Coral Reef Inspection of Selected Coral Reefs on Upolu Samoa following the September 29, 2009 Tsunami.

Edward Lovell, Joyce Ah-Leong, Lui Bell, Pulea Ifopo, Mikaele Faamai,
Juney Ward, Posa Skelton, Brian McAdoo

1.0 Introduction

Following the tsunami of Sept. 29 2009, UNESCO International Tsunami Survey Team (ITST) was coordinated by the New South Wales University's Australian Tsunami Research Centre (ATRC) and the University of the South Pacific arrived in Apia Samoa on October 12, 2009. They were joined by the Government personnel to form the Marine Environmental Assessment Team (MEAT). The team consisted of members from the Ministry of Agriculture and Fisheries (Joyce Ah Leong, Mikaele Faamai); Ministry of Natural Resources and Environment (MNRE) (Juney Ward, Pulea Ifopo); Secretariat of the Pacific Regional Environmental Programme (SPREP) (Lui Bell); The University of the South Pacific (Ed Lovell; Posa Skelton); Vassar College, USA (Prof. Brian McAdoo).

The assessment strategy involved the inspection of several sites of over a four day period. The sites chosen were coral reef areas adjacent to the locations of substantial terrestrial tsunami impact. Islands were inspected for beach erosion particularly for turtle nesting sites. Stranded turtles were also documented. Where possible marine protected areas and fisheries reserves were inspected as there was previous data regarding the nature of the marine benthos. As well, the Coral Reef Recovery Planning (CERP) site of Vaovai was inspected in 2006 providing a before appraisal of the tsunami effect.

2.0 Methods

Generally there were four approaches to the marine assessment.

i) The broad areas were assessed by manta towing. The percentage of living and dead coral was recorded as well as the substrate types. Assessment of the bathymetry using a GPS linked echo-sounder was conducted.

ii) Inspection was made of the underwater coral reef communities with special emphasis on the hard corals and substrate using point-intercept-transect (PIT) and photo-assessment.

iii) Mobile invertebrates (holothuria, mollusks etc.) and fishes were noted.

iv) The islands were visited and the beaches assessed for damage and for marine turtles and their nesting areas.

Deeper areas were assessed using self-contained underwater breathing apparatus (SCUBA).

Generally, the group was divided into two teams. One was confined to the inspection of the shallow reef. This was an attempt to sample the inshore fringing reef or the offshore barrier reef.

This was conducted by Juney Ward and Ed Lovell with assistance from Lui Bell and Pulea Ifopo. The second team was tasked with manta towing, bathymetric assessment and island inspection including assessment of the turtle nesting sites and stranded turtles. This was conducted by Joyce Ah Leong, Posa Skelton, Brian McAdoo, Pulea Ifopo, Mikaele Faamai and Lui Bell.

3.0 Results

3.1 Namu'a Island: October 15 Thursday

The survey was conducted on both sides of Namua Island in the back reef zone of the barrier reef. High surf prevented inspection of the reef flat so the survey was confined to the area behind the reef on what was previously a sandy bottom habitat. The current across the reef was very strong as the wave generated currents flowed into the lagoon. A snorkel survey revealed substantial deposition of boulder materials graded from the back reef area as larger boulders to mixed reefal material comprised as rubble with coral fragments. This was confirmed to be new substrate by Ifopo and Ward who had experience in the marine protected area.

The coral fragments represented the varied reef flats species, as well as those occurring in the lagoon. The percentage of living coral fragments varied between 10-30% with some areas being more numerous probably due to the *in situ* nature of the large stands of branching *Acropora*. Large *Porites* colonies (<1m) were displaced and strewn across the sand bottom forming boulder and rubble moraines extending into the lagoon.

Holothurians were abundant on the rubble (*Stichopus chloronotus, Holothuria atra*) with assemblages of juvenile fishes hovering over the broken rubble (e.g. Parrot fish and varied small coral fishes). The team did not observe any edible-size fishes.

Rubble, boulders and recently dead coral fragments were characterized by a greenish tinge of newly colonized algae.

Manta tows revealed large piles of rubble/coral fragments forming ridges extending north-west between Namu'a and Fanuatapu. Large *Porites* (~1m diam.) were intact.

3.2 Vailoa: October 16 Friday

This site is an inshore fringing reef composed largely of *Porites* species. The beach had numbers of colonies of *Pocillopora damicornis* and *Pavona* spp which had been washed up and were evident as bleached colonies.

Three contiguous point intercept transects (PIT's) were conducted to provide a description of the benthic assemblage. Both branching and massive Porites species were observed (e.g. *Porites rus, P. cylindrical, P. lobata, P. lutea?, P. anne*).

Manta-tow revealed some damaged corals (*Acropora* spp.) with lots of rubble.

3.3 Lalomanu: October 16 Friday

On land, this area suffered some of the greatest damage from the impact of the tsunami waves. Offshore, the barrier reef is relatively close to shore with a narrow channel running east to west. Large waves seaward of the barrier reef prevented inspection of the outer reef flat and crest. The assessment was by snorkeling transecting taking notes and taking photographic images of the inner reef and inshore area.

The beach was littered with rubbish and building material from the destruction of the homes inland. This extended in to the inshore channel where coral bommies and piles of rubble with living coral fragments characterized the environment. Substantial coral rubble was evident on the channel bottom throughout extending to >5m depth.

On the abruptly sloping inshore margin of the barrier reef, large boulders and plates were evident. On the reef flat damaged coral occurred as rubble piles with intervening areas of bare reef rock with the sand having been removed. Further seaward, corals suffered less damage. There were substantial corals on the inner reef flat which were protected by their position within reef holes or other protective features of reef morphologies. Larger reef structures such as bommies offered protection from damage on their lee margins.

Opposite the reef passage, the amount of upturned tabulate corals and shards of coral plate material increased. Among the coral boulders was substantial debris such as clothing, roofing materials and other house construction items.

3.4 Vaovai Coral Reef Area: October 19 Saturday

This area is characterized by two channels on other sides a fringing reef located at the mouth of a river. Adjacent is a barrier reef system containing an island which borders an extensive lagoonal system.

This area is a marine protected area developed by the United Nations Development Programme (UNDP). It was also a focus of a CERP assessment in 2006 in which a coral reef description based on photo transects was conducted.

Extensive damage to the back reef with rubble piles and broken coral fragments was observed. Displaced large colonies were evident and considered the main source of damage through abrasion and impact. By contrast, the reef flat further to seaward and adjacent the reef margin showed little damage with a higher level of coral diversity. Colonies in this area were not generally damaged nor displaced. This was considered to be the result of adaptation to a wave environment.

Off the reef edge, a similar phenomenon of increased coral fragmentation and damage observed with decreasing little damage in the offshore area. This offshore area was characterized by large plate corals (*Acropora hyacinthus, A. cytherea, A. clathrata*) with many of these undamaged. This also included the large branching species such as *Acropora nobilis* and *A. intermedia*.

Manta tow surveys and bathymetric assessment were carried out. Starting from the channel (on the landward side of Nuusafee) moderate damage was noted on broken tabulate corals. Towards the western side of the Nuusafee fringing reef little damage was noted.

Damage to the existing living coral resulted from the same mechanisms as on the reef flat with the lack of displaced boulders, colonies, fragments rubble and sand reducing the impact of the tsunami to successive but short lived periods of high currents. Despite this generalized relationship, there were areas of substantial damage. Large plate corals (*Acropora hyacinthus, A. cytherea, and A. clathrata*) were upended, broken and dead standing. Closer inspection has surmised that though the tsunami has moved substantial material creating rubble piles and impacting other corals, many of the colonies were long dead. Coralline algal covered surfaces indicated that death may have been due to the 2005 coral bleaching event or that disease which was present amongst the tabulate corals has been responsible for much of the death. Bioerosion has predisposed the dead standing coral to displacement and breakage. The large plate size with relative thin attachment has made this material vulnerable to removal from the surface. This appears to be the case with the large living colonies as well, where the large table portion of the colony is not adequately supported by the stem like attachment allowing displacement and upending.

4.0 Discussion

Each site had unique characteristics. Namua exhibited the creation of new habitat with the boulder rubble extending over the lagoon floor. The abundance of fragmented but living coral provides hope for subsequent growth of the fragments with restoration of the living coral cover and other benthos.

A general conclusion was that damage was greater on the barrier back reefs and the more inshore portion of the fringing reefs due to the transport of shingle, boulders and displaced coral colonies. These caused damage to the attached coral through impact and burial. Seaward the wave was manifest as large but normal wave where there is a short period of rapid water flow as the wave passes. Without entrained material, the wave is not particularly, of itself, destructive to well attached corals.

Protection of coral reef areas by islands or reef features is important to survival of attached organisms.

It appeared evident that the width of the reef may be important in the reducing of impacts ashore. The direct nature of wave impact and refraction around the island with reinforcement of the energy as the waves converge, augmenting damage in both the marine environment and on shore.

The inshore Porites dominated fringing reef community at area of Vailoa suffered little damage. Though the reticulated nature of the *Porites rus* was occasionally displaced as boulder-like material the remainder of the massive Porites colonies survived at a low relieve consolidated community. Branching colonies exhibiting higher relief and the abundance of *Pocillopora* colonies on the beach illustrates the hazard of growth extending above the general living substrate.

5.0 Recommendations

1. Initiate a clean-up of beach and subtidal areas at locations such as Lalomanu.

2. Survey the fore-reef area to assess the impact on the reef front and determine impact from material removed and assess damage created by material falling down the reef front.

3. Develop a monitoring program to assess the medium and long-term effects of the tsunami on the coral reef benthos and fish populations.

4. Compare the resilience of the MPA and non MPA locations to assess to see if there is a protection benefit.

5. Reconsider the locations of the no-take zone with regard to the tsunami hazard.

6. Assess the foraging and nesting areas for the turtles at Aleipata

7. Assess the state of food-fish population

6.0 Acknowledgements

The team acknowledged the Government of Samoa for initiating this post-tsunami assessment. The Fisheries Division (MAF) provided the boat, survey/dive equipment, personnel and transport. UNESCO provided funding for fuel and dive tanks. MNRE provided personnel, vehicle, and survey equipment. The USP personnel were supported by their institution and the University of New South Wales, Australia. SPREP provide personnel, equipment and a vehicle.

Project leaders: Dale Dominey-Howes, Australian Tsunami Research Centre (ATRC), Sydney, Australia. Randolph Thaman, University of the South Pacific and SOPAC.

7.0 Appendix 1.

Marine Turtles Stranded on Land after the Samoa Tsunami

1. Introduction

The tsunami waves that swept through parts of the Samoa Islands on 29 September 2009 brought a lot of marine life with them, portions of which were stranded on land when the waves subsided. In addition to the reef fishes of varying sizes, marine turtles, a few sharks and dolphins were also stranded. Only two dolphins were reportedly left on land dead and were buried. This report focuses on marine turtles and attempts to give an account on the number and fate of marine turtles that were left on land after the tsunami waves.

The MPA work in both districts of Safata and Aleipata as well as general conservation effort contributed significantly to the high numbers of stranded turtles being released back to the sea. For example, the first turtle that was tagged and released was brought to the home of the MPA officer by a construction worker because he knew turtle conservation is part of the officer's tasks. The other four turtles tagged and released were held by Police Officers posted in one of the affected villages and communication with SPREP lead to these being brought in for tagging and then releasing. The other two turtles that were tagged and released were kept by a village in the Aleipata District MPA. The release of other turtles for which no information was recorded is believed to be linked to the successful campaign and positive response of the communities and individuals to conserve marine turtles.

2. Methodology

Most of the information was obtained from interviews with certain individuals (e.g. Pulenuu, fishermen) in villages most affected by the tsunami. The tagging, tissue sampling and measurements and recording of information on turtles that were available were conducted by DEC and SPREP representatives.

Turtle tagging was done using a Stockbrand applicators and titanium tags with the SPREP R-series.

Turtle tissue sampling was done using a sharp blade to cut out a small piece of tissue from both the hind flippers of each turtle sampled. Each tissue was transferred directly to a separate vial containing DMSO.

It was only possible to visit two offshore islands where turtle nesting occurs, Nuutele Island off Aleipata and Nuusafee Island, off Vaovai/Poutasi. DEC has been monitoring turtle nesting on Vini Beach for several years. Turtle nesting on Nuusafee has only been reported by the community but no monitoring has been conducted there to assess and confirm actual turtle nesting. For this report, visual inspections on the beaches were conducted and using past photographs for comparison where available. It was only possible to visit Vini Beach on Nuutele Island during this preliminary survey due to sea conditions. The whole island of Nuusafee was inspected.

3. Results

3.1 Turtles

Number of turtles stranded on land and fate: Table 1 summarizes data on reported and actual observations of turtles washed up by the tsunami and stranded on land. At least fifty one marine turtles were reportedly stranded on land of which seven were released by DEC/SPREP, at least 41 were reportedly released by communities, Government officials, resorts and individuals where they were found, one consumed and the fate of three reported is unknown. The 41 includes seven turtles that were reportedly taken to another village near town which were kept in a river but swept away/escaped after heavy rain making the river to rise. Reports relayed to the team on the releases of turtles back to the sea indicates that more than 51 turtles were stranded, almost all were released back.

A total of seven marine turtles were tagged with titanium tags, tissue samples collected, length measurements taken and then released. Table 2 lists information recorded for these turtles. Of these seven, one was brought in by a construction worker, four were brought from the Police post at Malaela after arrangement by SPREP and DEC, and two were tagged at Malaela after the village found them in the mangrove area and stocked them in a smaller pond. One of these two turtles was already tagged when checked. Records in the DEC turtle tagging database confirmed that this particular turtle (green) was tagged and released at Satitoa in October 2008 (it was caught in a fishing net at that time).

Species composition of turtles stranded on land: All of the seven turtles tagged and released by DEC and SPREP were green turtles. The turtle that was consumed was a hawksbill turtle. One of the turtles with an unknown fate was also a green. All of the turtles released at Tafitoala Safata were described as green turtles except one.

Turtle stranding by village affected: The highest numbers of stranded turtles reported were at Malaela, Aleipata (19+ turtles) followed by Tafitoala Safata (13 turtles). It is noted that the areas in both villages where turtles were mostly found (alive) have inland waterways and surrounding vegetation, e.g. mangroves areas. The vegetation seems to have acted as a filter when the wave went out]. Four stranded turtles were reportedly released in Lalomanu, at least 2 were released at Coconut Beach Resort, 2 released at Vaovai, Falealili and 1 at Salesatele.

Size of stranded turtles: Carapace measurements were only possible on eight turtles (7 tagged and released + 1 consumed). These measurements are recorded in Table 2. Of the seven turtles (green) tagged and released, two (with curved carapace lengths of 91.5 cm and 101.5 cm) seem to have reached maturity stage. The hawksbill turtle that was consumed has also reached maturity length (curved carapace length of 100 cm). One of the turtles, a green with an unknown fate, stranded at Ulutogia, also seemed to have reached maturity length. Most of the turtles reported seem to have been sub-adults.

Cuts on individual stranded turtles: Of the seven turtles tagged and released, only one seemed to have a major crack on its carapace. This involved the large green caught by the village in the mangrove area. It was informed that the crack resulted from handling when moving the turtle from the mangrove area, where it was caught, to the small pond when the turtle fell on a rock. The green turtle saved by the construction worker from Falealili also had a crack in the centre of its carapace. Parts of the tips of its front flippers also showed peeling of the skin showing the white layer underneath the skin. The large hawksbill that was consumed had large cuts/cracks on the side of the carapace indicating that it was knocked around quite a bit.

3.2 Turtle nesting islands

Vini beach on Nuutele Island: Turtle nesting occurs on the north and south sides of Nuutele, where there are sandy beaches. It was only possible to visit Vini Beach, on the south-west side of the island, during this work. For the last couple of years, large rubbles have been accumulating on the part of the beach where turtle nesting occurs, making most of it unsuitable for turtle nesting. Comparison with the beach profile in 2003, 2004 and 2007 clearly shows the rubble accumulated up to 2007. The inspection on 15 October, 2009 indicated that the tsunami waves seem to have “removed” the rubble layers on the beach and exposing the sand layer that was

there before. However, it is necessary to conduct a more thorough survey to examine the sand in depth whether it is suitable for turtle nesting. The angle at which the tsunami wave hit the beach seems to have helped in the removal of the top layer of rubble. It also seems the wave swept across it at an angle as opposed to bounding upon it! Also looks like it was just water with no debris at that time.

Nuusafee Island: The impact on Nuusafee however was different as it seems the wave hit it directly from the south-east? Slaps of calcium material along the shore were torn and washed up onto the beach. With the exception of what appears to be a new deposit of sand on the west tip of the island and small fraction (5 meters across) on the south-east side, the rest of the island is unsuitable for turtle nesting due to high rubble build-up on the sand making it impossible for any turtle to crawl across to any suitable area under the bushes, deep erosion making it impossible for any turtle to crawl up, and rubble covering suitable sand areas for turtle nesting. The sandy beach area may not be suitable if the sea reaches it during high tide-in addition, it is too exposed not having any vegetation over it.

Table 1: Marine turtles reported stranded on land after Tsunami, September 2009

	Fate	**Date**	**Place**	**#**	**Village total**	**Species**
Confirmed	Tagged/ Released	1-Oct	Aleipata, Malaela	4		Greens
Confirmed	Tagged/ Released	15-Oct	Aleipata, Malaela	2	6	Green
Confirmed	Tagged/ Released	30-Sep	Falealili, ??	1	1	Green
TOTAL				**7**		
Confirmed	Consumed	29-Oct	Safata Tafitoala, consumed in Fusi	1	1	Hawksbill female
TOTAL				**1**		
Reported	Released	??	Aleipata, Lalomanu	4	4	unknown
Reported	Released	6-Oct	Aleipata, Malaela	1		unknown
Reported	Released	15-Oct	Aleipata, Malaela	10+		
Reported	Escaped from river at Laulii where they were kept when river flooded	15-Oct	Aleipata, Malaela/Laulii	7		
Reported	Released	Before 1-Oct	Aleipata, Malaela	1	19+	unknown
Reported	Released	??	Aleipata, Salesatele	1	1	unknown
Reported	Released	17-Oct	Falealili, Vaovai	2	2	unknown
Reported	Released	29-Oct	Safata, Tafitoala	8		7 green?, 1 hawksbill?
Reported	Released	29-Oct	Safata, Tafitoala	5	13	All green?
Reported	Released	30-Sep	Siumu, Maninoa	2+	2+	unknown

TOTAL				**41+**		
Reported	Unknown? Released?	30-Sep	Aleipata, Ulutogia	1	1	Green
Reported	Unknown	30-Sep	Aleipata, ??	1		unknown
Reported	Unknown	6-Oct	Aleipata, Lotofaga,?	1?		unknown
TOTAL				**3**		

Table 2: Information on Tsunami-stranded turtles that were tagged and released by DEC and SPREP.

(Tissue samples for genetic analysis were collected from all these turtles).

Date	Place Obtained	Species/ Sex	Measurements (cm)	Tags	Info/Observation	Release Date/Place
15 Oct 09	Malaela, Aleipata	Green female	CCL_{Min}: na CCL_{Max}: 101.5 CCW: 90.5	Already tagged: Left: R39447 Right: R39448	• Tagged and released by DEC on 30 Oct 2008 at Satitoa; • Upper left side carapace cracked (from handling when moving from mangrove by village) • No bleeding from cracks and turtle seemed to be well and strong when released	15 Oct 2009 Malaela beach (infront of affected village)
15 Oct 09	Malaela, Aleipata	Green female?	CCL_{Min}: 72 CCL_{Max}: 75.2 CCW: 65.2	New tags: Left: R47080 Right: R47079	• No cuts, well and strong when released	15 Oct 2009 Malaela beach (infront of affected village)
1 Oct 09	Malaela, Aleipata	Green	CCL_{Min}: 67.5 CCL_{Max}: nm CCW: 59.0	New tags: Left: R47089 Right: R47090	• Turtle brought in from Malaela	1 Oct 2009 Mulinuu, Apia from boat slipway
1 Oct 09	Malaela, Aleipata	Green	CCL_{Min}: 57.0 CCL_{Max}: nm CCW: 53.0	New tags: Left: R47095 Right: R47096	• Turtle brought in from Malaela	1 Oct 2009 Mulinuu, Apia from boat slipway
1 Oct 09	Malaela, Aleipata	Green female	CCL_{Min}: 91.5 CCL_{Max}: nm CCW: 82.0	New tags: Left: R47093 Right: R47094	• Turtle brought in from Malaela • Seemed weak while tagging but strong when released	1 Oct 2009 Mulinuu, Apia from boat slipway
1 Oct 09	Malaela, Aleipata	Green female?	CCL_{Min}: 70.0 CCL_{Max}: nm CCW: 65.5	New tags: Left: R47091 Right: R47092	• Turtle brought in from Malaela	1 Oct 2009 Mulinuu, Apia from boat slipway
29 Sep 09	Falealili	Green	CCL_{Min}: 56.0 CCL_{Max}: 56.4 CCW: 50.0	New tags: Left: R47098 Right: R47097	• Turtle brought in from Falealili	29 Sep 2009 Sogi, Apia