Pacific Community
Communauté du Pacifique

RESCCUE

CLIMATE CHANGE IMPACTS IN NORTH EFATE, VANUATU

AGENCE FRANÇAISE DE DÉVELOPPEMENT

FONDS FRANÇAIS POUR L'ENVIRONNEMENT MONDIAL

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Date of publication
March 2016

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ABBREVIATIONS AND DEFINITIONS

CBAP	Capacity Building and Awareness Plan
CCA	Climate Change Adaptation
CCCPIR	Coping with Climate Change in the Pacific Island Region
CRISP	Coral Reef Initiatives for the Pacific
DPSIR	Drivers, Pressures, State, Impacts, and Responses Analysis
ENSO	El Niño Southern Oscillation
FAD	Fish Aggregating Device
GIZ	Deutsche Gesellschaft für Internationale Zusammebarbeit (a German-based development project management organisation)
ICM	Integrated Coastal Management
IDD	Initial Diagnosis Document
IPCC	Intergovernmental Panel on Climate Change
KfW	German Development Bank
NGO	Non-Governmental Organisation
PICT	Pacific Island Countries and Territories
RCP	Representative Concentration Pathways (from IPCC AR5)
RESCCUE	Project name, representing the activity of 'Restoration of ecosystem services and adaptation to climate change'
SPC	Pacific Community / Communauté du Pacifique (formerly known as Secretariat of the Pacific Community)
SPREP	Secretariat of the Pacific Regional Environmental Programme
SRES	Special Report on Emissions Scenarios (from IPCC AR4)
VFD	Vanuatu Fisheries Department
VNSO	Vanuatu National Statistics Office

1. INTRODUCTION

The Pacific Islands region is extremely vulnerable to the impacts of climate change due to a number of inter-connected factors relating to the biogeography and socio-economic profile of small island countries. Key among these are:

1. The concentration of settlements within the coastal zone;
2. A high reliance on coastal and marine resources for livelihoods and food security;
3. Exposure to ocean influenced hydro-meteorological hazards such as tropical cyclones and storm surges;
4. Limited freshwater availability due to small water catchments;
5. Fragility of ecosystems to disturbance;
6. Modification of coastal and terrestrial habitats;
7. Small economies;
8. Geographic and biological isolation from mainlands.

Vanuatu is one such vulnerable Pacific nation, and the RESCCUE (restoration of ecosystem services and adaptation to climate change) project is working in the north of Efate Island, from Mangaliliu village in the northwest to Epao village in the northeast (inclusive; see Figure 1) to promote climate change adaptation. The communities in North Efate have certain characteristics that promote the resilience[1] of their people and environment to the impacts of climate change, and will facilitate effective adaptation. These characteristics include:

1. A high level of biodiversity within marine, coastal, and terrestrial ecosystems;
2. The presence of fringing reefs and islands that provide physical protection from storms;
3. A relatively low population that is scattered over a number of small village communities;
4. Well-developed knowledge of environmental processes and conditions due to the close relationship between people and ecosystems;
5. A history of coping with adverse physical conditions and environmental change; and
6. Access to markets and alternative livelihood options.

The RESCCUE project site includes the islands of Nguna, Pele, Lelepa, Emao and Moso and almost 50 km^2 of marine ecosystems (coral reefs, seagrass meadows, lagoons, mangroves and beaches), 180 km^2 of terrestrial ecosystems (including forests) with a total population of approximately 8,000 people (VNSO 2009). The project area also includes an established network of marine protected areas at Nguna-Pele, as well as multiple community-managed tabu (protected) marine areas. The Vanuatu RESCCUE project commenced in October 2015 with comprehensive stakeholder engagement to identify natural resource dependencies, key environmental issues and threats, resilience attributes and possible climate change adaptation opportunities.

This Study on Climate Change Impacts and Adaptation Actions in North Efate seeks to:

1. Synthesise existing knowledge about current and projected local climate change impacts, both positive and negative;

[1] The capacity to withstand and recover from disturbances, or resilience (Gunderson and Pritchard 2002), is often described as the maintenance or return to a stable state (Nyström et al. 2008).

2. Clarify and improve the contribution of identified Integrated Coastal Management (ICM) activities to climate change adaptation; and
3. Identify other activities contributing effectively to climate change adaptation that will be implemented in collaboration with local authorities and stakeholders.

Climate Change Adaptation (CCA) measures will be a fundamental component of all ongoing RESCCUE activities. The thematic study areas and ICM will contain CCA measures based on knowledge of potential climate change effects and engagement with communities. It was therefore agreed[2] with the Pacific Community (SPC) that this submission is an 'interim' study that will be finalised as part of the North Efate ICM Plan (due 15 February 2017). This allows the CCA options to evolve with the development of the thematic deliverables and the development of the ICM and through stakeholder engagement. The CCA options will become a component of the ICM, directing actions and adding greater value to the ICM document.

This study therefore principally addresses objective 1 above, providing a summary of existing knowledge on current and projected local climate change impacts. The study addresses objectives 2 and 3 in part as it also sets out the steps the RESCCUE project will undertake to improve the contribution of ICM and related activities in CCA and the approach the RESCCUE project will apply to achieve this in collaboration with key stakeholders.

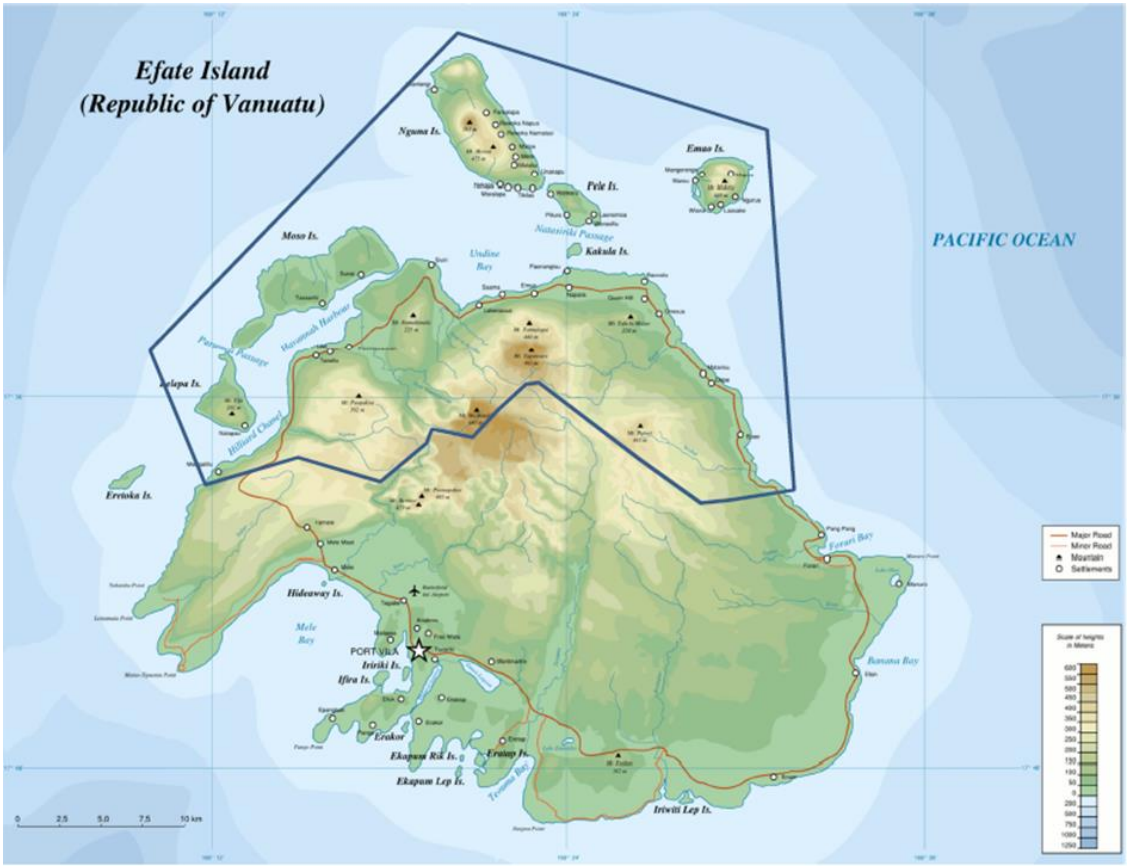

Figure 1. North Efate RESCCUE Project Area

[2] R. Billé, personal communication, 29 September 2015.

2. APPROACH

2.1 Identifying Adaptation Actions

A key consideration of the North Efate ICM will be to incorporate current knowledge on the potential impacts and risks from climate change so that all RESCCUE activities include effective adaptation measures. The RESCCUE team, in consultation with local communities and stakeholders, will determine how ICM activities can help communities adapt to future climate change risks to improve community and ecosystem resilience, and the types of activities needed to achieve this.

Due to the spatially extensive nature of climate change impacts and the interconnected responses required, adaptation and resilience measures will be discussed in collaboration with all stakeholders and will be determined as an integral part of the ICM development. All measures proposed will be consistent with the *Vanuatu National Climate Change Adaptation Strategy 2011*, and where appropriate, will seek to be collaborative with other applicable climate change related projects in or adjacent to North Efate.

2.1.1 Community Vulnerability Assessment

In North Efate, marine ecosystems provide important goods and services for coastal and island communities, particularly food security, livelihoods, income and coastal protection. The implications of climate change on food security and livelihoods are significant and in combination are likely to present a major challenge for dependent communities. A community-scale assessment of the vulnerability of dependent communities to the projected impacts of climate change on marine ecosystems and the goods and services they provide is underway in the 23 North Efate villages. The assessment considers implications of climate change on fish and invertebrates targeted for food security, income from fisheries and tourism for livelihoods, employment in aquaculture, and reef area as a proxy for coastal storm protection. The semi-quantitative assessment uses a series of indicators to score and rank each village on a 3-point scale (1=low, 2=medium, 3=high) based on their: *Exposure* to marine habitat changes and degradation; *Sensitivity* to declines in ecosystem goods and services; and *Adaptive Capacity* based on social indicators of health, education, size of the economy and governance (see Johnson et al. 2015). The results of the community vulnerability assessment will identify which communities are most vulnerable to projected climate change and the drivers of this vulnerability, which will inform the identification of effective adaptation actions for inclusion in the ICM. It will be important to balance the output of the community vulnerability assessment with any identified positive effects of climate change.

2.1.2 Thematic Diagnoses and Action Plans

Adaptation actions will also be included in the thematic diagnoses and action plans that will be developed in the lead up to the development of the North Efate ICM. These thematic diagnoses and action plans include:

- Waste and wastewater management;
- Invasive species;
- Ecological restoration and rehabilitation;
- Sustainable fisheries;
- Community based protected areas; and

- Alternative income generating activities.

The thematic diagnoses and action plans will identify activities that take into account anticipated impacts of climate change and help build community resilience. The diagnoses and action plans will build on the areas of community vulnerabilities identified in the Initial Diagnosis Document (IDD) and seek to strengthen community's ability to use natural resources and economic and financial mechanisms to support development. They will need to address current and anticipate environmental changes and risks through climate change, environmental degradation or the onset of natural hazards. Through the strengthening of resource management in North Efate, community resilience to climate change should also increase. This resource management will be a key component to the North Efate ICM.

2.2 Mainstreaming Climate Change Adaptation

The ICM will identify climate change and adaptation measures at a range of spatial and government levels to facilitate mainstreaming of adaptation in decision-making for North Efate. Substantial work has already been undertaken within Vanuatu and North Efate to mainstream climate change adaptation under the *Coping with Climate Change in the Pacific Island Region* (CCCPIR) programme. The CCCPIR programme has enabled mainstreaming at the national level, including an amendment of the *Environmental Management and Conservation Act 2002* and associated Regulations, as well as the mainstreaming of climate change in an amendment to the *Foreshore Development (Amendment) Act 2013*.

At the sectoral level, CCCPIR has completed a revision and mainstreaming of the National Forest Policy, and is working with the National Provident Fund to mainstream a new Livestock Investment Scheme. Recently CCCPIR initiated a programme to mainstream climate change considerations into land use planning including the development of a draft *National Land Use Planning Policy*, and revising the Land Lease Issuance process to include climate change adaptation and disaster risk reduction considerations. CCCPIR has also developed a draft *National Climate Change Communication Strategy*. Recently the Vanuatu programme has joined forces with the Vanuatu Meteorology Services to develop Seasonal Climate Forecasts with adaptation advice to farmers. SPC has also started a new KfW Development Bank (German aid) funded project that focuses on post-Tropical Cyclone (TC) Pam fisheries sector rehabilitation that will be conducting complementary activities in North Efate. The RESCCUE project will build on all this work through established relationships with government agencies to identify areas where climate change can be incorporated into regulations and policy. In addition, the RESCCUE project will endeavour to effectively collaborate with other programmes to share information and implement joint activities, where possible.

2.3 Communication and Engagement

Community education and engagement on climate change and potential local impacts is an important component of building local capacity to adapt to climate change. The RESCCUE team will work with stakeholders to document traditional knowledge, and identify knowledge gaps and areas to focus education and awareness raising. Community engagement undertaken by the RESCCUE Project has shown that there exists considerable knowledge of climate change and natural variability. Largely because communities depend on the resources of the land and sea and have first-hand knowledge of the changes and effects taking place in their region. However, there are some gaps in

their knowledge and any community education or awareness raising activities will build on existing knowledge and seek to fill critical these gaps.

The capacity building required has been set out in the Vanuatu RESCCUE Capacity Building and Awareness Plan (CBAP). Required capacity building includes:

- Training on climate change, its drivers and impacts;
- Adaptation and how communities can adapt to change; and
- Ways of communicating and sharing knowledge about climate change for chiefs as the key decision makers in the communities.

Based on current community awareness and capacity building needs, the RESCCUE project and its activities will take a collaborative approach working with communities to address the issues that are important to them and minimise their vulnerability to climate change. The project will engage with Village Chiefs, Village Councils and committees, existing environmental networks, and make special consideration to young people and women. The RESCCUE project also needs to work closely with the appropriate Vanuatu Government Departments to ensure activities are coordinated and results can be sustainable in the long-term.

Climate change adaption is a key consideration for all activities identified in the ICM. For example, in the agroforestry sector, improved and sustainable agricultural techniques will be implemented in partnership with landowners to increase resilience to climate change impacts using local resources and benefiting from traditional knowledge and low-carbon solutions. The RESCCUE team will capitalise on existing traditional knowledge and human capital to assist communities to implement sustainable agroforestry models to maintain direct cash-based income from reforestation. In the marine sector, ICM activities will build on and collaborate with existing initiatives at Nguna and Pele to ensure a consistent approach with communities and the transfer of information from pilot programmes to other communities in North Efate.

3. BACKGROUND – CLIMATE PROJECTIONS AND LIKELY IMPACTS IN NORTH EFATE

3.1 Climate Change in North Efate

As an island group in the western Pacific, Vanuatu is exposed to a range of natural climate hazards. In a report for the International Decade for Natural Disaster Reduction for Pacific Island Countries (UNISDR 2005), Vanuatu was classified as highly vulnerable to natural hazards, including tropical cyclones, coastal and river flooding, drought, earthquakes, landslides, tsunami and volcanic eruptions. Vanuatu is also vulnerable to episodic long dry spells and prolonged wet conditions associated with the El Niño (warm) and La Niña (cool) phases of the El Niño-Southern Oscillation (ENSO). In addition, changes to the surface and ocean climate will impact on Vanuatu, including increasing air and sea temperatures, changing rainfall patterns, ocean acidification, altered ocean currents and circulation, and sea-level rise (Bell et al. 2011a).

Changes in air temperature have already been observed in Efate, with maximum and minimum temperatures (measured at Bauerfield Airport, Port Vila) increasing in the period 1948 to 2011 by +0.11 and +0.16 °C, respectively (BoM and CSIRO 2014). The most recent climate projections for Vanuatu by 2100 are that (BoM and CSIRO 2014):

- ENSO will continue to be a source of interannual climate variability;
- Annual mean temperatures and extreme daily maximum temperatures will continue to rise;
- As a result of increasing maximum temperatures, the risk of thermal coral bleaching is expected to increase in the future;
- More extreme rainfall events are expected;
- Ocean acidification will continue; and
- Sea level will continue to rise.

These projections in Vanuatu (including the North Efate project site) under the IPCC moderate emissions scenario (AR4 SRES A2) and very high emissions scenario (AR5 RCP 8.5[3]) for 2030–2035, 2050 and 2090–2100 are summarised in Table 1.

Table 1. Current average climate in Vanuatu, and future projections based on the IPCC AR4 SRES A2 (moderate) emissions scenario (blue) and updated IPCC AR5 RCP8.5 high emissions scenario (red) where available (data sources: Knutson et al. 2010, Ganachaud et al. 2011, BoM and CSIRO 2014).

Climate/ocean feature	1980-1999 average	Projected change		
		2030–2035	2050	2090–2100
Air temperature (°C)	24.2 (Efate)	+0.5 to +1.0	+0.8 to +2.0	+1.9 to +4.0
Sea temperature (°C)	27.1[a]	+0.7 to +0.8	+1.2 to +1.6	+2.2 to +2.7
Rainfall (annual)	2118 mm (Efate)	-6 to +8%	-12 to +14%	-15 to +34%
Rainfall (monsoon)	*n/a*	+1%	+1%	+5%
Tropical cyclones (number per decade)	24[b]	+3 to +21% cyclone intensity, but reduced frequency [c]		
Wave height (m) Dec-Mar/Jun-Sep	1.1/1.3	0/0	n/a	-0.1/0
Sea level (cm)	+6 since 1960	+8 to +18	+17 to +35	+42 to +89
Ocean pH (units)	8.08	-0.4	-0.8	-1.5
Ocean currents	Increase in South Pacific Gyre	SEC decreases at equator; EUC becomes shallower; SECC decreases and retracts west[d]		

a = average for Vanuatu EEZ derived from the HadISST dataset; b = between the 1969/70 and 2010/11 monsoon seasons; c = 2100 regional projections; d = SEC: South Equatorial Current, EUC: Equatorial Undercurrent, SECC: South Equatorial Counter-current.

Since 1939, Vanuatu has experienced 124 tropical cyclones. Several of these severe storms have caused loss of human life, disrupted livelihoods and resulted in millions of dollars of damage to infrastructure. Weather events of increased intensity are projected in Vanuatu, with climate change projections of an increase in the maximum intensity of tropical cyclones (as the mean global sea 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).

[3] RCP8.5 'business-as-usual' high emissions scenario assumes that atmospheric CO_2 concentration rises from present day values of ~400ppm to ~540ppm in 2050.

Changing rainfall patterns are projected with more extreme rainfall events, however there is low confidence in the mean annual rainfall projections, with a range of CMIP5 (Coupled Model Intercomparison Project, Phase 5) outputs for annual average rainfall change from an increase to a decrease, and the model average is near zero. The projection of more extreme rain events (with high confidence) will result in more extreme wet and dry periods, which will impact communities and ecosystems in terms of more extreme flooding and droughts (Bell et al. 2011b).

Average ocean pH in the southwest Pacific is currently ~ 8.1 and varies seasonally and spatially by ~0.3 units due to changes in sea surface temperature (SST) and upwelling of deep waters rich in carbon dioxide (CO_2). Increased emissions of anthropogenic CO_2 have decreased the pH of the tropical Pacific Ocean by 0.06 pH units since the beginning of the industrial era (Raven et al. 2005). The current rate of decrease is ~0.02 units per decade, which is unprecedented in the past 300 million years (Le Quéré et al. 2009). Based on the IPCC RCP8.5 high emissions scenario, tropical Pacific pH is projected to decrease by a further 0.15 units from the historical 1986–2005 period into the 2040–2060 period. Moreover, dramatic changes in aragonite saturation[4] are also projected to occur as a result of changes to pH levels.

3.2 Expected Climate-Related Impacts

In North Efate, the greatest direct impacts from climate change are expected to be due to extreme weather events, such as tropical cyclones, flooding and drought, as well as changes to marine and coastal resources due to increasing SST, ocean acidification, and sea-level rise. The resulting impacts will lead to thermal coral bleaching, compromised reef structure, and physical damage to reefs, seagrass meadows and mangroves, which when combined with other pressures on marine habitats from overfishing and coastal development, will generated greater degradation. Ultimately, habitat declines will impact on the species that depend on these habitats, such as mammals, fish and invertebrates, as well as the communities and industries that rely on these species for food and livelihoods. These direct and indirect effects of climate change are expected to reduce the productivity of coastal fisheries in Vanuatu by 20–50% by 2100 (Bell et al. 2011b).

The increased acidity of seawater is reducing the saturation state of aragonite, the mineral that calcifying organisms, such as corals, certain plankton and shellfish use to build calcium carbonate skeletons. Saturation levels greater than 4 are considered optimal for calcification while levels less than 3.5 are considered very low for a healthy reef system to continue reef-building (Langdon and Atkinson 2005). Saturation levels less than 3 are considered extremely marginal for growth of corals, with no major reef systems currently found at locations with these levels. Model projections suggest that by mid-century the entire tropical Pacific region will have shifted to sub-optimal conditions, with aragonite saturation between 3 and 3.5. This represents a drop of approximately 0.6 in the tropical region, corresponding to a decline in coral calcification rate of about 10% (Chan and Connolly 2013).

Climate change will also drive changes in terrestrial resources. These changes may include:

- Variable freshwater supplies due to more extreme wet and dry periods;

[4] Aragonite saturation is important for marine environments, as the more negative the change in aragonite saturation is, the larger the decrease in aragonite available in the water, and the harder it is for marine creatures to produce their skeletons and shell

- Altered agricultural productivity due to increasing air temperatures, saltwater intrusion from storm surge and sea-level rise, and CO_2 fertilisation effect on plant growth;
- Degraded natural barriers such as mangrove forests being impacted by sea-level rise and severe storms; and
- Compromised coastal infrastructure.

These changes have implications for forest ecosystem diversity and invasive species as well as water management, food security and community safety in North Efate.

Some of the key ecological impacts expected to occur in North Efate due to climate change are presented in Table 2. This list is not exhaustive and there will be flow-on social and economic effects to the communities of North Efate. For example, potential negative effects include increased rainfall extremes becoming more commonplace which may result in shortages of water for even basic uses such as drinking and cooking, depending on water demand and local storage capacity. Reduced productivity of coastal fisheries will result in lower catches and lower incomes with income critical for the purchase of family needs such as store bought food, household expenses and school fees.

Potential positive effects may include increased rainfall providing more water resources which if water storage and distribution infrastructure is improved, will increase available water resources for communities. Increased temperatures and CO_2 fertilisation through greater atmospheric $C0_2$ may lead to greater agricultural production if other limiting factors, such as water supply are addressed.

Table 2. Likely ecological impacts that will be experienced in North Efate based on current climate projections and field studies.

Environmental change	**Likely impact**
Increasing seawater pH	Degradation of coral reef structures; Altered marine species community structure; Reduced productivity of coastal fisheries; Compromised feasibility of mariculture ventures
Rising SST	Increased incidence of coral bleaching further compromising reef resilience; Altered distribution of some fish species (thus reducing catchability)
Altered local currents	Reduced productivity of coastal fisheries
Higher intensity storms/ cyclones	Increase in severe reef and seagrass damage further exacerbating other impacts; Increased damage to agricultural crops; Increased damage to aquaculture facilities and other infrastructure
Higher rainfall extremes (more drought/ flood events)	More variable water supply; Increased food crop damage/ failures; Increased variability in coastal fisheries production (less certainty in catches); Increased habitat damage due to land-based pollutants; Wetter climate periods will increase availability of freshwater habitat for freshwater fisheries production; periods of higher rainfall may assist increased plant growth rates for forests and crops
Rising air temperatures	Increased food crop damage/ failures
Increased atmospheric CO_2 concentration	Atmospheric CO_2 fertilisation of plants in warmer temperatures when water is not limiting may increase plant growth rates in e.g. forests and

	cropping land.
Higher storm surge/ sea level rise	Possible loss of mangroves leading to lower coastal fisheries productivity and compromised coastal protection; Lower agricultural productivity in coastal regions due to saltwater intrusion

4. AREAS OF VULNERABILITY IN NORTH EFATE

Communities in North Efate are almost entirely subsistence based, relying primarily on family run agricultural plots and fishing for food security and livelihoods. They are highly dependent on their natural resources for household food, income, fuel, cultural significance, and disaster recovery. Such high dependence on natural resources, many of which are projected to be impacted by climate change, heightens the vulnerability of North Efate communities to adverse changes. These communities have shown they can recover from the impacts of natural hazards, such as TC Pam and improved sustainable management of their natural resources will help reduce identified areas of vulnerability.

Community consultation by the RESCCUE project in late 2015 consisted of three major activities: Participatory Rural Assessment, Vulnerability Risk Analysis, and Drivers, Pressures, State, Impacts, and Responses Analysis (DPSIR). Through these activities the key areas of vulnerability for North Efate were identified as:

1. Impacts from extreme weather events, such as TC Pam.
2. Degradation of marine environments and fisheries resources.
3. Coastal development that is compromising terrestrial resources.
4. Water insecurity.

4.1 Impacts from Extreme Weather Events

TC Pam was a severe (category 5) storm with sustained winds of 269 km/h when it passed the east coast of Efate on 13 March 2015 (Emergency Response Coordination Centre[5]). Coastal and island communities, fringing reefs, beaches and coastal terrestrial habitats of northeast Efate were severely impacted by TC Pam. Within the RESCCUE 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. In the aftermath of TC Pam, conservation areas and closed fisheries were re-opened to fishing throughout Efate, creating additional pressure on already depleted fisheries.

Post-cyclone surveys at 14 reef sites documented average hard coral cover of 19.5% and 39% on north and north-west reefs, respectively, and signs of significant physical damage (see Vanuatu RESCCUE IDD for full results). Notably, the 2015 surveys documented 26–55% macroalgae cover on northern reefs, which is considerably higher than on north-west reefs and in previous surveys (Pakoa 2007, Raubani 2009). All surveyed sites showed indications of relatively low fish abundance (although

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

variable monitoring makes it difficult to compare to previous surveys), particularly piscivores (snappers and groupers) and large herbivores (parrotfish). Although depletion of these key functional groups can be an indicator of overfishing, a recent study demonstrated that cyclones can alter the distribution and catchability of some fishery target species up to many months after the event (Tobin et al. 2010). However, due to data limitations it is not possible to accurately attribute the cause of apparent low fish abundances. Although post-disturbance reef data is also limited, there is some evidence after TC Bola (1988), TC Dani (1999) and crown-of-thorns starfish outbreaks (2006) that the coral reefs of north Efate are resilient to disturbances. However, extreme weather events are projected to become more severe but less frequent due to climate change, and coupled with increasing population pressures and coastal development, increased damage may compromise the ability of reefs to recover.

Extreme weather events will also directly impact villages and coastal terrestrial ecosystems, such as mangrove and inland forests and community agricultural land. After TC Pam, northeast Efate was most severely impacted, as evidenced by damage to villages, public infrastructure, agricultural crops and shorelines (Government of Vanuatu 2015). TC Pam caused coastal flooding and storm surges (the worst flooding being in Takara), damaged homes (both those made from store-bought and traditional materials), destroyed or disrupted agricultural plots, water systems throughout the region were damaged and many drinking water supplies were contaminated. Forest vegetation on hillsides and coastal areas was uprooted or stripped of branches or leaves, and this loss of habitat in water catchments reduced the availability of clean water, building materials for rebuilding houses and fuel for cooking. There was also severe riverbank erosion near Port Havannah (Al Creek). Adaptation actions that increase cyclone preparedness, improve community safety during and after cyclones, and provide for rapid post-cyclone recovery of ecosystems and their resources will be key to building community resilience.

4.2 Degradation of Marine Environments and Fisheries

Reef vulnerability is expected to increase under future climate change scenarios, and within only 14 years (by 2030) the combined effects of ocean acidification and thermal stress is expected to result in 90% of Vanuatu reefs being highly to critically threatened (Burke et al. 2011). Based on the predicted impacts of climate change on tropical Pacific habitats, coral reefs are considered to be the most vulnerable marine habitat in North Efate with reductions in reef-building calcification rates and structural integrity expected due to ocean acidification, and decreased coral cover and diversity due to thermal bleaching as ocean temperatures increase. Addressing local threats, such as overfishing, is therefore critical for minimising pressures, and building resilience to future threats.

Seagrass will be most vulnerable to the physical impacts of storms and cyclones as well as sedimentation and turbidity due to high rainfall events delivering terrestrial pollutants. Mangroves are expected to be impacted by the physical impacts of storms and cyclones and sea-level rise, particularly if they are unable to migrate landward due to barriers (Bell et al. 2011a). These habitats support the diverse resources North Efate communities are so reliant on. Consequently, larval reef fish, coastal fisheries for demersal fish and invertebrates, dugong and turtle populations, mariculture ventures and beach erosion are all expected to be impacted by climate change.

There will also be direct effects of climate change on tuna, including changes to their distribution and abundance due to increasing SST and changes in the convergence between the Western Pacific

Warm Pool and the Pacific Equatorial Upwelling, and reductions in primary productivity (Ganachaud et al. 2011, Le Borgne et al. 2011, Lehodey et al. 2011, 2013). However, nearshore tuna resources are not expected to decline significantly due to climate change and may present opportunities to supplement protein sources through the use of nearshore community fish aggregating devices (FADs). This is the focus of other projects in North Efate in collaboration with the Vanuatu Fisheries Department (VFD) and will be integrated into RESCCUE CCA activities as appropriate.

Aquaculture ventures in North Efate include trial mariculture for giant clam, trochus and green snail for restocking in Mangaliliu, Lelepa and Moso (JICA 2015). These aquaculture commodities have calcareous shells and are therefore expected to be vulnerable to ocean acidification in particular as well as the influences of increasing SST and high rainfall events (Pickering et al. 2011). North Efate communities have expressed a desire to increase livelihood income through expanding aquaculture ventures, such as the tilapia ponds in Lamin (north-eastern area), wetland-produced watercress in Epule (north-eastern area), and specialty products such as trochus and green snail. Future climate change projections will need to be considered whether expanding existing ventures or initiating new ventures, to ensure the long-term sustainability and profitability of activities.

4.3 Coastal Development

Consistently, communities, government and NGOs report that land-based pollution (sediment and nutrients) and coastal development are a threat to the North Efate environment and water quality (Pakoa 2007, community workshops 2015). This needs to be investigated further too adequately determine the impacts of coastal development on water quality. Current drought conditions that are the result of a strong El Niño event have decreased freshwater supplies and agricultural production of food for the largely subsistence communities in North Efate. Unfortunately reduced agricultural productivity has coincided with a re-establishing phase of crops damaged by TC Pam, thereby compounding food and water insecurity issues. Efate has a high annual average rainfall of 2,118 mm, and as a result, communities have historically not required extensive water capture and storage infrastructure but have instead relied on the many rivers and streams that flow year-round. However, climate change is projected to increase rainfall variability. Planning for periods of reduced water availability in terms of improving self-determined water infrastructure and management and diversifying agricultural practices and crop varieties to increase drought resistance will be important adaptation actions for the RESCCUE project.

As climate change starts to influence the intensity of extreme weather events and sea level rise, the management of coastal developments will need to consider the nature, location and extent of development along the coast and risks posed by extreme events. Healthy connected ridge to reef ecosystems are critical for supporting the resilience of the natural resources that communities depend upon for food, water, livelihoods and cultural connection.

Mangrove forests are also under threat from harvesting for wood for fuel and building material and clearing for coastal development. Future climate change impacts are expected due to sea level rise and storm damage and, although mangroves can naturally adapt by migrating landward with any sea level rise, this is only possible if barriers such as roads and buildings do not block their movement. North Efate communities depend on mangrove and forest trees for wood for cooking and as a livelihood commodity, and therefore sustainable management will be an important adaptation. Mangrove conservation efforts are still under discussion and will be a key part of any future

adaptation to climate change in the ICM, particularly between Paunagisu and Takara where the largest areas of mangroves exists (ca. 82 km^2), with consideration of where new developments are located to allow for landward migration.

4.4 Water Insecurity

Given the current drought as a result of El Niño conditions, water shortage is currently a primary concern among communities. The current water shortage reported by communities the region seems to primarily be a result of inadequate water infrastructure, management, storage, and distribution. However, mean rainfall is quite high, and with relatively simple improvements in water storage, communities should be able to become quite resilient to periods of lower rainfall. Especially when supplemented by periods of higher rainfall.

5. Climate Change Adaptation Actions – Building Resilience

Climate change will potentially have a major effect on environmental, social, and economic components of North Efate communities, their long term sustainability and their local ecosystems as well as economic revenue. Adapting to climate change impacts is an imperative in all sectors in North Efate due to the potential implications for natural resource management, long-term infrastructure planning, livelihoods and food security. In recognition of the increasing pressures from a rapidly changing climate, and the significant exposure and vulnerability faced by communities in North Efate, the RESCCUE project is working in collaboration with Vanuatu government agencies, NGOs and communities to improve the capacity for adaptation and resilience planning through the development of an ICM Plan that will identify appropriate on-ground CCA actions to be implemented. Importantly, an integrated ecosystem-based approach is being implemented since North Efate subsistence communities rely strongly on their terrestrial, coastal and marine resources, and healthy connected ecosystems will enhance resilience to climate change and facilitate adaptation which needs to be balanced against any over exploitation of natural resources.

5.1 Current Condition of Ecosystems in North Efate

The current condition of ecosystems in North Efate plays an important role in determining how they will respond to climate-related disturbances (both sudden on-set events such as cyclones, and slow on-set process such as sea level rise), and whether they are able to cope with an increasing rate and magnitude of change. Some projected climate-related changes are within the historic variability range experienced by species however, the rate of change is projected to exceed this historic exposure (Hönisch et al. 2012). Natural adaptation and resilience may, therefore, not be sufficient to cope with projected changes and will need to be supported by appropriate strategic action. The range of strategies available to enhance resilience of ecosystems will vary spatially and temporally depending on:

1. The response of species, communities and ecosystems to climate change;
2. Their current condition;
3. Trade-offs with other socio-economic imperatives; and
4. Existing governance arrangements and management paradigms.

5.2 Understanding Resilience

Understanding and identifying the economic and social attributes necessary to facilitate resilience to climate change is critical, and includes factors such as:

- Profitability of businesses;
- Livelihood diversity;
- Equitable property rights;
- Perception of risk;
- Financial flexibility to cope with change; and
- Good governance – improving the processes for making and implementing decisions at all levels of society (van Putten et al. 2013, Marshall et al. 2010).

Communities with a high proportion of members employed in a particular livelihood activity, high subsistence or low overall employment rates, low geographic mobility, and specialised skills have been identified as highly vulnerable to climate change (Grafton 2010). A number of factors also exist that are known to limit the ability of communities and sectors to adapt to climate change which include:

1. The projected rapid rate of change;
2. Weak social and economic structures;
3. A high dependence on natural resources;
4. Inflexible management regimes; and
5. Significant other pressures, such as habitat destruction, pollution, invasive species, and pathogens.

5.3 Building Resilience through ICM

The North Efate ICM will be supported by a number of thematic diagnoses and action plans that aim to identify the source of climate change vulnerabilities of North Efate ecosystems and communities, their current resilience attributes, and effective CCA actions. These action plans will:

- Build on interventions that have occurred in North Efate (e.g. SPC/GIZ Nguna-Pele CCCPIR programme);
- Consider resilience to climate change and natural hazards in terms of ecosystem restoration;
- Partner with government agencies, community initiatives and other current programmes in North Efate;
- Engage with Village Chiefs, Village Councils and committees, existing environmental networks and make special consideration to young people and women; and
- Support local governance structures and use existing mechanisms to ensure any interventions benefit the entire community equally.

The project will also focus on a CCA approach that is holistic, collaborative, coordinated and ultimately sustainable in the long term.

The ICM process will ensure that communities are fully engaged in the adaptation process, and managing the adaptation actions, since they are the primary resource managers in North Efate. These adaptations are not likely to fully compensate for the expected severity of climate change

impacts, but that they represent a starting point that communities will build upon as they progressively adapt. It is the ability to monitor and adapt to changes that is most important to install in communities. In general, adaptation actions will focus on:

1. Providing assistance for tools and approaches with high social acceptability that support local needs in terms of natural resource management;
2. Strengthening community-based management that is simple but focused on specific objectives and performance indicators so it can be recognisable and enforced by the local community;
3. Improving the management of the coastal zone and increasing community participation in management; and
4. Developing practical and sustainable ways to strengthen community resource monitors networks and leadership within North Efate villages.

Some example adaptations actions that may be included in the ICM Plan and implemented by RESCCUE in collaboration with appropriate stakeholders are summarised in Table 3.

Table 3. Example adaptation actions for building community resilience to climate change.

Community asset/ need	Key climate vulnerabilities	Drivers of vulnerability	Potential target actions
Productive coastal fisheries	Degradation of supporting coastal habitats; Lack of clear information on habitat status and trends; Shift in species distribution and abundance	Overexploitation; High resource dependence; Cumulative habitat pressures	Sustain production of coral reef fisheries through climate-informed, community-based ecosystem approaches to fisheries management (CEAFM) Transfer some fishing effort by coastal communities from coral reefs to oceanic species, particularly tuna, by installing fish aggregating devices (FADs), in collaboration with VFD and SPC Fisheries division (FAME) Minimise other pressures on marine habitats by addressing land based activities that deliver pollutants
Water security	More variable rainfall; Inadequate water storage and supply infrastructure; Damage to infrastructure by extreme events	Poor existing infrastructure; No alternative water sources	Enhance community capacity to self-manage water infrastructure Improve water capture, storage and delivery infrastructure to minimise drought impact Increase water storage capacity to increase supply over dry periods
Productive agriculture	Crop failures due to salt intrusion and drought; CO_2 fertilisation effects. Physical damage to crops by storms	High resource dependence; Low cultivar diversity	Improve harvest storage and preservation to extend the shelf life of crops when good harvests are made Diversification of crop varieties and improved agricultural techniques for increased drought/ salt tolerance Selection of crop varieties to take advantage of increased CO_2 availability Review location of crop sites and relocate if saltwater intrusion or storm surges are a threat
Healthy coastal habitats	Degradation of reef, seagrass and mangrove habitats; Reduced biodiversity	Poor habitat condition; Inflexible management; Cumulative habitat pressures	Maintain the natural adaptive capacity of habitats by managing catchment vegetation to reduce delivery of sediments and nutrients to coastal habitats Remove any constraints to mangrove and seagrass habitat movement as environmental conditions change.
Enhanced mariculture livelihoods	Physical damage by storms; Compromised growth and shell deformities	Low investment; Limited local skills and training	Develop hatchery and grow-out systems for expansion of semi-intensive and intensive freshwater pond aquaculture Review location of sites and relocate if sea level rise and storm surges are a threat
Sustainable eco-tourism	Degradation of tourist sites;	Low investment	Manage marine habitats and human interaction with marine habitats to reduce direct and

Community asset/ need	Key climate vulnerabilities	Drivers of vulnerability	Potential target actions
	Fewer 'good weather' days; Damage to infrastructure by storms		indirect impacts from human activities Climate-proof tourism infrastructure, e.g. reviewing structural design standards
Sustainable coastal development	Degradation of habitats due to direct and indirect impacts of development; Damage to infrastructure by storms and sea level rise	Inadequate consideration of climate change in EIA process; Poor coordination; Lack of climate change awareness	EIA process to consider future climate change implications in terms of infrastructure standards (climate-proofing) and location Siting new developments to consider sea level rise, storm surge and landward migration of mangroves

In addition, all RESCCUE ICM and CCA activities will consider the findings of the Pacific iCLIM project in Fiji, Tonga and Vanuatu that identified regional and national-level barriers to climate change data and information management in the Pacific (Brown et al. 2015) which include:

- Policy Barriers – a lack of supportive government or institutional policy or strategy.
- Institutional Barriers – a lack of institutional champions, key roles or partnerships.
- Operational and Human Resource Barriers – a lack of documented or formalised processes being implemented to support solutions, as well as staff roles and skill sets to carry out operational activities.
- Information and Communication Technology Barriers – a lack of appropriate e-infrastructure and IT systems.

Effective adaptation under RESCCUE will take an ecosystem-based approach that integrates across sectors and jurisdictions. Historically, interventions in North Efate to build community resilience in relation to CCA, disaster risk reduction, and natural resource management have failed to deliver long-term positive changes. Therefore, the Vanuatu RESCCUE project will focus on CCA interventions designed in partnership with local stakeholders to meet local needs and build local capacity to try and achieve long-term sustainability. The RESCCUE project will also identify and implement economic and financial mechanisms to support ICM and CCA activities in order to ensure interventions are viable and thus sustainable. While the level of resource-dependency and socioeconomic circumstances will drive to some degree the most appropriate adaptation options, adapting to a changing climate will inevitably require trade-offs between biological assets and socioeconomic benefits (Koehn et al. 2011).

6. CONCLUSION

This interim study will be undated as part of the ICM submission in February 2017. The updated study will outline specific tangible on-the-ground CCA activities being or to be implemented as part of the thematic diagnoses and action plans and how these contribute in the development of the ICM.

It will be important for the ICM to achieve balance in its approach to addressing the possible effects of climate change. As well as the potential significantly adverse sudden and slow-onset effects from climate change, there exists the potential for climate change to generate positive effects if acknowledged and appropriately captured. Therefore the CCA adaptation strategies to be included in the ICM will build on the areas where resilience needs to be strengthened as identified in the IDD and further assessed in the thematic diagnoses and action plans.

REFERENCES

BoM [Australian Bureau of Meteorology] and CSIRO (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Chapter 16: Vanuatu. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia.

Bell, J.D., Johnson, J.E., Hobday, A.J. (Eds.) (2011a) Vulnerability of tropical Pacific fisheries and aquaculture to climate change, pp. 733-801. Noumea, New Caledonia, Secretariat of the Pacific Community, Noumea, New Caledonia.

Bell, J.D., Johnson, J.E., Ganachaud¸ A.S., Gehrke P., Hobday, A.J., Hoegh-Guldberg, O., Le Borgne, R., Lehodey, P., Lough, J.M., Pickering, T.D., Pratchett, M.S., Waycott, M. (2011b). Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories. Secretariat of the Pacific Community, Noumea, New Caledonia, 386 pp.

Bell, J.D., Andrew, N.L., Batty, M.J., Chapman, L.B., Dambacher, J.M., Dawson, B., Ganachaud, A.S., Gehrke, P.C., Hampton, J., Hobday, A.J., Hoegh-Guldberg, O., Johnson, J.E, Kinch, J.P., Le Borgne, R., Lehodey, P., Lough, J.M., Pickering, T.D., Pratchett, M.S., Vunisea, A., Waycott, M. (2011c) Adapting tropical Pacific fisheries and aquaculture to climate change: Management measures, policies and investments. In J.D. Bell, J.E. Johnson & A.J. Hobday, eds. Vulnerability of tropical Pacific fisheries and aquaculture to climate change, pp. 803-876. Noumea, New Caledonia, Secretariat of the Pacific Community, Noumea, New Caledonia.

Bell, J.D., Ganachaud A., Gehrke P.C., Griffiths S.P, Hobday A.J., Hoegh-Guldberg O., Johnson J.E., Le Borgne R., Lehodey P., Lough J.M., Matear R.J., Pickering T.D., Pratchett M.S., Sen Gupta A., Senina I., Waycott, M. (2013) Mixed responses of tropical Pacific fisheries and aquaculture to climate change. Nature Climate Change, 3: 591-599.

Bell, J.D., Allain, V., Allison, E.H., Andréfouë, S., Andrew, N.L., Batty, M.J., Blanc, M., Dambacher, J.M., Hampton, J., Hanich, Q., Harley, S., Lorrain, A., McCoy, M., McTurk, N., Nicol, S., Pilling, G., Point, D., Sharp, M.K., Vivili, P., Williams, P. (2015a) Diversifying the use of tuna to improve food security and public health in Pacific Island countries and territories. Marine Policy, 51: 584-591.

Bell, J.D., Albert, J., Andréfouët, S., Andrew, N.L., Blanc, M., Bright, P., Brogan, D., Campbell, B., Govan, H., Hampton, J., Hanich, Q., Harley, S., Jorari, A., Lincoln Smith, M., Pontifex, S., Sharp, M.K., Sokimi, W., Webb, A. (2015b) Optimising the use of nearshore fish aggregating devices for food security in the Pacific Islands. Marine Policy, 56: 98-105.

Brown, RA, Gonelevu, M, Mackay, S, McGregor, K, Kocovanua, T, Iaken, R, Iautu, F, Lepa, M, Tuiafitu-Malolo, L, Fulivai, S, Pelesikoti, N, Mackey, BG (2015) Barriers to effective adaptation and resilience planning in the Pacific: an information management perspective. Griffith University, Queensland and SPREP, Samoa. ISBN 978-192-221-680-9.

Burke, L., Reytar, K., Spalding, M. et al. (2011) Reefs at Risk Revisited. Washington DC, World Resources Institute, 114 pp.

Chan, N.C.S., Connolly, S.R. (2013) Sensitivity of coral calcification to ocean acidification: a meta-analysis. Global Change Biology, 19: 282–290, doi:10.1111/gcb.12011

Chin, A., Lison De Loma, T., Reytar, K., Planes, S., Gerhardt, K., Clua, E., Burke, L., Wilkinson, C. (2011) Status of Coral Reefs of the Pacific and Outlook: 2011. Global Coral Reef Monitoring Network, 260 pp.

Cochrane, K.L., Andrew, N.L., Parma, A.M. (2011) Primary fisheries management: a minimum requirement for provision of sustainable human benefits in small-scale fisheries. Fish and Fisheries, 12: 275–288.

Done, T.J., Navin, K.F. (1990) Vanuatu Marine Resources: Report of a biological survey. Australian Institute of Marine Science, Townsville, Australia. 272 pp.

Ganachaud A.S., Sen Gupta A., Orr J.C., Wijffels S.E., Ridgway K.R., Hemer M.A., Maes C., Steinberg C.R., Tribollet A.D., Qiu, B. (2011) Observed and expected changes to the tropical Pacific Ocean. In: Bell JD, Johnson JE, Hobday AJ (Eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the pacific Community, Noumea, New Caledonia, 101-187.

Government of Vanuatu (2015) Tropical Cyclone Pam: Lessons Learned Workshop Report. Port Vila, Vanuatu, 55 pp.

Grafton, R.Q. (2010) Adaptation to climate change in marine capture fisheries. Marine Policy, 34(3): 606-615. doi:10.1016/j.marpol.2009.11.011

Gunderson, L.H., Pritchard, L. (2002) Resilience and the behavior of large scale systems. Island Press.

Heenan A., Pomeroy, R., Bell, J., Munday P., Cheung , W., Logan, C., Brainard, R., Amri, A.Y., Alino, P., Armada, N., David, L., Guieb, R., Green, S., Jompa, J., Leonardo, T., Mamauag, S., Parker, B., Shackeroff, J., Yasin, Z. (2015) A climate-informed, ecosystem approach to fisheries management. Marine Policy, 57: 182-192.

Hoegh-Guldberg, O., Andréfouët, S., Fabricius, K., Diaz-Pulido, G., Lough, J., Marshall, P., Pratchett, M.S. (2011) Vulnerability of coral reefs in the tropical Pacific to climate change. Bell JD, Johnson JE, Hobday AJ (Eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the pacific Community, Noumea, New Caledonia, 251-296.

Hönisch, B. et al. (2012) The geological record of ocean acidification. Science, 335:1058–1063.

JICA [Japanese International Cooperation Agency] (2015) Grace of the Sea in Coastal Villages: Project Completion Report. JICA, Vanuatu Fisheries Department and IC Net, Port Vila, 182 pp.

Johnson, J.E., Bell, J.D., De Young, C. (2013) Priority adaptations to climate change for Pacific fisheries and aquaculture: reducing risks and capitalizing on opportunities. Food and Agriculture Organization of the United Nations, FAO Fisheries and Aquaculture Proceedings No. 28. Rome, FAO, 76 pp. DOI: 10.13140/2.1.4395.

Johnson, J.E., Bell, J.D., Sen Gupta, A. (2015) Pacific Islands Ocean Acidification Vulnerability Assessment. Report to the Secretariat of the Pacific Regional Environment Programme (SPREP), Apia, Samoa, 40 pp.

Koehn, J.D., Hobday, A.J., Pratchett, M.S., Gillanders, B.M. (2011) Climate change and Australian marine and freshwater environments, fishes and fisheries: synthesis and options for adaptation. Marine and Freshwater Research, 62(9): 1148-1164.

Langdon, C., Atkinson, M.J. (2005) Effect of elevated pCO2 on photosynthesis and calcification of corals and interactions with seasonal change in temperature/irradiance and nutrient enrichment. Journal of Geophysical Research: Oceans (1978–2012), 110. http://onlinelibrary.wiley.com/doi/10.1029/2004JC002576/full

Le Borgne, R., Allain, V., Griffiths, S.P., Matear, R.J., McKinnon, A.D., Richardson, A.J., Young, J.W. (2011) Vulnerability of open ocean food webs in the tropical Pacific to climate change. In: Bell JD, Johnson JE, Hobday AJ (Eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the pacific Community, Noumea, New Caledonia, 189-249.

Lehodey, P., Hampton, J., Brill, R.W., Nicol, S., Senina, I., Calmettes, B., Portner, H.O., Bopp, L., Ilyina, T., Bell, J.D., Siebert, J. (2011) Vulnerability of oceanic fisheries in the tropical Pacific to climate change. In: Bell JD, Johnson JE, Hobday AJ (eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia, 433–492.

Lehodey, P., Senina, I., Calmettes, B., Hampton, J., Nicol, S. (2013) Modelling the impact of climate change on Pacific skipjack tuna population and fisheries. Climatic Change, doi.org/10.1007/s10584-012-0595-1

Le Quéré, C., Raupach, M.R., Canadell, J.G., Marland, G., et al. (2009) Trends in the sources and sinks of carbon dioxide. Nature Geoscience, 2: 831 - 836.

Marshall, N.A., Marshall, P.A., Tamelander, J., Obura, D., Malleret-King, D., Cinner, J.E. (2010) A framework for social adaptation to climate change; Sustaining Tropical Coastal Communities and Industries. Gland, Switzerland, IUCN, 36 pp.

Nyström, M., Graham, N.A.J., Lokrantz, J., Norstroem, A.V. (2008) Capturing the cornerstones of coral reef resilience: Linking theory to practice. Coral Reefs, 27:795–809.

Pakoa, K.M. (2007) Vanuatu, in Status of Coral Reefs in the South West Pacific 2004. R. Sulu (Ed), IPS Publications, University of South Pacific, Fiji.

Pickering, T.D., Ponia, B., Hair, C.A., Southgate, P., Poloczanka, E.S., Patrona, L.D., Teitelbaum, A., Mohan, C.V., Phillips, M.J., Bell J.D., De Silva, S. (2011) Vulnerability of aquaculture in the tropical Pacific to climate change. In: Bell JD, Johnson JE, Hobday AJ (Eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia, 647–731.

Pratchett, M.S., Munday, P.L., Graham, N.A.J., Kronen, M., Pinca, S., Friedman, K., Brewer, T.D., Bell, J.D., Wilson, S.K., Cinner, J.E., Kinch, J.P., Lawton, R.J., Williams, A.J., Chapman, L., Magron, F., Webb, A. (2011) Vulnerability of coastal fisheries in the tropical Pacific to climate change. In: J.D. Bell, J.E. Johnson & A.J. Hobday, eds. Vulnerability of tropical Pacific fisheries and aquaculture to climate

change, 493-576. Noumea, New Caledonia, Secretariat of the Pacific Community, Noumea, New Caledonia.

Raubani, J. (2009) The status of coral reefs in Vanuatu 2007, in South West Pacific Status of Coral Reefs Report 2007. C. Whippy-Morris (Ed), CRISP, Secretariat of the Pacific Regional Environment Programme, Noumea, 167-208.

Raven, J., et al. (2005) Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society, http://eprints.uni-kiel.de/7878/1/965_Raven_2005_OceanAcidificationDueToIncreasing_Monogr_pubid13120.pdf

SPC (2012) Fish Aggregating Devices. Policy Brief 2012/19. Secretariat of the Pacific Community, Noumea, New Caledonia.

Tobin, A., Schlaff, A., Tobin, R., Penny, A., Ayling, T., Ayling, A., Krause, B., Welch, D., Sutton, S., Sawynok, B., Marshall, N., Marshall, P., Maynard, J. (2010) Adapting to change: minimising uncertainty about the effects of rapidly-changing environmental conditions on the Queensland Coral Reef Fin Fish Fishery. Final Report, Fisheries Research and Development Corporation Project 2008/103, Fishing & Fisheries Research Centre, James Cook University, Townsville, Australia, 160 pp.

UNISDR [United Nations International Strategy for Disaster Reduction] (2005) Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. United Nations.

VNSO [Vanuatu National Statistics Office] (2009) http://www.vnso.gov.vu/index.php/census-and-surveys/censuses. Accessed January 2016.

van Putten, I.E., Jennings, S., Frusher, S., Gardner, C., Haward, M., Hobday, A., Nursey-Bray, M., Pecl, G., Punt, A., Revill, H. (2013) Building blocks of economic resilience to climate change: A fisheries example. Regional Environmental Change. doi:10.1007/s10113-013-0456-0

World Resources Institute (2012) Reefs at risk revisited: Summary for Decision-makers. Burke, L., Reytar, K., Spalding, M., Perry, A. (Editors). Washington D.C., USA.