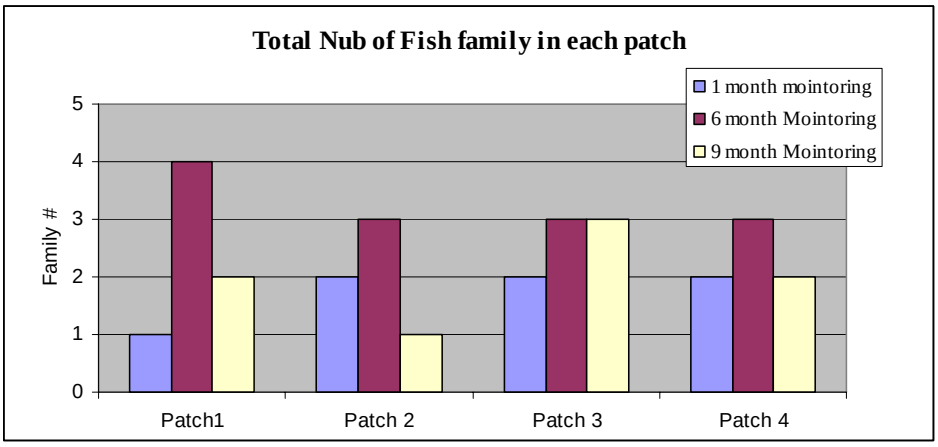
To be completed

3.2 Fish monitoring

Only two trigger fish were observed during the baseline survey just after the restoration trials were established. After 1 month a small community of fish (total of 11 fish from by 5 families) was observed. Three juvenile parrot fish were noted among patches #1 and #2, and 3 small emperor and 3 goatfish were recorded at patch #3, while 2 fusiliers were recorded at patch #4 along with one of the triggerfish mentioned above. After 6 months a total of 60 fishes were observed at the restored patch with sizes ranging between 1-5cm. (all juvenile sizes).

To be completed





3.3 Maintenance

Some trash (human rubbish) was also removed from the site which presumably was transported by the inundation of nearby land caused by the February king tides. Many coral transplants had been knocked over on their sides due to wave action, and maintenance included straightening and replanting of the coral transplants.

The 9 month monitoring did not include maintenance work as the coral colonies were undisturbed and macro algae had not markedly increased.

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4 Community involvement in monitoring activities

To be completed

5 Discussion

5.1 Coral growth and adaptation

The trends in the volume of live and dead coral after 9 months post transplantation are showing that the transplant method and aims are succeeding and that the coral transplants are following expected patterns.

The reduction in live coral volume and increase in dead coral volume in the early phases after transplantation is to be expected as the transplanted colonies were initially placed on the sand surface or buried in the sand down to the live sections of the colonies, in order to increase their stability and maximize their survival. Therefore, subsequent die back of the live coral sections adjacent to the sand was expected to occur due to abrasion and movement of surface sand. In addition, some colonies did not recover from the initial transplantation and have died within the first month following transplantation. Some mortality is usually expected due to the change in habitat and because some colonies were probably moved 2-3 m deeper than where they were collected on the fringing reef slope. The transplanted corals also require time to adapt to the different habitat from their source which may help explain the apparent lack of noticeable growth despite the high summer growth period that would be expected in corals. In an earlier project (restoration of a degraded reef by transplanting 3-D coral colonies, Moturiki Island, Fiji –Fisk *et al*., 2006) we noted that transplanted corals might well be stressed over long period (up to 9 months) after their relocation.

The coral transplants experienced major disturbances from the king tides and flooding and strong wave action and this also explains the decline of live coral volume at 3 months post transplantation. After 6 months, there was an increase in the live coral volume, indicating that coral colonies might have started to adapt to the new habitat after the earlier disturbances and have started to grow. The further increase in live coral volume after 9 months suggests that coral colonies had stabilized and adapted to their new habitat and that conditions have been favorable for growth.

Although the numbers of observed fish is low after the first month post establishment, it is encouraging to note that many of the newly settled fish were juveniles, indicating that the patches might act as attractive habitat for fish recruitment. The 1-month monitoring time occurred in summer when many juvenile fish normally settle onto reefs, but the time period following establishment is too short to conclusively demonstrate any effect of the patch reefs attracting juveniles. This is predominantly due to the lack of time for the transplanted corals to adapt and grow sufficiently to produce suitable habitat, especially with respect to protection and cover for the juveniles.

In the future, it is hoped that the coral transplants will continue to grow and eventually form a canopy over the patches. Also it is hoped that a zone of dead coral underneath the live coral canopy can be established and that this zone will be free of *Drupella* spp and COTS starfish. This dead zone can be an important habitat for other invertebrates and a substrate that supports turf algae that can be used by juvenile fish as a food source. The presence of healthy growing live coral patches is the aim of the project with the prediction that these patches will support healthy populations of juvenile fish as a consequence.

5.2 Fish colonisation

Results of monitoring fish populations on the newly established coral patches are encouraging. The overall number of fish recorded on the patch reefs is low and may be a consequence of the lack of a complete live coral canopy within the patches that can afford protection for juvenile fish in particular. It is also relatively early stages after patch reef establishment, and high numbers of fish may not be expected to colonise the patches after a number of summer seasons and presumably after the patches have a closed canopy of live coral.

The range of fish families that are observed within the patches is similar to what can be seen in the nearby fringing reef habitats. This is expected as it may be that fish are gradually moving from the fringing reefs and adopting the new patches as additional habitat. The presence of small juvenile fish also may be evidence that newly settled fish are selecting the patches as suitable habitat, which is one of the main aims of the project. Fish families recorded on the patches include predominantly algal grazing species as well as some piscivore species.

5.3 Maintenance

The low level of maintenance particularly in relation to the lack of necessary removal of potential factors that could impede the recovery and growth of coral transplants is an encouraging sign. However, it will be necessary to be continuously vigilant to ensure no predators or macro algae establishment is allowed to inhibit transplant growth especially during this early phase of the project.

6 Future Work Schedule

The maintenance and monitoring schedule commenced 1-month after the establishment of the coral patches and completion of the baseline assessment in late November 2006 (Table 5). More regular maintenance activities were undertaken in the early stages of the project to ensure to success of operations while the initial stage is often critical for coral transplants survival. For the first 2 months, maintenance visits were conducted every two weeks. Monitoring sessions are planned at 1-month, 6-month, 12-month and 18-month after restoration. Maintenance of the site occurs at each visit to the restored site, every 3 months.

	2006			2007												2008					
Activities	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Tuvalu scoping exercise																					
Scoping report																					
Initial project set up and community consultation																					
1-month monitoring and community workshop																					
3-month maintenance trip																					
6-month maintenance & monitoring trip																					
9-month maintenance trip																					
12-month maintenance & monitoring trip																					
15-month maintenance trip																					
18-month final maintenance & monitoring trip																					

Table 2. Work plan for Restoration Experiment 1
Tuvalu sand based patch reef transplantation trial

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Appendix 1. Monitoring underwater pictures

Appendix 2. Monitoring datasheets template for coral and fish

TUVALU FISH MONITORING
(Number of Fish – Size Class)

Site:	**Date**:	**Schedule**:		**Obs** :
FISH FAMILY / GROUP (Main Species)	**PATCH 1**	**PATCH 2**	**PATCH 3**	**PATCH 4**

Size Classes : **1**=1-5cm (finger tip to first joint)
2=5-10cm (finger tip to knuckle)
3=10-20cm (finger tip to wrist)
4=20-40cm (finger tip to elbow)
5=40+cm (elbow+)

TUVALU CORAL MONITORING

Site:	**Date:**	**Schedule:**		**Obs** :
	PATCH 1	**PATCH 2**	**PATCH 3**	**PATCH 4**
MORTALITY (%)				
BLEACHING (None – Slight – Partial - Major)				
DRUPELLA / COTS (# Removed)				
MACROALGAE (None – Low - Medium - High)				
DIMENSIONS (cm)	**PATCH 1**	**PATCH 2**	**PATCH 3**	**PATCH 4**
Max. Diam (LxB) =				
Dead / Total Ht = D1 / T1				
D2 / T2				
D3 / T3				
D4 / T4				
D5 / T5				
D6 / T6				

DEAD / TOTAL HEIGHTS: From sand to upper dead & upper live branch tips; in cm

Appendix 3. Monitoring datasheets for coral and fish