Marine Ecosystem Assessment

North Efate, Vanuatu

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Executive Summary

The RESCCUE North Efate project site from Mangaliliu in the West to Epao in the East and coastal islands includes a diversity of environments that support natural resources important for food security and livelihoods of local communities. The population is mostly concentrated in 27 villages on the Efate coast plus communities on the islands of Lelepa, Moso, Nguna, Pele and Emao, and are heavily dependent on marine habitats for subsistence and income generation. The coral reefs, seagrass meadows, mangroves, beaches and intertidal habitats of North Efate support a high diversity of marine plants and animals and also species of conservation concern, including dugongs and marine turtles. Consistently, communities, government and NGOs report that the greatest threat to the marine and coastal environments of North Efate are tropical cyclones, overexploitation of fisheries, coral predation and bleaching, land-based pollution and coastal development (Raubani 2009, Pakoa 2007, RESCCUE IDD 2015).

Surveys conducted by the RESCCUE project at 14 sites in November 2015 assessed the physical impacts of Tropical Cyclone Pam that passed the East coast of Efate in March 2015. The surveys documented significant coral damage on northeast reefs and less damage as distance increased away from the cyclone path. Repeat surveys at 16 sites in May 2016 collected more detailed baseline benthic data using photo transects (Korel Lukluk), bleaching assessment and water quality sampling. The results of these surveys documented some recovery since TC Pam (indicated by high numbers of juvenile corals at some sites), moderate to extensive coral bleaching at most sites, and significant longer-term reef degradation at some coastal sites, most likely due to coral predation by crown-of-thorns starfish (known locally as posen sta).

Water quality sampling in North Efate found that most parameters tested were either below detectable limits or low, except for fine sediments and chlorophyll-a at some sites. The concentrations of most parameters sampled were below results from around Port Vila, indicating relatively good water quality in North Efate.

These results indicate that reef ecosystems in North Efate are in a relatively healthy condition considering the multiple disturbances of tropical cyclones, coral predation, coral bleaching and heavy fishing pressure. However, some locations have experienced significant coral decline as a result of these disturbances, and recovery may take decades or they may not return to a coral dominated state. Reducing anthropogenic pressures on reefs, particularly overfishing, will be important to the future recovery and ultimately condition of these reefs. Importantly, the ability of North Efate reef ecosystems to provide food security and livelihood opportunities for local communities will depend on their resilience and ability to resist and recover from cumulative human and climate stressors.

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INTRODUCTION

The North Efate site includes large areas of coral reefs, seagrass meadows and mangrove forests, although their exact extent is unknown. Bathymetry surveys by SOPAC in the early 1990's identified fringing reef along most of the northwest Efate coast and around the islands of Lelepa and Moso (Smith 1991), except along the North Efate coast across from Moso Island, which is dominated by mangroves. This section of the coastline represents the largest area of mangroves in the project site. Preliminary surveys have documented 82 km^2 of mangroves between Paunangisu and Takara, as well as 0.9 km^2 near Emua and 4 km^2 near Lakenasua (OceansWatch unpublished data). Reef surveys conducted since 1989 confirm that most of the North Efate coastline and the islands have fringing reef with seagrasses (Pakoa 2007, Raubani 2009, Reef Check 2009, Done and Navin 1990), however no spatial distribution mapping is available.

These environments provide critical goods and services to coastal communities, as well as essential coastal habitats that provide protection from extreme events. Information on their spatial distribution and condition is a key knowledge gap that will be needed to inform integrated coastal management actions. The communities of North Efate are highly dependent on their natural resources for household food, income, cultural significance, and disaster recovery:

- Mangroves and coastal wetlands – food security and livelihoods (crabs, shells), firewood and building timber, and coastal protection;
- Coral reefs – food security and fisheries livelihoods (fish and invertebrates including sea cucumber, triton, trochus, green snail and giant clam), tourism income and coastal protection; and
- Seagrass meadows – food security and fisheries livelihoods (fish and invertebrates including sea cucumber, triton, and green snail), and tourism income.
- Dugongs and marine turtles – cultural significance and tourism income.

A global assessment found that Vanuatu coral reefs are currently most threatened by land-based pollution and overfishing, which affect between 75% and 90% of reefs (Burke et al. 2011). Most reefs in North Efate are currently in the very high to critical threat categories when local pressures are considered (Chin et al. 2011). Vanuatu reefs are in the top nine most vulnerable worldwide to the effects of coral reef degradation due to high reef dependence (World Resources Institute 2012), and coastal communities were ranked 8th most vulnerable to the effects of ocean acidification of the 22 Pacific Island nations assessed (Johnson et al. 2016). Reef vulnerability is expected to increase under future climate change, and by 2030, the combined effects of ocean acidification and thermal stress will result in 90% of Vanuatu reefs being highly to critically threatened (Burke et al. 2011). Addressing local threats is therefore important for minimising current pressures, and building resilience to future threats, particularly as climate change is projected to reduce ocean pH, increase sea temperatures, increase cyclone intensity, raise sea levels and change rainfall patterns, which will have implications for species, environments, communities and industries (Bell et al. 2011).

These projections have started to eventuate in North Efate, with a severe Category 5 cyclone – Tropical Cyclone (TC) Pam – passing along the northeast of Efate in March 2015, and thermal coral bleaching occurring in early 2016. The RESCCUE Marine Team collected post-TC Pam benthic reef data in November 2015, and further baseline status data on key marine resource in the North Efate project site to determine current status and the impacts from recent disturbances – TC Pam and coral bleaching – on critical resources:

- Assessment of reef habitat condition (2015) and recovery post TC Pam (2016; 16 sites);
- Assessment of thermal coral bleaching extent and severity (14 sites);
- Baseline finfish underwater visual census of key target groups (30 transects; documented in Welch et al. 2016);
- Baseline water quality data (nutrients, sediment, ecotoxicology) at 13 sites as a collaboration with the UK Centre for Environment, Fisheries and Aquaculture Science (CEFAS).

The information has been used to identify key marine resource issues and support decision-making and recommendations in the RESCCUE Marine Diagnosis and Action Plan (2016).

METHODS

The habitat surveys conducted measured three components of the North Efate marine environment: (1) current reef condition, (2) reef recovery post-TC Pam, and (3) coral bleaching severity and extent. The methods used included a benthic photo transect (known locally as Korel Lukluk) with online software analysis (using the SPC Coral Portal), rapid reef health assessments of cyclone damage recovery, and coral bleaching assessments.

Survey sites

The 16 sites selected to conduct the benthic reef health surveys were considered representative of the different fringing reefs in North Efate, including island offshore, island nearshore, and coastal fringing. Surveys were conducted using SCUBA in 6-12 m depth on the reef slope. Three replicate transects were surveyed at each site, at a minimum of 10 m apart in the same depth and within the same habitat type (e.g. reef slope). The start of the first transect at each site was marked using GPS coordinates. Repeat surveys of seven RESCCUE sites assessed in November 2015 for post-TC Pam impacts were conducted to determine recovery and enable statistical analysis of the data (sites RESC 1–11; see Table 1). An additional nine sites were surveyed using Vanuatu Fisheries Department (VFD) benthic sites on Moso and Lelepa Islands (VFD 49, 99, 109, 119), and new sites in the northeast of the project area (RESC 15–19). A map of all sites is provided in Figure 1.

Table 1. RESCCUE survey sites and coordinates from November 2015 and May 2016.

Site number	Site name	Latitude	Longitude	Depth (m)	Tabu area
RESC1	Port Havannah	17.59278	168.24338	9-10	-
RESC2	Tanoliu	17.56666	168.27115	4-5	-
RESC3	Moso (east)	17.54198	168.2702	7-12	Tasariki
RESC4	Moso (east)	17.55506	168.23645	5-7	-
RESC5	Lelepa (east)	17.59417	168.21989	8-10	-
RESC6	Mangaliliu	17.63028	168.20605	5	Mangaliliu
RESC7	Emua	17.53729	168.37587	4-5	-
RESC8	Siviri	17.52205	168.32798	4-6	Siviri
RESC9	West Paonangisu	17.52733	168.39773	4-6	-
RESC10	Saint Lawrence	17.54072	168.33592	4-5	-
RESC11	Lakenasua	17.53925	168.35571	4-6	-
RESC12	Piliura, Pele Island	17.49352	168.39772	5	Pele
RESC13	North Pele	17.47989	168.39584	5-6	-
RESC14	Newora, Nguna Island	17.48215	168.36215	5	Woralaapa
RESC15	East Nguna (sth)	17.47053	168.38768	6-8	-
RESC16	East Nguna (nth)	17.4608	168.38058	5-8	Laonamoa
RESC17	Emao	17.47473	168.47336	5-8	Marou
RESC18	Paonangisu	17.51146	168.41908	3-10	-
RESC19	West Nguna	17.47623	168.35065	5-7	-
VFD 49	Moso (west)	17.51965	168.25281	6	-
VFD 99	Lelepa (west)	17.57467	168.21198	6-8	-
VFD 109	Lelepa (west)	17.59446	168.19614	10	-
VFD 119	Lelepa (west)	17.61288	168.21247	6-8	Natapau

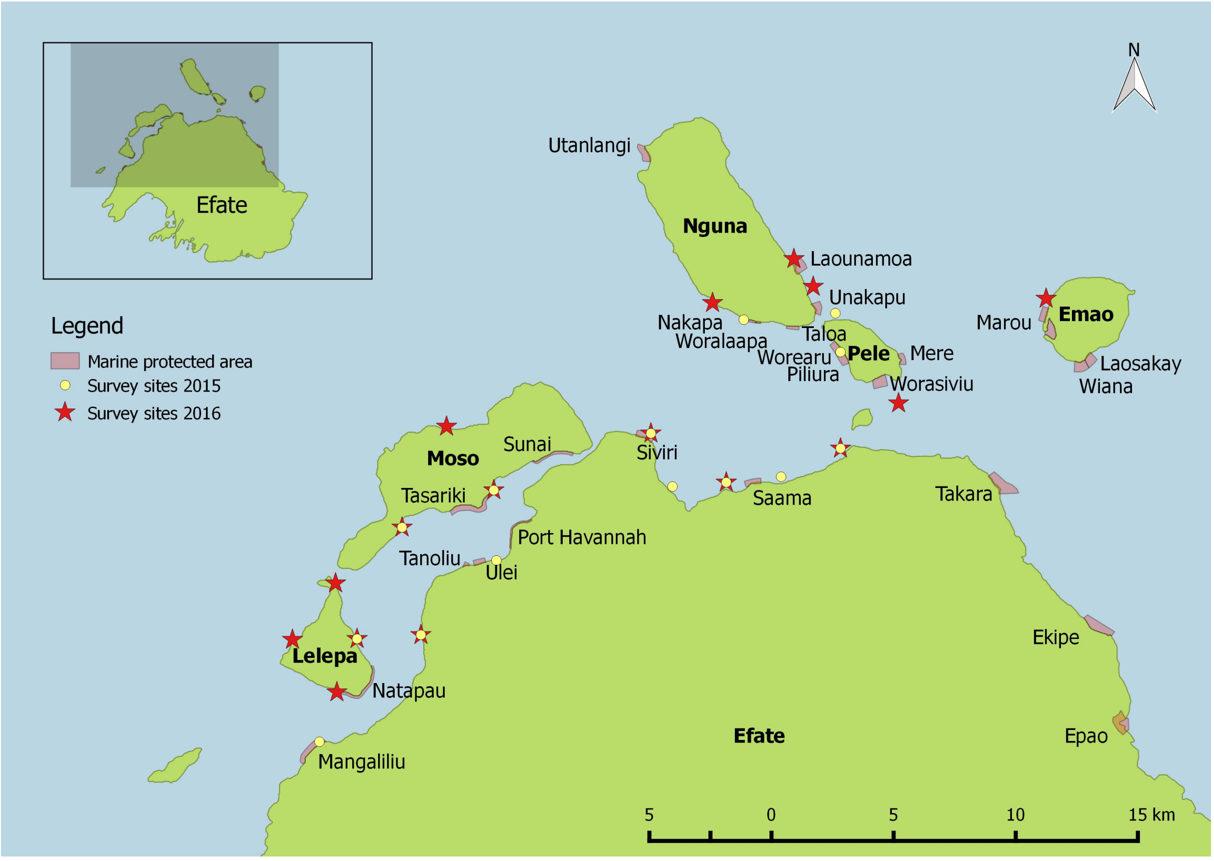

Figure 1. Map of 2015 and 2016 reef survey sites and tabu (marine protected) areas.

Eight survey sites from the two survey periods in 2015 and 2016 are within tabu areas (Table 1). However, a comparison of survey results on reef condition within and outside tabu areas was not possible since many sites were opened to fishing and gleaning after TC Pam. Any comparison of results with protection status would require further investigation of current fishing practices, and dates of reopening tabu areas, and would be useful for any future reviews of specific tabu area effectiveness.

Korel Lukluk

The benthic photo transect method was based on the Korel Lukluk method used by VFD developed by the L'Institut de recherche pour le développement (IRD) (Dumas et al. 2009). For each site, three replicate transect lines (20 x 1 m) were placed on the reef slope along the same depth contour. The transect lines were defined by a colour-marked survey tape attached to the substrate. Distance between the three replicates was at least 10 m. Photos were taken from 1 m above the substrate using a standard Canon D30 Powershot underwater camera, at 1 m intervals, to cover the entire transect area. High quality photos captured by this 12 Mpixels camera are 4000 x 3000 pixels in size. As frame area can differ slightly between transect photos, a colour-mark was included in each frame to help delineate the frame area captured by the camera. Each image was taken from directly above (perpendicular to) the transect line so as to avoid image distortion. No optical zoom was used.

Image processing

Digital images from each transect line were imported to Coral Portal[1], an online analysis tool maintained by SPC. The images were analysed for: (1) substrate composition (sand, coral, rubble, crustose coralline algae or live rock, macroalgae), (2) coral composition (by family or genus), (3) percentage and size of juvenile corals, and (4) percentage of coral bleaching.

Coral bleaching assessment

The rapid reef health assessment method was used to quantify benthic (substrate) composition, incidence of threats or impacts, trends over time (where 2105 sites were resurveyed in 2016), and key biota presence/absence. The coral bleaching assessment method was used when bleaching had been observed, to quantify the severity and extent of coral bleaching. The assessments were conducted using SCUBA to assess the types of corals affected, the proportion of those coral that are bleached and the severity of bleaching on a 4-point scale (1=upper tips, 2=pale or fluorescent, 3=totally white, 4=recently dead). The coral bleaching assessment provides a snapshot of current bleaching conditions, and impact extent. The coral bleaching assessment provided a snapshot of current site condition, and bleaching impact severity and extent.

The observer swam the same three replicate transect lines (20 x 1 m) placed on the reef slope for the photo transects, along the same depth contour. The distance between the three replicates was at least 10 m. The observer recorded the site details (depth, visibility, habitat type, complexity, temperature), substrate composition, macroalgae and coral cover, coral life forms, and proportion of coral bleaching and severity for each replicate. Notes were taken on juvenile coral presence and size.

Data analysis

The survey data from the three transects (20 x 1 m) was averaged for each site and analysed for substrate cover, coral cover, macroalgae cover, coral lifeforms, percentage of each coral lifeform showing signs of bleaching (upper surfaces, fluorescent or totally white), percentage of coral recently dead (in the last 1-2 months and most likely the result of bleaching stress), and signs of other impacts, such as disease, predation by crown-of-thorns starfish (COTS) or drupella or anchor damage. These data were used to assess the extent and severity of thermally-driven coral bleaching, and provide fundamental reef health information for each site.

RESULTS

The impacts of climate change, including increased intensity of extreme events, higher temperatures, and changes to agricultural productivity and water availability, are being felt across Vanuatu, and are projected to increase in the future. Climate change projections are that average maximum surface temperatures will increase, rainfall will most likely increase and become more extreme, extreme temperatures will increase in frequency, number of dry days will increase, sea level will rise, ocean circulation will change, and ocean pH will decline causing acidification that will impact significantly on coral reefs (BoM and CSIRO 2014).

The results of the Participatory Rural Assessment (PRA), Vulnerability Risk Analysis (VRA), and Drivers, Pressures, State, Impacts, and Responses Analysis (DPSIR) undertaken in North Efate for this IDD, suggest the environmental issues of North Efate fall within four primary categories:

[1] www.spc.int/coastalfisheries/cpc

- Impacts from extreme weather events, such as TC Pam;
- Marine and fisheries declines;
- Terrestrial resource; and
- Water resources.

Extreme Weather Events: Tropical Cyclone Pam

Vanuatu is extremely vulnerable to a range of natural hazards. In a report for the International Decade for Natural Disaster Reduction for the Pacific Island Countries, Vanuatu was classified as highly vulnerable to natural hazards, including cyclones, storm surge, coastal flood, river flood, drought, earthquakes, land-slides, tsunami and volcanic eruptions. Vanuatu is also vulnerable to anomalously long dry spells and prolonged wet conditions associated with the El Nino (warm phase) and La Nina (cool phase) of the El Nino-Southern Oscillation. Since 1939, Vanuatu has experienced 124 tropical cyclones, of which 45 were categorised as having hurricane force winds. Several of these disasters have caused loss of human life, disrupted livelihoods and resulted in millions of dollars of damage to infrastructure.

Extreme weather events, such as severe tropical cyclones, are projected to become more frequent in Vanuatu, with climate change projections of an increase in the maximum intensity of tropical cyclones as the mean global temperature rises, of between +3% to +21% by 2100, or between +2% and +11% if expressed as maximum wind speed (Knutson et al. 2010). Ultimately, tropical cyclone numbers are projected to decline in the southwest Pacific in the future but those that do occur are likely to be more intense (BoM and CSIRO 2014).

The most recent tropical cyclone to hit Vanuatu was TC Pam. This was a category 5 (severe) storm with sustained winds of 269 km/h when it passed the east coast of Efate on 13 March 2015 (Emergency Response Coordination Centre[2]). Coastal and island communities, fringing reefs, beaches and coastal habitats of northeast Efate were severely impacted by TC Pam. Within the project area, the north-east was most severely impacted, as evidenced by damage to villages, public infrastructure and shorelines, and the north-west was the least affected (Government of Vanuatu 2015).

The people of North Efate report that the devastation caused by TC Pam was much worse than was expected, despite extensive cyclone warnings and preparation in many communities (primarily driven by the Red Cross). In the aftermath of TC Pam, conservation areas were opened to fishing throughout Efate, creating additional pressure on already depleted fisheries. Current drought conditions that are the result of the a strong El Nino event have decreased agricultural production and are also increasing demand for and pressure on marine resources.

Post-cyclone rapid reef surveys conducted at 14 sites by RESCCUE in November 2015 documented average hard coral cover of 19.5% and 39% on north and north-west reefs, respectively (Figure 2) but could not access the most impacted north-east reefs due to bad weather at the time of the surveys. These data represent a decline in coral cover from previous surveys (noting that site locations and methods vary), and are most likely the result of TC Pam damage. The earliest surveys from 1989 after TC Bola recorded average coral cover of 20.5% on north-west reefs (Done and Navin 1990). In 2004, coral cover in north Efate was 60–75% (Pakoa 2007), and surveys in 2006-2007 recorded average

[2] http://ec.europa.eu/echo/what/civil-protection/emergency-response-coordination-centre-ercc_en Accessed November 2015

hard coral cover of 49% across 11 sites in north Efate (Raubani 2009), representing the highest coral cover of all reefs surveyed in Vanuatu at that time. Unpublished Reef Check surveys in 2009 recorded the lowest coral cover for north Efate sites of 7–16%, which is substantially lower and is likely to be due to predation by crown-of-thorns starfish that was first observed in 2004.

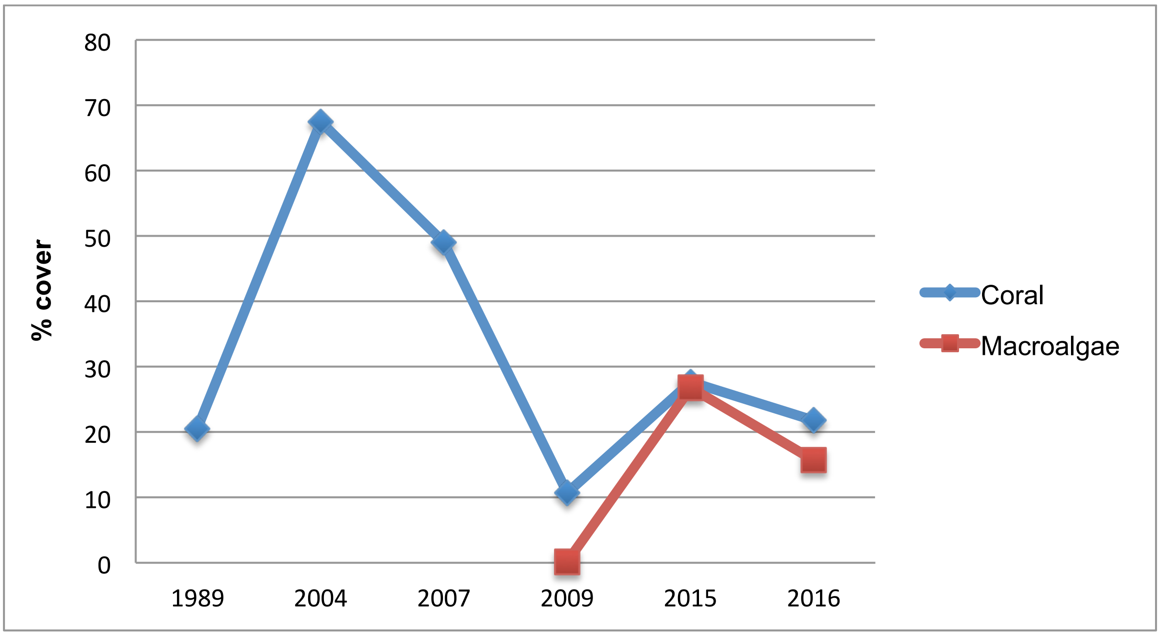

Figure 2. Percentage of live hard coral and macroalgae cover for reefs in North Efate using available survey data since 1988.

Notably, the 2015 rapid surveys documented macroalgae cover on northern reefs of 26–55%, which is considerably higher than on north-west reefs, where macroalgae cover was an average of 16%, and in previous surveys of the same region. This increase in macroalgae cover mirrors a decline in coral cover from 2009 when many sites in North Efate were experiencing a COTS outbreak. Unfortunately there are no long-term records of macroalgae cover. The presence of high macroalgae cover can be an indicator of recent disturbance, which has been observed after tropical cyclones in other regions (e.g. Chin et al. 2006, GBRMPA 2011). The spatial patterns of impact severity documented are consistent with proximity to the path of TC Pam, and reef recovery will depend on:

- reef condition prior to the cyclone;
- absence of other perturbations, including human pressures such as land-based pollution and overfishing; and
- the return period between disturbances.

Repeat surveys at 16 sites in May 2016 (7 at the same locations; see Figure 1) documented average hard coral cover of 22% on all reefs (Figure 2), with significant spatial differences in both coral and macroalgae cover. The reefs in the northwest sub-region, around Moso and Lelepa Islands, and Emao had relatively high hard coral cover and low macroalgae cover, while reefs in Undine Bay and around Nguna-Pele islands had low coral cover of approx. 5% and higher macroalgae cover of 48% and 25%, respectively (Figure 3).

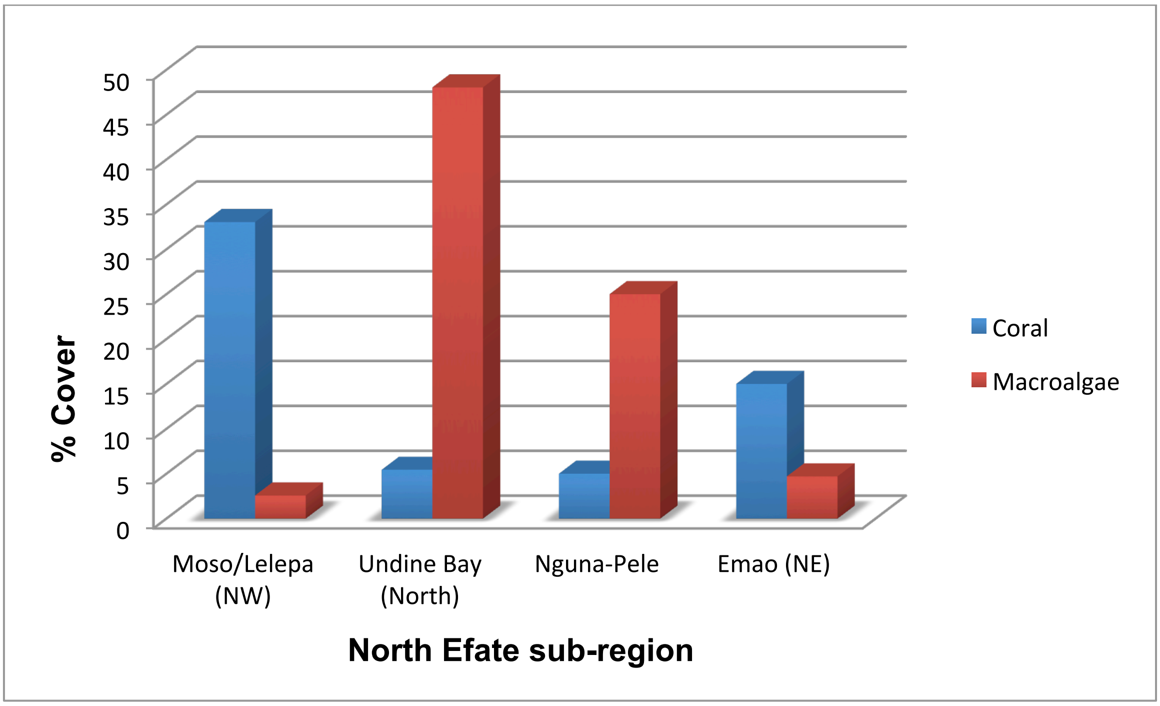

Figure 3. Results of 2016 reef survey for coral cover (%) and macroalgae cover (%) for 4 monitoring sub-regions.

All reef sites surveyed had moderate to high coral diversity (except Lakenasua in the north), consistent with previous surveys. The surveys in 2016 documented high numbers of juvenile corals at some sites that had low overall coral cover, consistent with recruitment and recovery post-TC Pam. Although post-cyclone reef data is limited, there is some evidence after TC Bola (1989), TC Dani (1999) and now TC Pam (2015) that the coral reefs of north Efate have a natural resilience to physical disturbances.

Crown-of-thorns starfish

Outbreaks of coral-eating crown-of-thorns starfish or COTS (*Acanthaster planci*) present a potential threat to reef condition and ultimately food security and income. COTS outbreaks were documented in the reefs of North Efate and the surrounding islands of Emao, Nguna, Pele, Moso and Lelepa in 2006, 2008, and 2014 (Dumas et al. 2014). COTS populations are described as an outbreak when they reach densities where the starfish are consuming coral tissue faster than corals are known to grow (Osborne et al. 2011). Local tourism operators and fishers are usually the first to observe increased COTS densities, and have identified this as a significant issue to the condition of the reefs that they depend on for their livelihoods.

Reef surveys in 2016 identified sites that were most likely impacted by COTS predation in the last 2-3 years, as reef structure remained intact but most corals were long-dead and overgrown by macroalgae. This was particularly evident at sites on the north Efate coast – Lakensua and Siviri –

that also had low live coral cover, 3% and 5% respectively. These sites also had the highest macroalgae cover of all sites surveyed, of 67% and 51%, respectively.

Current control programmes use manual collection and shore disposal of individual COTS, and since 2006, some SCUBA operators have done this on key dive sites at their own expense. Village-scale control programs through local NGOs (e.g. TasiVanua) are also undertaken with variable success. Ultimately, long-term solutions lie in understanding and mitigating the causes of COTS outbreaks in North Efate. The current scientific consensus is that COTS outbreaks can be influenced by a range of anthropogenic changes, including nutrient-driven increases of larval prey (large phytoplankton) availability and removal of adult or larval predators (Brodie et al. 2005, Fabricius 2010).

Coral bleaching 2016

Reef surveys in 2016 at 14 sites documented a high percentage of bleached corals at sites in Havannah Bay, and Nguna Island (Figure 4). Low bleaching levels were observed at sites on the exposed sides of Moso and Lelepa islands, and in Undine Bay (Figure 4), although this latter observation is likely due to the low coral cover. Most corals that were bleached had either their upper surfaces bleached, or were fully white. No recent mortality was observed in August 2016.

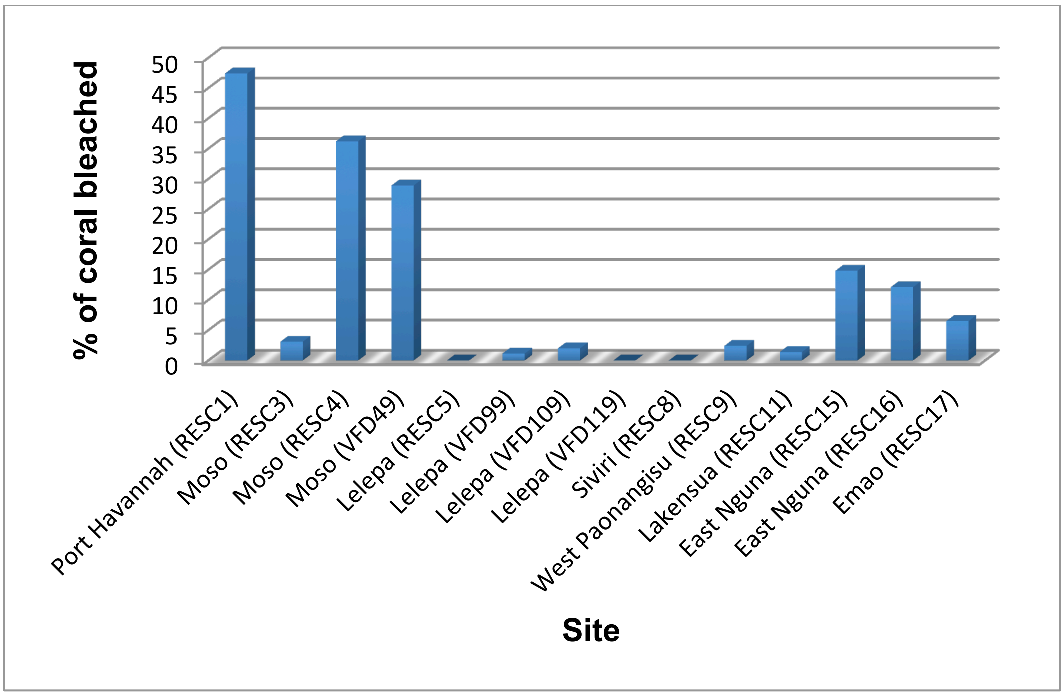

Figure 4. Results of 2016 coral bleaching surveys with the percentage (%) of coral showing signs of thermal bleaching – upper surfaces, paling, fluorescent or totally white – for all sites surveyed.

The results were spatially variable, with some sub-regions in North Efate experiencing greater bleaching than others. Sites on the northwest around Moso and Lelepa islands, and around Nguna and Pele islands experiencing the highest percentage of bleached corals, at 14% and 13% respectively (Figure 5). In comparison, reef sites in Undine Bay and around Emao had lower levels of coral bleaching (Figure 5).

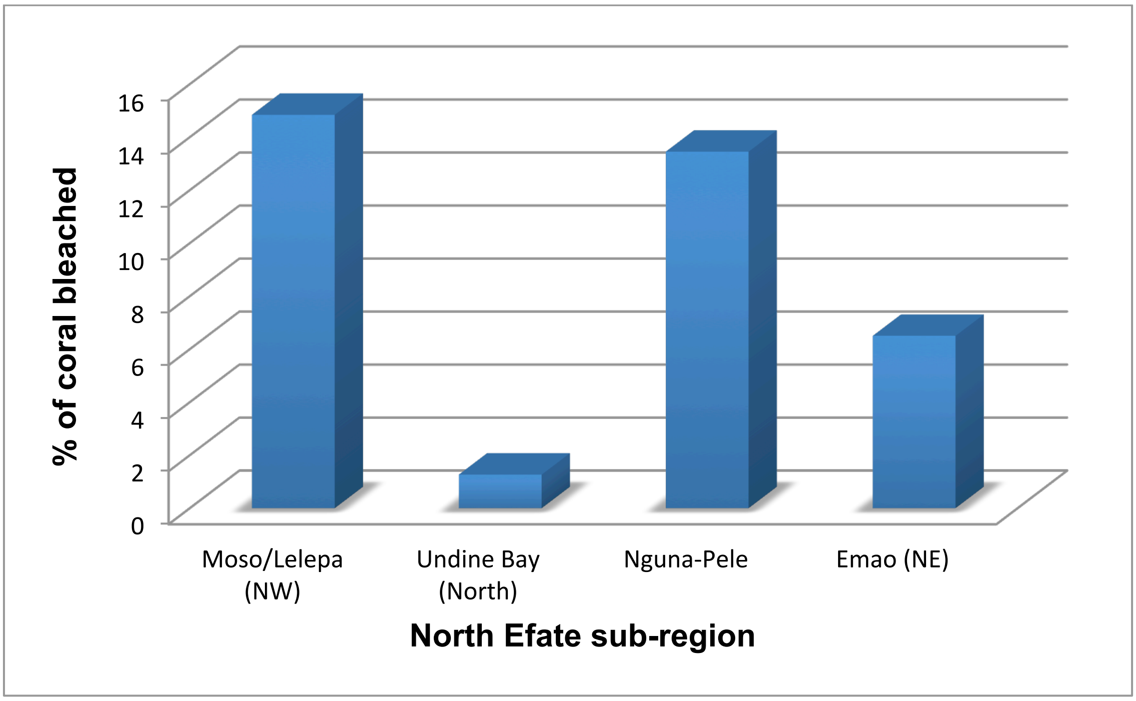

Figure 5. Results of 2016 coral bleaching surveys showing percentage (%) of coral showing signs of thermal bleaching – upper surfaces, paling, fluorescent or totally white – for 4 monitoring sub-regions.

While qualitative analysis of coral diversity and juvenile density is underway, a summary of results by reef site are provided in Table 2. These results show that at some sites live coral cover declined between 2015 and 2016 surveys, particularly at Moso east (RESC4), Siviri, West Paonangisu, while at other sites coral cover has increased – Moso east (RESC3) and Lelepa east. This is most likely due to the different survey depths and will be further investigated once the quantitative results are complete.

Table 2. Summary of reef indicator results for all reef surveys in North Efate. Structural complexity is measured on a 5-point scale, from smooth substrate (=1) to highly complex (=5). Coral diversity is measured

Site number	Site name	Structural complexity	Live coral cover (%)*	Macroalgae cover (%)*	Coral diversity
RESC1	Port Havannah	2	32/37	15/1.3	moderate
RESC2	Tanoliu	3	47	14	moderate
RESC3	Moso (east)	4	56/78	8/6	high
RESC4	Moso (east)	3	28/13	12/2	high
RESC5	Lelepa (east)	4	36/70	10/3	moderate
RESC6	Mangaliliu	3	33	38	high
RESC7	Emua	3	17	55	high
RESC8	Siviri	4	12/5	26/51	high
RESC9	West Paonangisu	3	26/8	31/27	high
RESC10	Saint Lawrence	2	23	26	high
RESC11	Lakenasua	2	7/3	42/66	low
RESC12	Piliura, Pele Island	2	9	28	moderate

RESC13	North Pele	2	27	28	moderate
RESC14	Newora, Nguna Island	2	34	43	moderate
RESC15	East Nguna (sth)	3	5	30	low
RESC16	East Nguna (nth)	4	5	20	low
RESC17	Emao	5	15	4.7	high
RESC18	Paonangisu	n/a			
RESC19	West Nguna	n/a			
VFD 49	Moso (west)	2	10	3	high
VFD 99	Lelepa (west)	4	19	3	high
VFD 109	Lelepa (west)	4	17	1.3	moderate
VFD 119	Lelepa (west)	4	20	0.7	high

* Data provided for 2015 and 2016 where both available.

Water Quality

Water quality sampling in Efate focused on areas around Mele Bay and Havannah Harbour. The water quality sampling included collection of samples for total and dissolved nutrients, coloured dissolved organic matter (CDOM), chlorophyll-a and contaminants. Initial results for North Efate sites are shown in Table 2. Salinity ranged from 34 – 35 ppt, with most sites classified as full ocean sites. Dissolved oxygen values were high, with concentrations above 8mg/L for all North Efate and Mele Bay sites. CDOM was very low (below detectable limits) indicating that freshwater influence around the sites was minimal at the time of sampling. Tryptophan, measured as a proxy for sewage contamination, was very low, indicating little sewage contamination around the sites.

Table 3. Water quality results for North Efate samples collected in May 2016.

Name	Area	RESCCUE site	Sample Depth	Salinity	DO (mg/L)	pH	Temp	Avg CDOM (µg/L)	Avg Tryptophan (µg/L)	Avg CDM/Try	Deltatox % normal
Middle Mele Bay	Mele Bay	-	0.5	34.4	8.10	8.25	28.2	0.00	0.39	0.00	92
Panjo Point	Mele Bay	-	0.5	34.4	8.10	8.23	28.2	0.00	0.59	0.00	93
New Port Marina Site	Mele Bay	-	0.5					0.00	0.58	0.00	102
Lelepa (outside)	Port Havannah	VFD 99	0.5	34.4	8.29	8.22	28.2				92
Lelepa (outside)	Port Havannah	VFD 119	0.5	34.5	9.33	8.26	28.5				97
Moso (lee)	Port Havannah	4	0.5	34.4	7.86	8.18	28.1	0.00	0.66	0.00	113
Moso (lee)	Port Havannah	3	0.5	34.4	7.73	8.20	28.0	0.00	0.54	0.01	112
Moso (outside)	Port Havannah	VFD 49	0.5	34.5	8.26	8.25	28.2	0.00	0.65	0.00	114
East Nguna (sth)	Port Havannah	15	0.5	34.5	7.99	8.24	27.0	-0.01	0.26	0.00	87
Emao (lee)	Port Havannah	17	0.5	34.2	8.38	8.27	28.3	0.00	0.67	0.00	100
Samoa Point Harbour - 1	Port Havannah	-	0.5	34.4	8.30	8.22	28.2				111
Samoa Point Harbour - 2	Port Havannah	-	0.5	32.8	5.02	7.90	27.5				124

Samoa Point Harbour - 3	Port Havannah	-	0.5	33.8	7.16	8.11	27.7	2.74	2.66	1.09	123

Toxicity at each site was assessed using a test of the effect of water samples on the survival of the bacteria, *Vibrio fisherii*. Nutrient data showed generally low concentrations of dissolved and total nutrients, however higher concentrations of dissolved inorganic nitrogen (DIN, uM) were measured at Mele Bay Sites and Samoa Point Harbour (Figure 6).

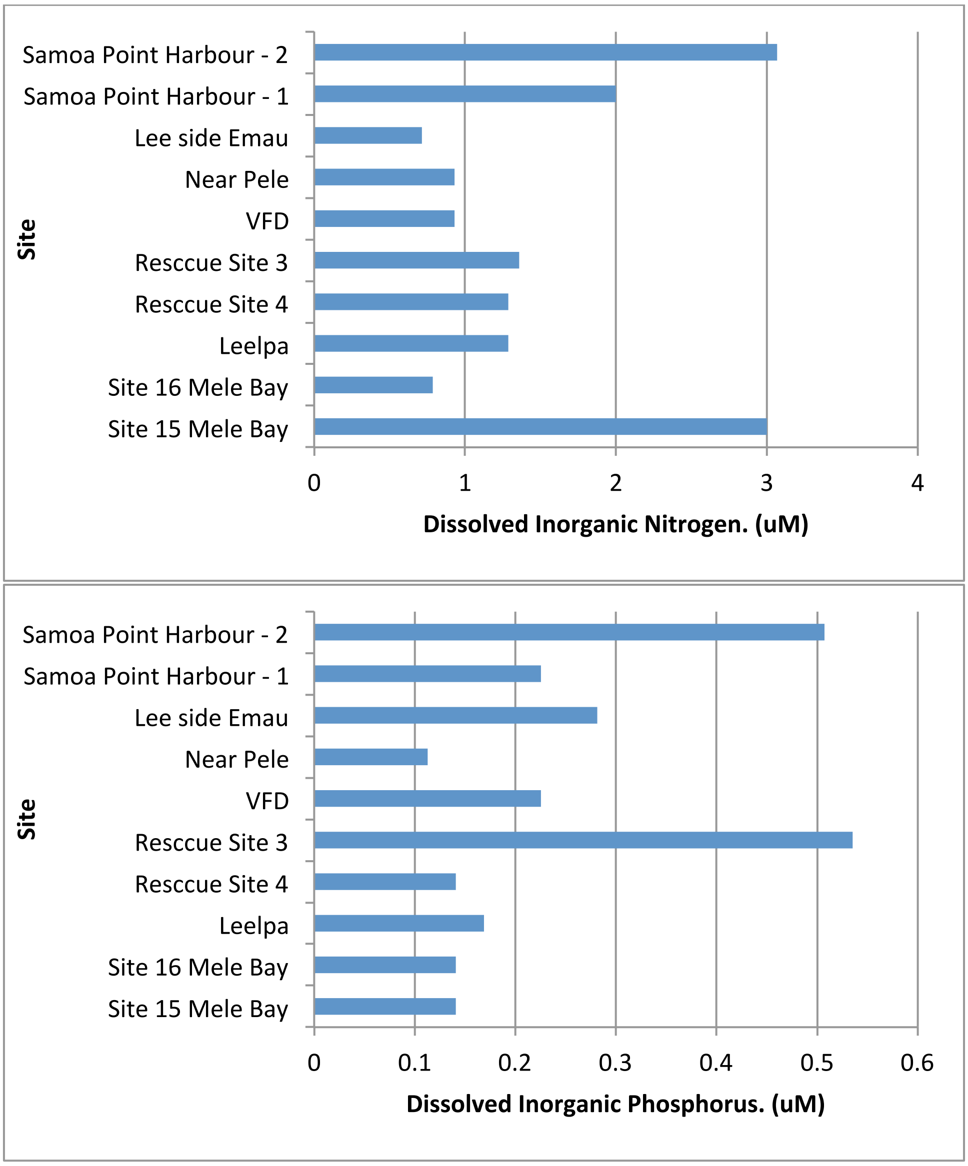

Figure 6. Concentrations of dissolved inorganic nitrogen and dissolved inorganic phosphorus in North Efate sites sampled in May 2016.

The samples were collected in May 2016, after an extended dry season, and thus are representative of low to no flow river conditions. Further sampling during the onset of the wet season would provide additional information on longer-term land-based water quality impacts on North Efate reefs. Although this initial sampling shows no sign of toxicity and low freshwater influence, some elevated nutrients were detected at Samoa Point, indicating possible coastal runoff. Additional samples taken from depth profiling show high fluorescence, which is indicative of high chlorophyll–a concentrations (above 1ug/L), which also indicate increased productivity. However, these measurements have not been fully validated at present. Concentrations of most parameters tested in North Efate sites were lower than for samples collected around Port Vila during the same sampling period.

CONCLUSIONS AND RECOMMENDATIONS

The RESCCUE reef surveys have documented for North Efate reef condition post TC Pam, as well as during the 2016 coral bleaching event at 16 sites. The results demonstrate that TC Pam damage was spatially variable, with reefs in the northeast and north being the most damaged by the cyclone. It also showed greatest damage in shallow areas, which is to be expected. Similarly, results show that coral bleaching was spatially variable with some reefs having more bleaching than others. This is most likely a consequence of local environmental conditions, such as depth, currents and tides, thermal history and species composition that have been shown to influence response and resistance to thermal stress (Maynard et al. 2010, 2015). In addition, some reef sites have been severely impacted by COTS outbreaks since 2004 and have very low coral cover (less than 5%).

Importantly, many reefs impacted by TC Pam were showing signs of recovery in May 2016, with coral growth and juvenile corals evident. Most reef sites had started to recover from bleaching within two weeks of the surveys in May 2016. Unfortunately, reef sites that were severely impacted by COTS outbreaks do not appear to be showing the same signs of recovery, which may be due to the fact that these reefs are so depauperate that there are not enough recruits from these sites or nearby reefs.

Recommendations

1. Severely degraded coral reefs in North Efate should be prioritised for management to minimise other pressures and allow natural recovery.
2. Healthy reef sites that have shown they are resilient to disturbances such as tropical cyclones and coral bleaching, should be considered in light of their current protection status to determine if they require protection or a management plan to maintain their condition.
3. Monitoring of community marine areas is essential to determine if current management is effective, and ensure sustainable management actions are either enforced or put in place.
4. Awareness raising and capacity building within the Nguna-Pele and TasiVanua Resource Networks is essential to empower community-based monitoring and management that addresses human activities impacting reefs in North Efate.

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APPENDIX A: COMMUNITY-BASED TABU AREA MAPS AND SURVEY QUESTIONS