

A SIMPLIFIED QUALITATIVE SCALE FOR ASSESSING AND COMMUNICATING CLIMATE CHANGE IMPACTS

A Dissertation submitted by

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For the award of

Master of Science

2013

ABSTRACT

This thesis reports that a simple qualitative scale for assessing and communicating climate change impacts can be applied effectively to assess climate change impact to a region. The results presented on this simple scale could improve clarity in communication of climate change to the public.

The study identifies different approaches to modelling various natural event variables and different climate change indexes. It concludes that there is currently no available simplified scale for assessing and measuring current climate change impacts. The thesis makes a case for the inadequacy of these approaches, as they either do not measure climate change impacts or they are too complex. Accordingly, this research presents a simplified qualitative scale for assessing and communicating climate change impacts.

The scale was designed on existing scale frameworks contained within the Australian Risk Management Standard and other scaling methods. The scale was distributed to 20 Pacific nations as part of a climate change impact survey. Participants used the scale to assess the impact of climate change across a number of sub-systems including terrestrial and marine, water, tourism, socio economic, culture, health, food and agriculture and meteorological. The survey successfully elicited assessments of the different climate change impacts evident across the Pacific Island nation states. The results are presented in graphic and tabular form which provides a readily accessible appreciation of the different impacts of climate change. This in itself demonstrates the merits of constructing a scale. The assessment results indicate that there is currently a moderate to severe impact from climate change across the Pacific region.

CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

MARK MACFARLANE

17TH February 2013

Signature of Candidate

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ENDORSEMENT

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Date

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr Joachim Ribbe Associate Professor in Climatology University of Southern Queensland for his support and direction during the thesis.

Thanks to the many Pacific Island organisations that utilised the scale for assessment of climate change impacts within their country. This was the first application of the scale.

I would like to thank the following persons – Bonnie Macfarlane for statistical support, Kate Fenning for graphics support, Anthony Forlin for the French translation of the survey and Anne Cullinan for editing services.

A special mention to my dad “Thomas Macfarlane” who passed away in December 2010 during completion of this thesis. This thesis is dedicated to him. My dad instilled the importance of passion and a good work ethic in me. Without this I would never have completed this work.

Finally, I would like to thank my family – my wife Sally, and my two boys Ben and William – for putting up with me during the completion of this thesis. Thank you.

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Chapter 1: Introduction

1.1. CONTEXT OF THE STUDY

The primary focus of this study is the assessment and communication of climate change impacts.

Firstly, the thesis identifies a need for a simplified qualitative scale for assessing and communicating climate change impacts.

Secondly, the study completes a literature review on existing scales to ascertain if there are existing scales or indexes that are simple and measure climate change impact.

The thesis then proposes a prototype of a scale. The prototype will be the initial model to test the concept of a simplified qualitative scale for assessing and communicating climate change impacts. The scale is then utilised by climate and meteorological experts across 18 Pacific Island countries to measure climate change impacts across the Pacific. The thesis concludes that the prototype scale can simplify communication of climate change impacts.

1.2. PROBLEM STATEMENT

From the mid-20th century, and on the balance of probabilities (Garnaut 2008), a number of key scientific organisations including the Australian Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), South Pacific Regional Environment Program (SREP), World Meteorological Organisation (WMO), the Intergovernmental Panel on Climate Change (IPCC) and the National Oceanic and Atmospheric Administration (NOAA) have clearly identified that the current phase of climate change is no longer in dispute. The Earth's climate is warming due to anthropogenic events resulting in an increase in greenhouse gas concentrations (Garnaut 2008). Warming of the

Earth's climate system is unequivocal, as it is now evident from observations in global air and ocean temperatures, and rising sea levels (Australian Bureau of Meteorology and CSIRO 2011).

In contrast, public opinion has not entirely agreed or supported the scientific findings. Models of future climate change, although supported by robust modelling and research, have been susceptible to negative perceptions from climate change sceptics in both the public and media arenas. This may have eroded public trust in the science. There is also the perception that climate change is too far in the future and not an issue we should be worrying about now (Lorenzoni 2006). However, the main reason for the negative response to climate change may be due to poor communication (Bently 2012).

A simplified qualitative climate change impact scale for assessing climate change impacts could improve effective communication of climate change to the public. This in effect may create a clearer focus that climate change is happening and not an issue in the distant future.

In addition, governments worldwide need to provide effective policy mitigations and adaptation solutions (Lorenzoni 2007, pp. 445-459). As part of the process, policymakers need to understand the current climate change impacts affecting a region. A clearer, simpler, quicker and more consistent approach to communicating current climate change impact may assist in the development and implementation of more effective business and government policy to manage vulnerability and adaptation.

Explicitly, a climate scale for measuring the impact of climate change may effectively support improved clarity and consistency in understanding current climate change impacts for policy initiatives. The policy initiatives listed below have a dependency on understanding climate change impacts. The list is provided to emphasise that a need exists to understand current

climate change impacts clearly if current policy is to be effective at achieving its outcomes.

- United Nations Millennium Declaration (UN General assembly 2000);
- The United Nations 2005 World Summit Outcome for the Environment(UN General assembly 2005);
- Mauritius Declaration (United nations 2005);
- The Pacific Islands Framework for Action on Climate Change 2006-2015(Secretariat of the Pacific Regional Environment Programme 2005). The Framework aims to ensure that Pacific Islands' peoples and communities can be resilient to the risks and impacts of climate change with a key objective to deliver on the expected outcomes under the following principles:
 - 1 Implementing adaptation measures;
 - 2 Governance and decision making;
 - 3 Improving understanding of climate change;
 - 4 Education, training and awareness;
 - 5 Contributing to global greenhouse gas reduction; and
 - 6 Partnerships and co-operation.

This is encapsulated by Expected Outcome 4.1 of the Framework, which aims for "*Strengthened human capacity to monitor and assess environmental, social and economic risks and effects of climate change*".

- The Australian Climate Commission was established by the Australian Government in 2011 to provide citizens with an independent and reliable source of information about climate change (Steffen 2011). In 2011, the Commission completed regional visits across Australia to ascertain general feeling and feedback from interested community individuals. One of the primary findings of the feedback indicated a need to provide more practical advice on climate change for community and industry. Australians want accurate and relevant information on climate change, including local and national impacts.

1.3. AIMS AND SCOPE

The primary aim of the study is to create a simplified qualitative scale for assessing and communicating climate change impacts that could improve communication of climate change to the public.

This involves using a risk-based approach to develop a scale that would:

- be suitable for the general public and policymakers;
- be simple to use and understand, with ease of use similar to other natural impact scales such as the Richter scale for measuring and communicating the force of an earthquake;
- support the assessment of a number of variables;
- provide for measures of relative magnitude and absolute magnitude;
- define the levels of climate change impact;
- make it easy to assess climate change impacts; and
- make it easy to understand results of assessments of climate change impacts.

It should be noted that this research does not test or evaluate the effectiveness of understanding of the scale with policymakers and the public.

Secondary to this are the following research questions:

1. What are the primary motivations for improving communication of climate change impacts?
2. Are there existing measures for assessing and communicating climate change impacts? How effective are these at simple communication of climate change impacts?
3. What is the most appropriate method to develop a simple qualitative climate change scale? Are there any existing frameworks that could be leveraged to develop a scale?
4. Can the prototype scale assess climate change impacts for a region?
5. What are the strengths of the prototype scale? What are the weaknesses? How could these weaknesses be mitigated?
6. How can the prototype scale be validated?

The scope region for testing of the prototype scale in this research includes Pacific small island countries. The Pacific region was selected as there is clear evidence that the Pacific Island region has to date already been impacted by climate change. For example, there is evidence of sea level inundation in Tuvalu causing salt water intrusion to freshwater lenses and the resettlement of 6000 displaced persons from the Carteret and three other atolls to the much larger island of Bougainville (Mimura 2007, pp.687-716).

The scale is used to measure climate change impacts to nine natural and human sub systems (marine and terrestrial, water, tourism, cultural, health, socio economic, food and agriculture, meteorological, and government/policy). For the purposes of this thesis a sub system is defined as explicit focus area upon which climate change events can be grouped against. Each sub-system contains a set of climate change impact events. A climate change impact event is an explicit impact due to climate change. The list of climate change events is not definitive and is focused on typical

events that effect small island countries within the Pacific. The list of climate change events for the purposes of this study can be found in the Appendix.

Out of scope

There are a number of items explicitly *not* addressed by the scale which could be the subject of subsequent further research in this area of study. These include:

- No evaluation on the ease of understanding of the output of the scale assessment with a sample of the public. This omission was mainly as a result of time constraints.
- No application of weightings to climate change events or sub-systems.
- No linkages between vulnerability events and impact events of climate change.

Ethics approval

An ethics approval reference University of Southern Queensland H10REA259 was approved in 2011.

1.4. SIGNIFICANCE OF THE STUDY

The research undertaken in this study is significant as it:

1. Outlines a clear motivation for a simplified qualitative scale for assessing and communicating of climate change to the public and policy makers.
2. Identifies that there is no existing simple scale/index/method/ measure for assessing and communicating climate change impacts.
3. Creates a useful prototype scale based on existing risk management methodology.

4. Utilises the prototype scale to elicit feedback from climatology and meteorological experts across 18 Pacific Island countries on current climate change impacts to their region. This is first time a simplified qualitative scale has been utilised to measure climate change impacts across a range of subject domains for a region.
5. Presents climate change assessment responses for Pacific Islands in a tabular and graphical format which provides a readily accessible appreciation of the different impacts of climate change. These presentations demonstrate the merits of utilising the prototype scale.

1.5. STRUCTURE OF THE DOCUMENT

The thesis consists of five further chapters.

Chapter 2 reviews the relevant literature. It details that there are a number of existing climate scales and indexes that are not fit for the purpose of communicating climate change impacts in a simple manner, either because they do not measure climate change impact or they are too complex.

Chapter 3 presents the methodology that was employed in creating the climate change scale. In addition, it outlines other methodologies that could have been utilised for the creation of the scale. The chapter reports that most scale development research is found within the realm of the social sciences. The chapter details the design of the Pacific Islands Climate Change Impacts Survey 2011, which asks respondents to utilise a prototype scale to assess climate change impacts across a number of natural and human sub-systems.

Chapter 4 details the results from the assessment. It presents findings as a number of tables and graphical map formats.

Chapter 5 provides a synopsis of the results. This chapter looks at the strengths and weaknesses of the prototype scale.

Chapter 6 provides a brief summary of the findings and conclusions and suggests further research agendas for the new climate change scale.

Chapter 2: Literature Review

2.1. CONTEXT AND BACKGROUND

Within the introductory chapter, the author established a broad motivation for the need for a simplified climate scale for assessing and communicating climate change impacts and asserted that it would be a useful tool for policymakers and the public to improve communication of climate change.

This literature review focuses on a range of existing scales and indexes that measure natural event variables and climate change aspects. It includes scales that measure:

- natural phenomena events
- climate vulnerability to natural systems
- climate change impact and vulnerability risk to financial markets and instruments.

The literature review aims to ascertain if similar scales already exist and how effective those scales are in communicating climate change impacts in an easy to understand output.

Each scale/index/measure is assessed using the following three questions:

- 1 Does the scale/index assess climate change impact?
- 2 Does the output of the scale assessment scale communicate climate change in an easily understood manner?
- 3 Does the scale or index assess climate change for a number of sub-systems for a region?

2.1.1. *Scales and indexes to measure natural phenomena*

Table 2.1 provides a summary of the review of scales and indexes to measure natural phenomena events.

The main conclusion is that a scale can be utilised to measure impact or intensity of a natural event on one or more variables. For example, the Fujita scale measures the impact of tornadoes on human built structures, vegetation, average damage path width and estimated wind speed. Prima facie, it provides for simple assessment and easy to understand results. It does this by scaling the damage from 1 to 10. Scale assessments that are easy to understand and communicate are also found in other natural phenomena scales reviewed. These natural phenomena scales are based on empirical measures that are abstracted from interval scales to ordinal scales. Overall it is evident that simplified and effective scaling exists for other natural phenomena.

Table 2.1: Some known simplified physical science scales for classification of natural phenomena events

SCALE NAME	PURPOSE	MAIN CLASSIFICATION MEASURE
Saffir-Simpson (Williams 2005)	Measures the intensity of hurricanes	Intensity of sustained winds.
Richter (Richter 1936, pp.1-32)	Measures the magnitude of earthquakes	Amount of seismic energy released by an earthquake.
Fujita (Marshall 2001, pp. 6-10)	Measures intensity of tornadoes	Damage tornadoes inflict upon human-built structures, vegetation, average damage path width, and estimated wind speed.
Beaufort (Saucier 1955)	Classifies wind speed	Observed sea conditions.
Torro (Godfrey 2008)	Measures tornado intensity in the United Kingdom.	Wind speed and damage intensity.
Nesis (Kocin 2004, pp. 177-194) (The North-East Snowfall Impact Scale)	Characterises and ranks North-East US snowstorms by intensity and impact.	Utilises population information and meteorological indicators.

2.1.2. Primary existing scales and indexes for measuring climate change impacts

The Köppen climate classification (Peel 2007, pp. 1633-1644) is one of the earliest measurement tools developed for climate, having been initially developed around 1900 by Wladimir Köppen. The classification only applies to generic climate regions of the same vegetation type. The scale focuses on a single variable vegetation type. The Köppen scale does not measure impact of climate change. Prima facie it allows for ease of assessment and simplicity in understanding the results of the assessment. The simplicity is due to the small number of colour shades to classify vegetation types.

The Thornthwaite climate classification system (Thornwaite 1948, pp. 55-94) is utilised to measure the impacts of climate change, and in particular precipitation and evaporation. The method was developed in 1949 by climatologist Charles Warren Thornthwaite. The method divides climates into groups according to vegetation characteristic, the vegetation being determined by precipitation effectiveness or P/E, where P is the total monthly precipitation and E is the total monthly evaporation. The sum of the monthly P/E values gives the P/E index, which is used to define five humidity provinces, with associated vegetation. A P/E index of more than 127 (wet) indicates rain forest; 64–127 (humid) indicates forest; 32–63 (sub-humid) indicates grassland; 16–31 (semi-arid) indicates steppes; less than 16 (arid) indicates desert. The Thornwaite system does not measure climate change impacts. Prima facie, it is simple to assess humidity associated with vegetation and provides result output, which is easily understandable. Its focus is on two variables (although there have been modifications including a moisture index which relates the water demand by plants to the available precipitation, by means of an index of potential evapotranspiration, calculated from measurements of air temperature and day length.)

The Strahler climate classification (Allaby 2004) was devised by Strahler in 1969. In this classification system, world climates are related to the main air masses that produce them. It includes:

- (a) equatorial/tropical air masses, producing low-latitude climates;
- (b) tropical and polar air masses, producing mid-latitude climates; and
- (c) Polar and Arctic air masses, producing high-latitude climates.

Sub-sets of these are based on variations in temperature and precipitation to give 14 regional types, plus highland climates, which are regarded as a separate category. The Strahler classification is not a scale and does not measure the impact of climate change. Prima facie, the system does provide for ease in assessment and understanding of output results.

The Aridity Index (Budyko 1958) developed by the United National Environment Programme (UNEP) and based upon earlier work by Köppen, Geiger and Thornthwaite, measures the degree of dryness of a climate at any location based upon annual and seasonal rainfall. It is not a scale but an indicator. The index utilises a fairly simple mathematical equation to assess aridity. This output number can then be assessed against the aridity index table to gain an understanding of the level of dryness of a climate. Prima facie the assessment is simple and the output is easily understandable. The Aridity Index does not measure climate change impact and is calculated on a number of variables.

The Holdridge Life Zone classification system (Leemans 1990) is utilised to classify land areas with a focus on mean annual bio-temperature (growing season length and temperature), annual precipitation, and ratio of annual potential evapotranspiration. It was developed by Leslie Holdridge in 1947 and refined in 1967. The system does not measure climate change impact but does utilise a number of variables. Although a fairly simple system, it may require some technical expertise in sourcing data such as precipitation

(annual, logarithmic) and bio-temperature (mean annual, logarithmic). The output is a simple coloured classification chart that could be easily understood by policymakers and the public.

The Australian and New Zealand Environment and Conservation Council State of the Environment Reporting Task Force has developed a set of indicators which looks at data and trends across physical, chemical, biological, and socio-economic domains (Australian and New Zealand Environment and Conservation Council State of the Environment Reporting Task Force 2000). These indicators do not focus on climate change impact.

In *Environmental Indicators for National and State of the Environment Reporting: The Atmosphere* (Manton 1998) the focus includes developing atmospheric indicators specific to the atmosphere as well as other environmental system indicators. There is a useful pro-forma template for describing guidance notes for each indicator.

The Australian Government State of the Environment Indices is made up of a variety of indices for measuring climate extreme variations within the Australian environment (Australian State of the Environment Committee 2006). They include:

- Number of tropical cyclones in various intensity category;
- Annual average windiness estimated from pressure gradient variations;
- Average intensity of precipitation falling on very wet days, the number of very wet days, and the proportion of total rainfall falling on very wet days;
- Percentage of the country with annual precipitation below the 10th and above the 90th percentile;
- Time series of percentage of the country warmer than 90th percentile and cooler than 10th percentile; and
- A real average of percentage of very cold or warm days or nights.

2.1.3 Climate scales and indexes for the environment

The UNEP-Environmental Indicators South Pacific (United Nations Environment Program 2004) provides a full set of environmental indicators for the South Pacific across air, water, land and biodiversity. The indicators do not assess climate change impact.

The methodology presented by National Institute of Water and Atmospheric research (NZ) for assessing the impacts of climate change on flood risk in New Zealand (Gray 2005) provides guidance on how to handle the possible impact of climate change when assessing floods. This methodology utilises weather models to estimate the impact of expected temperature changes on future rainfall and the flow-on to peak flow levels. The method does not measure climate change impacts.

Climate Extremes indices were developed as part of the Australian State of the Environment Project in 1997 (Nicholls 2000). They are a set of time-series extreme indices focusing on storms, precipitation and temperature. The method does not measure climate change impacts.

The revamped 2008 US Climate Extremes Index (Gleason 2008, pp.2124-2137) focuses on an aggregate set of conventional climate extreme indicators: temperature; precipitation; Palmer drought severity index; and tropical storm and hurricane wind velocity. Again the focus is on variability within climate/weather indicators rather than domain impact. The method does not measure climate change impacts.

In 1998, a Common Sense Climate Index (CSCI) was proposed by James Hansen (Hansen 1998, pp.4113-4120). The objective of the index is to measure climate change based upon easy to understand climate indicators. It aims to measure the degree to which climate change is occurring and is closely correlated to the global surface temperature. The method does not measure climate change impacts and is not considered further in this thesis.

The South Pacific Sea Level and Climate Monitoring Project (Watson 2011, pp.368-377) was developed in 1991 in response to concerns by member countries of the South Pacific Forum over potential risk around global warming on climate risks and sea-level rises in the South Pacific. The project provides key data about sea-level rises which will be analysed during the risk assessment stage of this project and included as a part of the climate change events. Sea-level variability and change are manifestations of climate variability and change. The information provided by these systems is purely data that can be subsequently used in climate modelling. The system does not measure climate change impacts in a scale format.

Within a report on scenarios for climate variability and change (National Assessment Synthesis Team 2001) there is some discussion around assessing the impacts of climate change using historical records, climate model simulations, and vulnerability analysis, which may be useful in assessing the strength and weaknesses of utilising data sourced from these areas. The method does not measure climate change impacts in a scale format and is not considered further.

In 2008 the School of Geography at the University of Oxford and the Tyndall Climate Change Research Centre, UK, compiled climate change country profiles (McSweeney 2008) for the United Nations Development Programme. This document focuses upon many developing countries (excludes Pacific developing nations) and provides country-level data plots from the most up-to-date climate observations and multi-model projections. They provide analysis and data on key climatic indicators but no focus on impacts across domain. The method does not measure climate change impacts in a scale format and is not considered further.

Peterson (2005,pp.83-86) has developed a set of climate change indexes derived from daily data received focusing primarily on extremes of climate. The method does not measure climate change impacts in a scale format.

Extreme climate analysis using extreme index time series for the Central/Eastern European region (Pongracz 2006) looks at detecting possible changes of intensity and frequency of extreme climatic events. This may be useful in understanding how a climatic event is defined within the context of this project. The method does not measure climate change impacts in a scale format.

The World Meteorological Organisation's (WMO) World Climate Data and Monitoring Programme facilitates the effective collection and management of climate data and the monitoring of the global climate system, including the detection and assessment of climate variability and changes. A core component of this is the development of change detection and indices. The focus is on meteorological events and associated climatic trends. This programme is leveraged from earlier work by the Climate Variability and Predictability group (CLIVAR) on the activities of the working group on climate change detection and related rapporteurs (Peterson 2001). The method does not measure climate change impacts in a scale format.

A Climate Change Index (Baettig 2007) provides measures of the strength of future climate change relative to today's natural variability. Its main impact variables are annual and seasonal temperature and precipitation, which are aggregated into a single index to measure strength of future climate change relative to present natural variability. The aim of the scale is to provide policymakers with a quick overview of complex scientific findings. The method does not measure current climate change impacts in a scale format.

Global Warming: Early Warning Signs (Union of concerned scientists 2000) online resources have been developed to allow US high school students to evaluate how global warming might impact upon the region where they live. The material was useful in understanding domain categories that climate change impacts. It did not provide indexing or scaling but merely an overall report on climate change impact upon a domain. The method used

could be considered as an alternative methodology for climate change impact assessment. However, it does not measure climate change impacts in a scale format. As a result of this it may not meet the goals of ease of usability of ease of understanding of the output buy the public.

2.1.4. Climate scales and indexes for financial markets and securities

There are a number of scales with names that could imply that they are focused on measuring climate change impact. However their outcomes are often more focused on other matters, including the climate change impacts on financial markets, public confidence surrounding financial markets and their associated securities. These indexes include the HSBC Climate confidence Index, Bakers Investment Group Climate Impact Index, and Climate Change Performance Index – German watch. The main finding from these scales and indexes is that any simplified scale should consider impacts to a country's financial markets as part of the assessment, due to the high level of interest by financial institutions in understanding the risk and impact of climate change to their operations and investments. This is particularly important in the current economic environment with climate change impacts competing against the current global financial crisis and global food crisis for media focus and program funding.

Maplecroft is a research and advisory consultancy based in Bath, England. They have developed a Climate Change Vulnerability Index. The main focus of the scale is to assess vulnerability to impacts of climate change at a sub-national level. However, it is difficult to get a clear understanding of the full function of the scale as it the scale is a proprietary product. The index seems to primarily focus on vulnerability risks.

2.1.5. Pacific Islands Applied Geoscience Commission (SOPAC)

Environmental vulnerability index

The South Pacific Applied Geoscience Commission (SOPAC) environmental vulnerability index (EVI)(Barnett 2008) looks at assessing environmental vulnerability i.e. the risk of damage to the natural environment within the South Pacific region. It is a detailed approach assessing the overall vulnerability of a country as a result of natural and human forces. This index assesses areas of influence ranging from individual meteorological factors such as high wind and dry periods to human introduced pests vehicles and tourists. It can assess vulnerability for 50 sectors (sub-systems) using indicators. For each sub-system, the index contains a definition, categorisation, data source, indicator scaling, approach to reducing vulnerability, description of the impact of vulnerability and policy/reporting relevance.

The SOPAC EVI system includes manuals for determining a description of the indicators, a technical report of overall assessment produced periodically, a training manual, a demonstration manual and a 'how to use' manual. A user who is completing an assessment would more than likely require extensive training on how to assess sub-systems using the EVI.

The SOPAC EVI focus is on estimating the vulnerability of the environment of a country to future shocks. It does not measure current climate change impact for a region. Using the index to assess a region's overall vulnerability would be time consuming and complex due to the number and detailed level of definitions around sub-systems and indicators.

2.1.6. Risk-based methods

A number of methods apply risk-based assessments to measuring climate change impacts. Chapter 3 will consider the use of risk-management methodology. Several risk management-based approaches were evaluated during the literature review. They mainly formed part of larger reports and

projects and focused on single sub-systems. The discussion below summarises those findings.

The report on climate change adaptation in agricultural programs within Australia developed a risk-management based approach to assess climate change impacts for Australian farmers (Australian Bureau of Rural Science and the Department of Agriculture, Fisheries and Forestry, 2004). The methodology involves establishing risk criteria; identifying, analysing and evaluating the risks, and developing risk treatments. This method is primarily focused assessing some impacts to farming.

The National Agricultural Monitoring System (Bruce 2006) is a web-based tool concept utilised to assess the impact of climatic variation on agricultural production within Australia. It is a risk-based assessment system.

In 2011, the Department of Sustainability, Environment, Water, Population and Communities released a report titled *Australia: State of the Environment 2011* (State of the Environment Committee 2011). This report is a comprehensive assessment of Australia's environment including atmosphere, inland water, land, marine and Antarctic environments; biodiversity; heritage; built environment; and coasts. Of interest to this research was the approach taken to assess current and emerging risks to Australia's climate. The authors adopted a risk-based approach using five impact assessment categories (catastrophic, major, moderate, minor, and insignificant) to measure a set of eight climate change events for Australia. The authors utilised a standard risk-management approach to determine if each event was 'almost certain', 'likely', 'possible', unlikely' or 'rare'. The events were then categorised as one of the impact categories previously mentioned. The result was an easily understandable assessment of eight climate change events, both current and future. This was the closest example of a simplified approach for measuring climate change impacts to

be discovered during the literature review. However, it was not a scale, and it measured the probability of occurrence rather than current impact.

2.2. RECENT MOTIVATION TO DEVELOP A SCALE

The study found no evidence of a simplified qualitative climate change impact scale having been designed. However, at the United Nations Framework Convention on Climate Change Bonn Climate Change Conference 2009, the Global Environment Facility (GEF) raised the prospect of measuring vulnerability and developing a vulnerability index to fairly distribute resources for climate change impacts (Global environment facility n.d.). Additionally, during these talks, Jan Kowalzig (Kowalzig 2009) of the UK-based development agency, Oxfam, backed the concept of a vulnerability index for climate change and called for it to be included for endorsement by all countries at the Climate Change International Scientific Congress in Copenhagen in 2009. He stated that the index is the link between adaptation and the financing mechanism. Saleemul Huq, Head of the Climate Change Group at the Institute for Environment and Development (IIED) also agreed that the principle is a good one as it provides a method to prioritise funding.

A key message from the Climate Change International Scientific Congress in Copenhagen in March 2010(University of Copenhagen 2009)was that an effective, well-funded adaptation safety net is required for those people least capable of coping with climate change impacts, and a common but differentiated mitigation strategy is needed to protect the poor and most vulnerable. To effectively manage such a safety net, climate change impact must be clearly understood for a region. The development of a scale as proposed in this document will provide this mechanism.

2.3. LITERATURE REVIEW FINDINGS

Upon completion, the literature review concluded that there is little if any evidence of any published research on assessing or communicating climate change impact using a simplified scale or index. The research did not seek to establish reasons as to why there was no available scale or motivation to design a scale. However, and as part of a broader theme on climate change communication, this may indicate a failing of the scientific community to effectively communicate climate change to the popular media and the public (Bentley 2012). In addition, this finding also highlights the danger the science of climate change focussing heavily on future climate change modelling. Public perception is biased towards climate change being regarded as a distant future threat (Lorenzoni 2006, pp.265-281). A more simplified and consistent approach to communicating current climate change impacts may assist in conversion of this perception bias.

The key detailed findings of the literature review were:

- Impact scales utilised to measure other areas of natural phenomena are easy to interpret for users and easy to apply for assessment purposes. Some of the scales could assess a number of variables for natural phenomena.
- Not all scales attempt to measure climate change impact and some scales focus only on future state vulnerability.
- Not all scales measure climate change or climate change impact, even though their name may suggest otherwise.
- The main classification domains of existing scales and indexes vary greatly. Existing climate measurement methods are utilised for measuring impact to sectors including physical science, economic and agriculture. In contrast, to the measurement methods that are utilised to measure other natural phenomena existing climate scales and

indexes are more complex. They are not easy to understand or use for assessment, e.g. SOPAC's Environmental Vulnerability Index.

As a result of the findings in the literature review it was deemed feasible to pursue the design of a simplified qualitative scale for assessing and communicating climate change. Initially, the first step was to understand possible approaches and methods to develop a prototype scale. As a result, a further literature review was undertaken to review scale development methods. The findings of this literature review are contained within Section 2.4, which follows.

2.4. LITERATURE REVIEW SCALE DEVELOPMENT METHODS

An additional literature review was undertaken to understand what scale development methodologies exist that could be used to develop a prototype simple qualitative scale for assessing and communicating climate change impacts. The initial focus of this literature review was to review scale development methods for the physical sciences. There was no prior research found for scale development in the physical sciences.

The literature review then looked at getting some form of understanding of a level of measurement rather than focusing specifically on scale development in the physical science sense. This led to discovery of theory of scales of measurement (Stevens 1946, pp.677-680). In Stevens' research, he claimed that measurement in science is undertaken using four different types of scales – nominal, ordinal, interval and ratio. In Stevens' paper, he points out that different types of information are measured in different ways (i.e. nominal, ordinal, interval and ratio). As a first step of scale design, it is important to identify into which category climate impact information would fit.

The literature review then reviewed scale development in the social sciences rather than the physical sciences.

2.5. A PROCESS METHOD FOR DESIGNING THE SCALE

Measurement instruments that are collections of items combined into a composite score, and intended to reveal levels of theoretical variables not readily observable by direct means are often referred to as 'scales' (De Vellis 1991).

Tharenou (2007) refers to a 'scale' as a measure consisting of two or more items designed to measure a construct. In the context of the development of a scale for measuring impact in climate change, and from the definitions above, a scale will be defined as a measure consisting of many inter-related items to measure impact on a region. This impact covers a range of domains such as human lifestyle, oceans, forests and economic.

Scales and other measurement instruments are utilised effectively in measuring the impact of natural forces. These scales provide a valuable and educational source of information for the community – including emergency services response planning, policy preparation, and prevention planning across socio-enviro-economic sectors. In the main these are single-item classification scales, and they focus on a main classification measure such as sea conditions assessed by the Beaufort scale to measure wind speed.

Tharenou (2007) proposes a methodology for developing a multi-item scale. Research completed by Hinkin (1995) and De Vellis (1991) proposes a sequential methodology for developing scales. Hinkin (1995) reviews scale development procedures for 277 measures and provides what could be considered best practices in scale development. Schwab (1980, pp.3-43) suggests that the development of measures has three basic stages:

- Stage 1 involves the generation of individual items.

- Stage 2 looks at the manner in which items are combined to form scales.
- Stage 3 is the scale evaluation.

Scales can be used to reduce complex conditions to a single number (World Meteorological Organization, 2011)

Scales are fundamental to all branches of science (De Vellis 1991), social sciences and management research (Tharenou, 2007). For the development of climate change scale, the thesis could utilise common guidelines from the social sciences scale development method as provided by De Vellis (1991).

From this limited literature review, the research has indicated that there is no one best method best suited for developing the scale. Most likely, the method will require a hybrid of approaches available from both business management, science and social science methodology.

Chapter 3: Methodology

3.1. INTRODUCTION

This research set out to establish whether a simplified qualitative scale for assessing and communicating climate change already exists. In Chapter 1 the motivation for having such a scale was established. In Chapter 2 the research aimed to establish if a simplified qualitative scale for assessing and communicating climate change exists. A literature review was conducted to understand and assess existing scales and indexes. The literature review confirmed that there is no available scale for assessing climate change which communicates results in a simple qualitative manner. Subsequently, the research looked to develop a simplified qualitative climate change scale for assessing and communicating climate change impacts. This discussion that follows reviews how the scale was constructed and what factors influenced the design.

3.2. DEVELOPMENT OF CLIMATE CHANGE IMPACT ITEMS

To understand the types of climate change impact events and their impacts on the Pacific region, the author set out to review existing climate assessment reports for this area. The output of the review would be a list of candidate items by country for the Pacific region and would form a key component of the prototype scale.

Additionally, the research aimed to review any additional material for detection of climate change events in the Pacific region, such as direct observation reports/data. Anecdotal evidence and expert knowledge would be utilised where appropriate.

The research aimed to establish a pre-determined and clearly-defined format for the scale measurement. This would feature levels of impact which are easy for the public and policymakers to understand.

3.3. DESIGN OF A PROTOTYPE SCALE

In the initial literature review, a risk-based method was identified within the Australian Government's Program Report on *Climate Change Adaptation in Agriculture* (Australian Bureau of Rural Sciences 2004). The approach measures climate change impacts for a single variable using a risk-management methodology.

The main standard for risk management in Australia is AS/NZS 4360:2004 (2004) and the design of the physical scale is be based around this standard as it would enable the key design goals for the prototype scale.

As described in Chapter 1, the key design goals were to use a risk-based approach to develop a scale that would:

- be suitable for the general public and policymakers;
- be simple to use and understand, with ease of use similar to other natural impact scales such as the Richter scale for measuring and communicating the force of an earthquake;
- support the assessment of a number of variables;
- provide for measures of relative magnitude and absolute magnitude;
- define the levels of climate change impact;
- make it easy to assess climate change impacts; and
- make it easy to understand results of assessments of climate change impacts.

An ordinal scale (Stevens 1946, pp.677-680) would provide for only measures of relative magnitude so would not be suitable.

In defining the levels of climate change impact, the AS/NZS Risk Management Standard (AS/NZS 4360 2004) Guidance Notes presents a simple consequence table as in Table 3.1.

Table 3.1: AS/NZS Risk Standard Simple Consequence Table

DESCRIPTOR	DEFINITION
Severe	Most objectives cannot be achieved
Major	Some important objectives cannot be achieved
Moderate	Some objectives affected
Minor	Minor effects that are easily remedied
Negligible	Negligible impact upon objectives

Source: AS/NZS 4360 (2004) Guidance Notes

These risk descriptors are easily understandable. To improve understanding, a sequential number was added to each descriptor, with the highest number 5 relating to severe and the lowest number 1 relating to negligible impacts. This then created the initial Strawman Climate Change Impact Scale, illustrated in Table 3. 2.

Table 3.2 Initial Strawman Climate Change Impact Scale

NUMERIC VALUE	DESCRIPTOR	DEFINITION
5	Severe	Most objectives cannot be achieved
4	Major	Some important objectives cannot be achieved
3	Moderate	Some objectives affected
2	Minor	Minor effects that are easily remedied
1	Negligible	Negligible impact upon objectives

Next, new definitions had to be created for each descriptor if the scale was to be relevant to climate change impacts and in addition meet the key design goals. The descriptors needed to:

- assess the sub systems on the scale of a country;
- relate to both human and natural systems; and
- meet the goal of ease of understanding for both assessors and users such as policymakers and the public.

These key goals were integral in evolving scale descriptors from those in Table 3.2. This refinement produced the second Climate Change Impact Scale Strawman, shown in Table 3. 3.






Table 3.3 Second Strawman Climate Change Impact Scale

NUMERIC VALUE	DESCRIPTOR	DEFINITION
5	Severe	Threatens the survival of the country; or Has extreme impacts on the viability of the country/island; or Has extreme impact on natural or human systems of the country/island.
4	Major	Threatens the survival or continued effective function of a natural or human system of the country/island; or Has a major impact on the government's strategic objectives; or Has a major impact on natural or human systems of the country/island.
3	Moderate	Does not threaten natural or human systems, but would mean that the system could be subject to significant maintenance or changed ways of operation; or Moderately impacts on the government's strategic/operational objectives; or Has a moderate impact on the natural or human systems of the country/island.
2	Minor	Threatens the efficiency or effectiveness of some aspect of natural or human systems but can be managed by adaptation actions; or Minor impact on the government's strategic/operational objectives; or Has a minor impact on natural or human systems of the country/island.
1	Negligible	Results in impacts that can be dealt by routine adaptation actions.

To improve understanding and usability, flexible headings and colour codes were added to each descriptor. The colours were then utilised in graphical representation maps in section 4.3 to make it easier for the user when reviewing impacts across a region. The output of this was the final design

illustrated in Table 3.4 – A Simplified Qualitative Scale for Assessing and Communicating Climate Change Impacts (the Scale)

Table 3.4: A Simplified Qualitative Scale for Assessing and Communicating Climate Change Impacts

A rating of...	Scale	Means that the occurrence of the impact
Severe 	5	<ul style="list-style-type: none"> Threatens the survival of the country. Has extreme impacts of the viability of the country/island Or has extreme impact on natural or human systems of the country/island.
Major 	4	<ul style="list-style-type: none"> Threatens the survival or continued effective function of a natural or human system of the country/island. Has a major impact on the governments strategic objectives; Or have a major impact on natural or human systems of the country/island.
Moderate 	3	<ul style="list-style-type: none"> Does not threaten natural or human systems, but would mean that the system could be subject to significant maintenance or changed ways of operation. Moderately impacts on the governments strategic /operational objectives; or Have a moderate impact on the natural or human systems of the country/island
Minor 	2	<ul style="list-style-type: none"> Threatens efficiency or the effectiveness of some aspect of natural or human systems but can be managed by adaptation actions. Minor impact on the governments strategic/operational objectives; or Has a minor impact on natural or human systems of the country/island.
Negligible 	1	<ul style="list-style-type: none"> Results in impacts that can be dealt by routine adaptation actions.

Once the Scale was designed, the next step was to devise a survey and test it on real countries with real users. The outcomes discussion that follows details how this was achieved.

3.4. OUTCOMES

A final product of the research is a simplified qualitative scale for assessing and communicating climate change impact that will be easily understandable by policymakers and the public. This Scale is the first for assessing climate change impact across many sub-systems in a standardised and simplified approach.

3.4.1. *Scale Application-Pacific Islands Climate Change Impacts
Survey 2011*

To test the Scale's effectiveness in practical application, a survey (Refer Appendix) was designed for distribution to 20 Pacific Island countries. The primary aim of the survey was to assess the impact of climate change across a number of sub-systems (terrestrial and marine, water, tourism, socio economic, culture, health, food and agriculture and meteorological) using the prototype scale.

In the context of the research thesis, a 'system' is defined as a core area of Earth's systems. For this research three core systems were identified – ecological, human and physical. A 'sub-system' is defined as a subsidiary system to a main system. For this research the following sub-systems were identified – terrestrial and marine, water, tourism, socio economic, cultural, health, food and agriculture, meteorological, and government. These sub-system categories were derived from the IPCC AR4 (Intergovernmental panel on climate change 2007) but do not necessarily align with them

The first section of the survey asked participants to assess climate change impacts to various sub-systems. Sub-systems assessed included marine and terrestrial, water, tourism, social-economic, culture, health, food and agriculture, meteorological, and government and policy. The participants were provided with a list of identified climate change impact events for each sub-system. The climate change impact events were not weighted or ranked in any order. They were then asked to assess each sub-system and its related impact events by assigning one rating number from the simplified Scale. This number represents the overall Scale rating for all climate change impacts for that particular sub-system. (See Section 4.1.)

The second section of the survey asked participants to assess systems in order of importance to their country. Systems included ecological, human, physical and others. (See Section 4.2.)

Lastly, the participants were asked to assess sub-systems (human, ecological and physical) in order of importance to their country. (See Section 4.3.)

The Pacific Island countries to be surveyed were chosen on the basis that they were small island countries, and excluded larger and more developed countries such as New Zealand and Australia. In the first instance the author attempted to contact the main United Nations Framework Convention Climate Change main contacts but had no responses. Subsequently, the author made contact directly with each country's administration and was provided with the appropriate contacts. The contacts were mainly a mix of professional meteorologists, climate change officer and technical scientific officers (refer table 3.5). These professionals are responsible for reporting climate change impacts for their country.

Table 3.5: List of respondents to the Pacific Islands Climate Change Impacts Survey 2011

Country	Survey respondent	Organisation	Title/position
American Samoa	Akapo Akapo	National Weather Service-American Samoa	Senior Meteorologist
Cook Islands	Maara Valimene	Cook Islands Meteorological Service	Operations Manager
Fiji	Alisi Pulini	Ministry of Foreign Affairs & International Cooperation	Climate Change Officer
Guam	Chip Guard	National Oceanic and Atmospheric Administration(NOAA)	Warning Coordination Meteorologist-Guam
Hawaiian Islands	Edward Young	National Oceanic and Atmospheric Administration(NOAA)	Deputy Director National Weather Service Pacific

Country	Survey respondent	Organisation	Title/position
Kiribati	Ueneta Toorua	Kiribati Meteorological Service	Research Officer
Marianas Islands	Juan T. Camacho	Governor Emergency Management Office-Saipan	Geophysical Seismic Technician
Marshall Islands	Reginald White	Office of the President –republic of Marshall Islands	Director Weather Service –Marshall Islands
Micronesia	David Aranug	National Oceanic and Atmospheric Administration(NOAA)	National Weather Service station Manager-Micronesia
Nauru	Nodel Neneiya	Department of Commerce, Industry and Environment– Nauru government	Climate change officer-Nauru
New Caledonia	Peggy Paulmin	Meteo France	Meteorologist –New Caledonia
Nieu	Rosslynn Pulehetoa-Mitiepo	Niue Meteorology and Climate Change Department	Coordinator of the Niue Climate Change Project
Palua	Maria Ngemaes	Palua National Weather Service	Meteorologist
Pitcairn Islands	Michele Christian	Government of the Pitcairn Islands	Head of Natural resources Department
Papua New Guinea	Kasis Inape	PNG National Weather Service	Meteorologist
Solomon Islands	Hudson Kauhiona	Ministry of Environment, Conservation & Meteorology	Senior Officer

Country	Survey respondent	Organisation	Title/position
Tokelau	Mose Pelasio	Department of Economic Development, Natural Resources & Environment	Director
Tuvalu	Maina Talia/Tafu Lusama	Tuvalu Climate Action network	Secretary
Vanuatu	Philip Malsale	Vanuatu Meteorology and Geohazards Department	Principal Scientific Officer
Wallis and Futuna	Franck Aucher	Meteo France	Meteorological Technician –Wallis and Futuna
Western Samoa	Sunny K Suesea	Climate and Ozone Services. Meteorology Division. Ministry of Natural Resources and Environment	Meteorologist

Overall, there were 18 respondent countries to the survey. Two countries did not respond to the survey: Tonga; and French Polynesia. No reasons were provided as to why either country failed to respond to the initial of a number of subsequent requests.

The results of the Pacific Island climate change impacts survey 2011 are detailed in Chapter 4 Results. This research does not test or evaluate the effectiveness of understanding of the simplified scale with policymakers and the public, but is based on the assumption that, as the scale has no more than five levels, it is easy to understand for the public and policymakers.

Chapter 4: Results

4.1. INTRODUCTION

This chapter presents the results from the Pacific Islands Climate Change Impacts Survey 2011.

The results of the climate change impact assessment are recorded and analysed within Section 4.2 below.

The results of the system assessment are provided in Section 4.3 below.

The results of the assessment of sub-systems are provided in Section 4.4 below.

4.2. CLIMATE CHANGE IMPACT ASSESSMENT DETAILED RESULTS

Table 4.1 summarises the assessments of the climate change impact upon nine climate sub-systems. The results are shown as percentages. A summary of the key highlights of the assessment is discussed next.

Approximately 20% of respondents recorded a severe impact to **marine and terrestrial sub-systems**. 30% of respondents recorded a major impact to marine and terrestrial sub-systems. The remaining 50% of respondents indicated a negligible to moderate level of impact to marine and terrestrial sub-systems. In total, all respondents have indicated a moderate or greater level of impact to marine and terrestrial sub-systems due to climate change impact.

Within **water sub-systems**, 37% of respondents recorded a major impact due to climate change. 21% of respondents indicated a severe impact. 26% indicated a moderate impact and 11% indicated a minor impact to water sub-systems. The key point of note is that 63% of respondents indicated a moderate or major impact on water sub-systems in their countries.

Combined with marine and terrestrial results it seems that water systems, both fresh and ocean, are being heavily impacted by climate change in the region.

Within **tourism sub-systems** most countries reported minor and negligible impacts (47%). No countries reported a severe impact to tourism sub-systems due to climate change at this stage. 11% of respondents reported a major impact and most respondents (26%) reported a negligible impact level on tourism sub-systems. The results indicate that tourism sub-systems are currently the least impacted by climate change in the region.

In response to **cultural sub-system** impacts, only around one-fifth of respondents (21%) recorded a negligible impact. This is compared to 37% who reported a moderate impact. This was the highest number of respondents for the tourism sub system.

Within **health sub-systems** 79% reported a moderate to major impact due to climate change (42% major and 37% moderate). Only 11% reported a minor impact rating of 2.

Within **social economic sub-systems** there were 21% reported negligible to minor impacts. In contrast, 42% reported a major to severe impact to socio economic sub systems due to climate change.

Within the **food and agricultural sub-systems** 10% of respondents reported a minor or negligible impact. The remainder (90%) reported a moderate to severe impact due to climate change. Of these, 26% recorded a severe Category 5 impact to food and agricultural sub-systems. This represents the highest number of respondents with a Category 5 impact level. The equal most stressed sub system due to climate change. There may be a correlation to the severe impacts to both water and marine terrestrial sub-systems, which are key inputs to food and agricultural systems.

Approximately, 25% of respondents recorded a severe Category 5 rating for **meteorological sub-systems**. A further 35% of respondents recorded a major Category 4 rating. In contrast there were only 5% of respondents who rated negligible for meteorological sub-systems.

Lastly, **government and policy sub-systems** reported a mainly minor to moderate impact for 59% of respondents. 41% of respondents recorded a major to severe rating for government and policy sub-systems.

4.3. CLIMATE CHANGE IMPACT ASSESSMENT RESULTS BY SUB-SYSTEM

This section provides results analysis on climate change impact ratings for each sub-system by country. Table 4.2 provides the result set of all Scale ratings for each sub-system in each country. There are 28 (~16%) assessment ratings of a severe Category 5 ratings out of a possible 172 assessment ratings. This is across 20 countries and nine sub-systems. According to the simplified Scale a Category 5 impact rating threatens the survival of a country. In the sections that follow the result set within Table 4. 2 will be analysed in detail for each sub-system.

Table 4.1: Pacific Island climate change impacts by sub-system

Climate change impacts	Severe (5)	Major (4)	Moderate (3)	Minor (2)	Negligible (1)
Marine and terrestrial	20%	30%	40%	5%	5%
Water	21%	37%	26%	11%	5%
Tourism	-	11%	42%	21%	26%
Social economic	21%	21%	37%	16%	5%
Culture	11%	16%	37%	16%	21%
Health	-	42%	37%	11%	5%
Food and agriculture	26%	32%	32%	5%	5%
Meteorological	25%	35%	25%	10%	5%
Government and policy	18%	24%	35%	18%	6%

Table 4.2: Climate change impact assessments by country

Pacific Island survey 2011 responses by country	Marine and terrestrial	Water	Tourism	Social economic	Culture	Health	Food and agriculture	Meteorological	Govt & policy
American Samoa	4	4	4	3	4	3	5	4	4
Cook Islands	3	4	3	3	3	3	4	4	3
Fiji	3	2	3	2	1	4	4	4	5
French Polynesia	No response	No response	No response	No response	No response	No response	No response	No response	No response
Guam	3	3	2	2	2	2	2	2	2
Hawaiian Islands	3	4	1	2	3	2	3	3	2
Kiribati	4	4	3	5	4	4	4	4	4
Micronesia	5	4	4	5	4	4	5	4	5
Nauru	5	5	1	4	3	4	3	4	3
New Caledonia	1	1	1	1	1	1	No response	1	1
Nieu	3	3	3	3	3	3	3	3	4
Marshall Islands	4	5	3	5	5	4	5	5	4
Palau	3	3	3	3	3	3	3	3	3

Pacific Island survey 2011 responses by country	Marine and terrestrial	Water	Tourism	Social economic	Culture	Health	Food and agriculture	Meteorological	Govt & policy
Papua New Guinea	3	3	1	3	1	3	1	3	5
Pitcairn Islands	4	5	2	4	1	3	4	5	2
Solomon Islands	5	4	3	4	2	4	5	4	0
Tokelau	4	3	2	3	3	4	4	5	0
Tuvalu	5	5	1	5	5	5	5	5	3
Vanuatu	3	2	2	4	3	3	3	3	3
Wallis and Futuna	2	No response	No response	No response	No response	No response	3	2	No response
Western Samoa	4	4	3	3	2	4	4	5	3

4.3.1. Marine and Terrestrial Sub-system Results

The climate change impacts that were assessed for marine and terrestrial included:

- a loss of diversity in fish species (e. g. migration and distribution of species);
- a loss in diversity of coastal birds;
- degradation of coral reefs;
- bleaching of coral reefs;
- marine ecosystems compromised;
- rise in non-indigenous invasive species;
- increasing coastal erosion;
- reduction in country/island size;
- increasing beach erosion;
- loss in diversity of species;
- increased periodic flooding from sea;
- permanent inundation from sea;
- reduced forest area;
- loss of mangrove areas;
- reduction in turtle nesting habitats;
- chronic island erosion;
- increased species extinctions;
- a loss of biodiversity;
- increase in ciguatera outbreaks – a disease caused by the consumption of certain warm-water fish that have accumulated orally effective levels of sodium channel activator toxins through the marine food chain. Symptoms of ciguatera include a range of gastrointestinal, neurological and cardiovascular disturbances (Lewis 2001,pp.97-106)
- a loss of tropical rainforest;
- a loss of savannah area;
- a loss of wetlands;

- a loss in native coastal woodlands;
- changes in wave climate and ocean circulation;
- increasing ocean acidification;
- increasing sea surface temperature;
- ongoing and continual rise in sea levels;
- seepage of saline water through rivers during dry seasons(increasing soil salt level);
- increasing grassland and savannah fires; and
- increasing changes in species habitats.

As recorded in Table 4.1, 50% of respondents reported a major impact or greater for marine and terrestrial systems. Four respondents (Solomon Islands, Micronesia, Nauru and Tuvalu) reported a Category 5 impact rating. This is the highest impact rating on the Scale and indicates an extreme impact to marine and terrestrial systems overall. The countries reporting Level 5 impact ratings for marine and terrestrial sub-systems seem to occur mainly in a cluster in the mid-North Pacific area. Three of the countries that reported Level 5 impact ratings for this sub-system are located in the region between the Equator to the Tropic of Cancer. The majority of respondents (8 in total) reported a Level 3 moderate impact rating. Wallis and Futuna and New Caledonia reported minor and negligible impacts respectively. The Wallis and Futuna rating of Level 2 seems low compared with other countries around them.

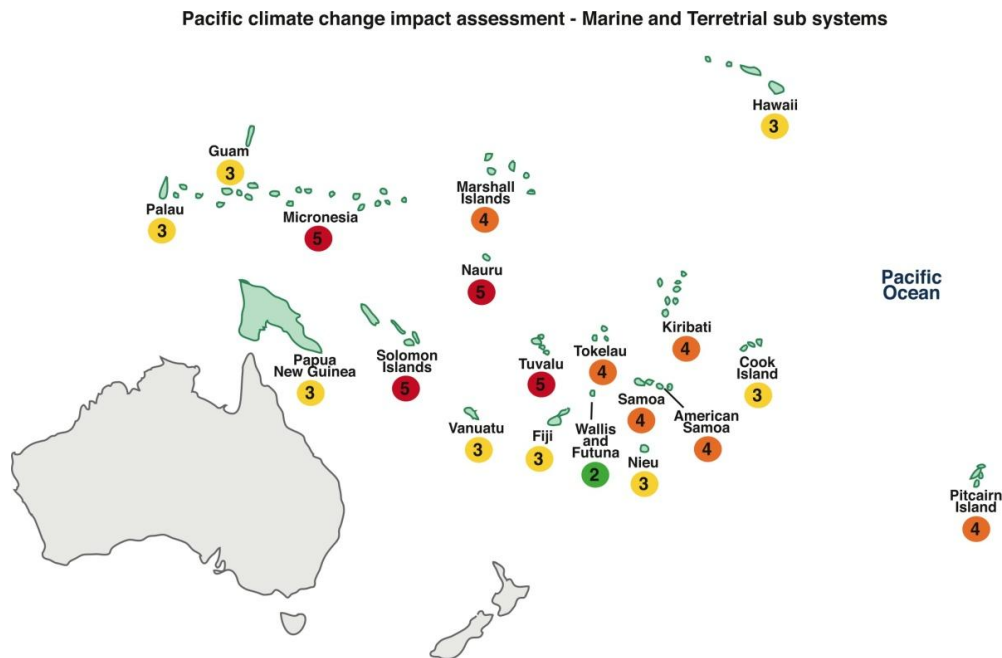


Figure 4.1: Scaling map for the impacts to marine and terrestrial sub-systems

4.3.2. Water Sub-system Results

The climate change impacts that were assessed for water sub-system impacts included but are not limited to water resources compromised e. g.:

- water tables rising to surface and reduction due to evapotranspiration;
- reduction in water supply (reduction in freshwater lenses);
- seawater intrusion into freshwater lenses;
- contamination of fresh groundwater supplies;
- soil salinization; and
- replacement of potable water supply.

Over half the respondents (58%) reported either a major or severe impact by climate change on water Sub-systems. Of these 37% reported a major impact to water Sub-systems. A severe level 5 rating was provided by the Marshall Islands, Nauru, the Pitcairn Islands and Tuvalu. It should be noted that three of these countries are geographically located close to each other (Marshall Islands, Tuvalu and Nauru) in the central mid-Pacific. Fiji, Vanuatu and New Caledonia reported minor or negligible impacts to water (level 2 and level 1). These three countries are closely geographically

located next to each other. Around 26% (5) of respondents reported a moderate impact to water sub-systems. The results of the survey point to a moderate to severe impact to water sub-systems across the Pacific due to climate change.

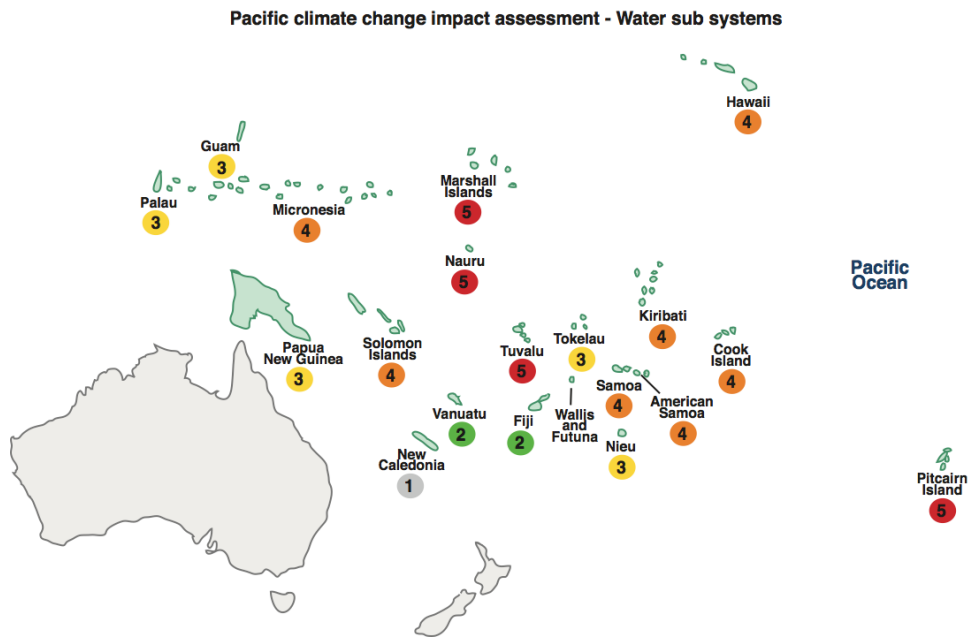


Figure 4.2: Scaling map for impacts to water sub-system

4.3.3. Tourism sub-system results

The impacts of climate change to tourism mainly focus on reduced tourist spending due to local impacts of climate change. The climate change impacts that were assessed for tourism sub-system impacts included but are not limited to:

- price competitiveness including exchange rates against the visitors' home currencies;
- transportation links;
- recent natural disasters; and
- political stability of the host country.

Around 47% of respondents reported a minor or negligible impact to tourism from climate change. Another 42% of respondents reported a moderate impact on tourism. Overall, 89% of respondents reported either a level 2 or level 3 impacts on tourism. Micronesia and American Samoa assessed the impact to Tourism as level 4 (Major). There were no severe level 5 ratings reported by any country for tourism impacts. Any increase in the number of natural disasters due to climate change will adversely affect the tourism sector of economies in the Pacific region. However, it is not a mutually exclusive factor.

The United Nations Economic and social commission for Asia and the Pacific (ESCAP) completed an economic and social survey of the Pacific region countries in 2010.(United Nations 2007) They reported that recent growth in visitor numbers and revenue earnings from tourism has supported economic growth in the Cook Islands, the Federated States of Micronesia, Fiji, Palau, Samoa, Solomon Islands, Tonga and Vanuatu. This in turn has progressed tourism into one of their most important income-generating sectors. In addition, they found that the extent of the tourism sector contribution hinged on a combination of factors including the economic health and pattern of consumer spending of mostly developed economies which account for a majority of tourist arrivals in the Pacific.

Ongoing stresses from global warming, especially warming of the Pacific Ocean, will lead to an increase in natural disasters such as more severe tropical cyclones and more intense storm surges associated with these storms. There is evidence of reduced tourism numbers and revenues for island nations of the Pacific.

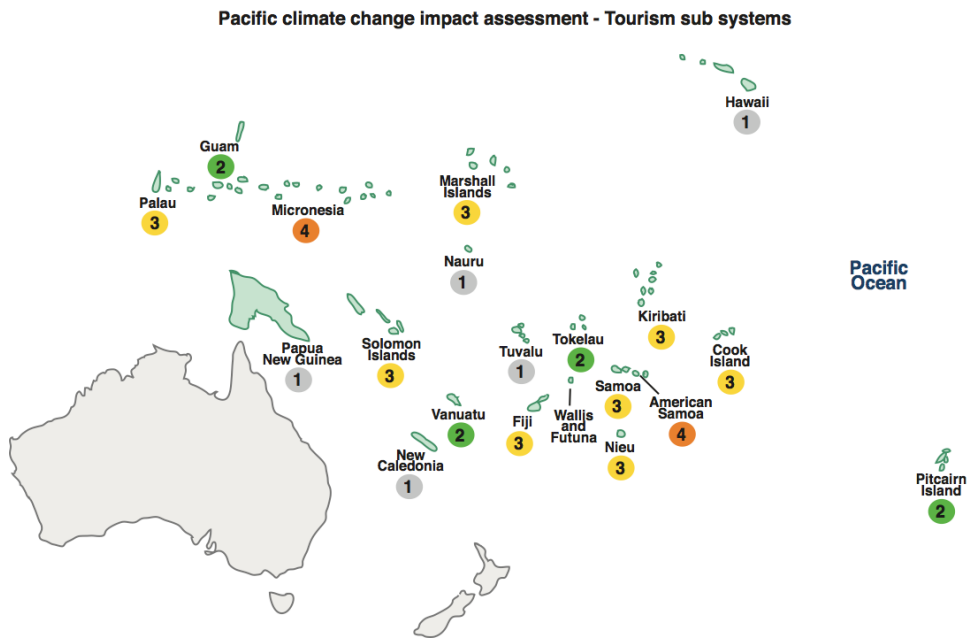


Figure 4. 3: Scaling map for the impacts to tourism sub-systems

4.3.4. Socio-economic sub-system results

Approximately, 79% of respondents reported a moderate or greater impact to the socio-economic sub-system. The climate change impacts that were assessed for socio-economic sub-systems included but were not limited to:

- infrastructure and facilities damage (e. g. government services, coastal protection works, causeways, roads, airports, ports);
- settlement damage;
- energy disruptions – utilities (power and water);
- fossil fuels;

- fuel wood;
- island abandonment;
- socio-economic well being compromised;
- transport interruptions increasing due to natural factors (e. g. closure of roads; airports; ports; marine resources and bridges);
- communication interruptions; increasing economic losses as a percentage of GDP;
- loss of productivity in main economic sectors;
- achieving poor sustainability levels;
- migration away from climate change impact areas;
- increasing poverty; and
- reduction in housing material availability (e. g. sago, bamboo, and grass thatching).

The majority of respondents (37%) reported a moderate impact rating in the socio-economic sub-system. The Marshall Islands, Micronesia and Kiribati all reported a severe Level 5 rating for this sub-system. The Marshall Islands and Micronesia are both located north of the Equator in the central North Pacific.

Around 21% of respondents reported a minor or lower impact to socio-economic sub-systems. This included Fiji, the Hawaiian Islands and Guam. It is worth noting that the GDP per capita of these countries (Level 2 and Level 1) is \$4,400, \$15,000, and \$49,214 respectively¹. These GDP per capita values are amongst the highest in the Pacific region. It may be that they allow for more robust adaptation strategies to climate change to be implemented.

¹ US Revenue Department 2011

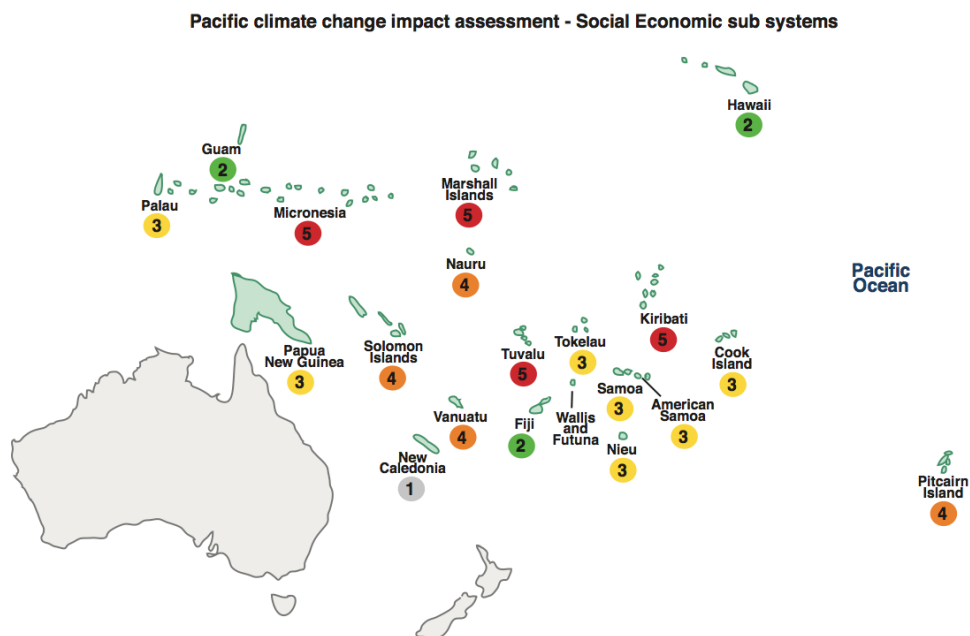


Figure 4.4: Scaling map for the impacts to socio economic sub-systems

4.3.5. Culture sub-system results

The Marshall Islands and Tuvalu reported a severe level 5 impact on cultural sub-systems. The climate change impacts that were assessed for cultural sub-system impacts included but are not limited to:

- loss of cultural heritage and/or spiritual sites;
- national sovereignty undermined; and
- loss of subsistence and traditional technologies, indigenous skills and knowledge and community structures.

Approximately, (37%) of respondents reported a moderate impact to culture from climate change. In contrast, 37% reported level 2 or lower impact levels to culture of their countries due to climate change. From the results the impacts to culture on the Pacific Island countries surveyed suffered seems to be the lowest impact to any sub-system. This may indicate that Pacific Islands' culture is more resilient and adaptive to climate change impacts than other Sub-systems even in the lower GDP per

capita countries such as Papua New Guinea and The Solomon Islands. Although, it should be noted that 64% recorded a moderate or higher level of impact on culture due to climate change. The Scale does not provide explicit areas of impact within the cultural Sub-systems that is being impacted greater

(e.g. loss of cultural heritage sites, or loss of subsidence and traditional technologies.)

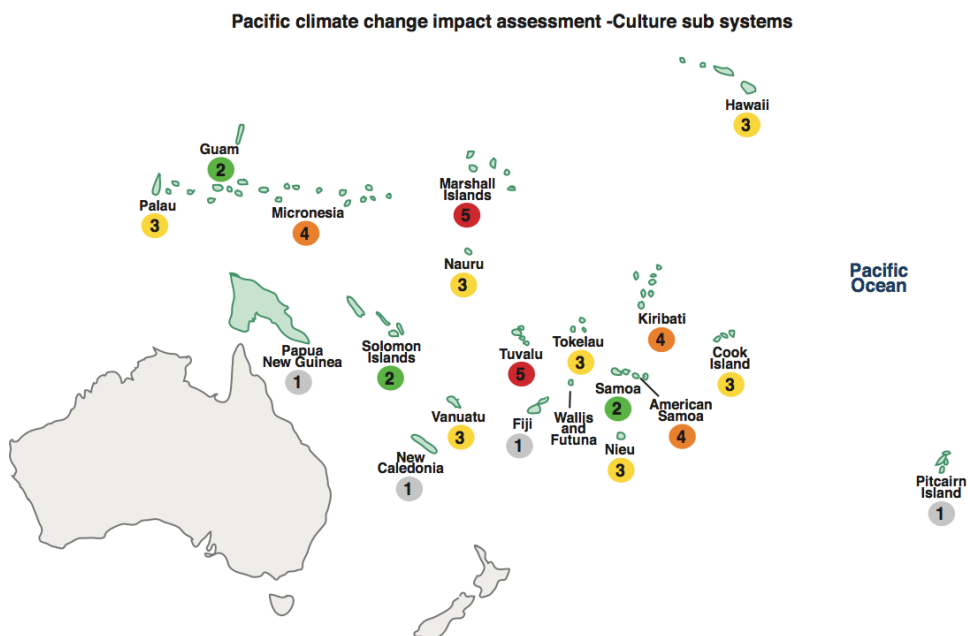


Figure 4.5: Scaling map for the impacts to cultural sub-systems

4.3.6. Health sub-system results

The climate change impacts that were assessed for health sub-system impacts included but are not limited to:

- increased incidence of water and/or food borne diseases;
- increased incidence of tropical diseases including malaria, dengue fever, Ross river fever, filariasis, schistosomiasis, diarrhoeal disease, heat stress, skin diseases, acute respiratory infections and asthma;
- increased incidence in mental disorders; and

- increase in morbidity and mortality from extreme weather events (e. g. drowning, increased injuries from extreme weather events and, reduction in dietary diversity).

No countries reported a severe impact to health sub-systems by climate change. In total, 79% reported either a moderate or major impact to health sub-systems due to climate change. Of these 42% reported a major impact level. Health sub-systems have the highest number of major ratings by any sub-system followed by water (37%) and Meteorological (35%). Only Guam and Hawaii reported minor impact to health sub-systems. This may be a result of a higher GDP per capita and a more resilient adaptive capacity health sub-systems impacts.

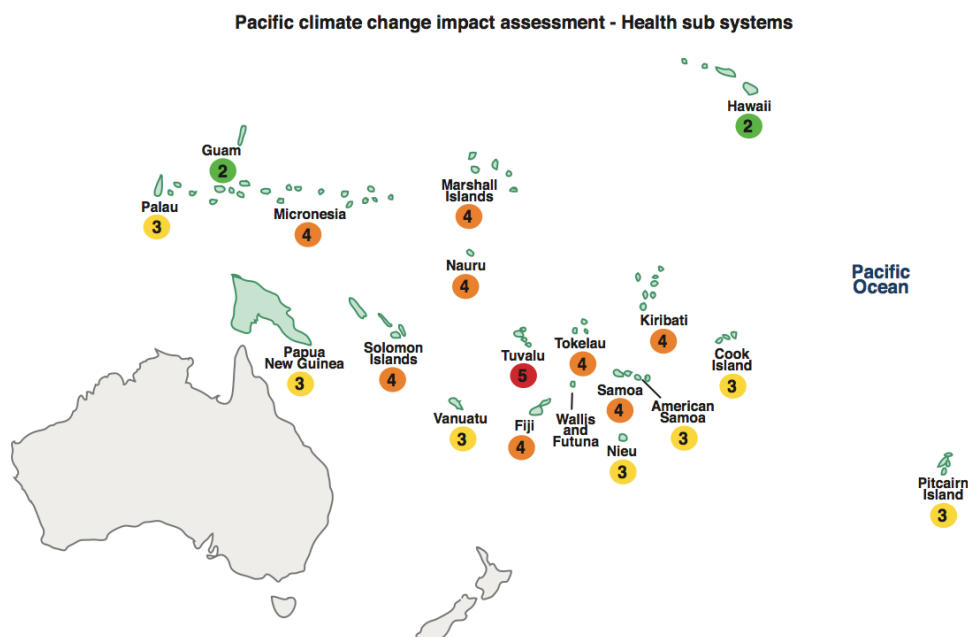


Figure 4.6: Scaling map for the impacts to health sub-systems

4.3.7. Food and agriculture sub-system results

The climate change impacts that were assessed for food and agriculture sub-system impacts included but are not limited to:

- reduction in food security;
- lower subsistence food yields;
- decline in total fish stocks;

- lower subsistence farming yields;
- lower commercial farming yields;
- lower reduction in soil fertility and/or nutrient availability;
- degradation of soils;
- reduction in land use;
- increase in agricultural pests (e. g. unwelcome insects);
- increase in unwelcome weed species;
- higher soil temperatures;
- increased destruction and degradation of key crops (sugarcane, yams, taro and cassava).

Food and agriculture systems reported the highest level of severe Category 5 ratings (26%). This was the most stressed sub-system across the Pacific Islands in 2011. Countries with a Category 5 level rating included The Solomon Islands, Micronesia, The Marshall Islands, American Samoa, and Tuvalu. A total of 90% of countries reported a moderate to severe impact to food and agriculture due to climate change. The result reflects that the food and agriculture sub-system is the second most impacted sub-system across the Pacific region. The most impacted sub-system being marine and terrestrial. Only Papua New Guinea (level 1 rating) and Guam (level 2 rating) reported negligible and minor impacts respectively.

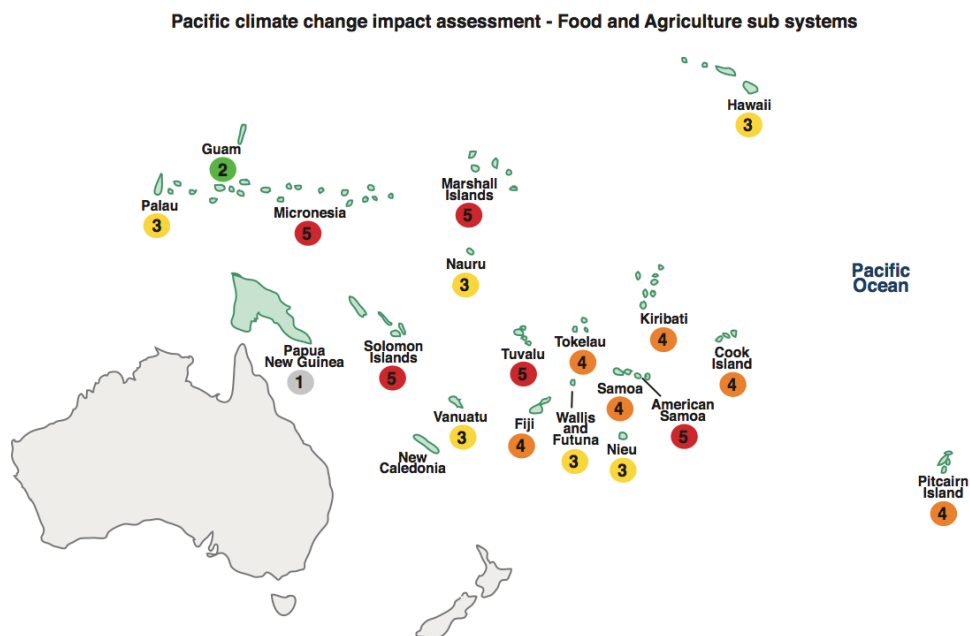


Figure 4.7: Scaling map for the impacts to food and agriculture sub-systems

4.3.8. Meteorological sub-system results

The climate change impacts that were assessed for meteorological sub-system impacts included but are not limited to:

- an increase in number of tropical cyclones;
- an increase in average intensity of tropical cyclones;
- extended drought conditions;
- increasing drought frequency;
- increased precipitation volume and intensity;
- increased daily temperature extremes;
- increased incidence and severity of floods;
- increasing ENSO(El Nino Southern Oscillation) extremities;
- increasing quasi-periodicity in El Nino Southern Oscillation (ENSO)
- increase in number and severity of storm surges;
- increasing evapotranspiration rates; and
- increasing incidence of mudslides.

Meteorological sub-systems reported the most number of respondents (60%) with an impact rating of major (4) or higher. A total of 25% of

respondents reported a severe category 5 impact rating. This included the countries of Tokelau, Micronesia, The Marshall Islands, American Samoa and Tuvalu. American Samoa, Tokelau and Tuvalu have been impacted by a number of major category 5 tropical cyclones in the last 7 years but especially in the 2003–05 seasons with Category 5 Tropical cyclones Heta, Olaf and Percy impacting these countries heavily. Only Guam and Wallis and Futuna reported a minor rating (2) for meteorological Sub-systems.

Another 25% of the respondents reported a moderate impact from meteorological factors.

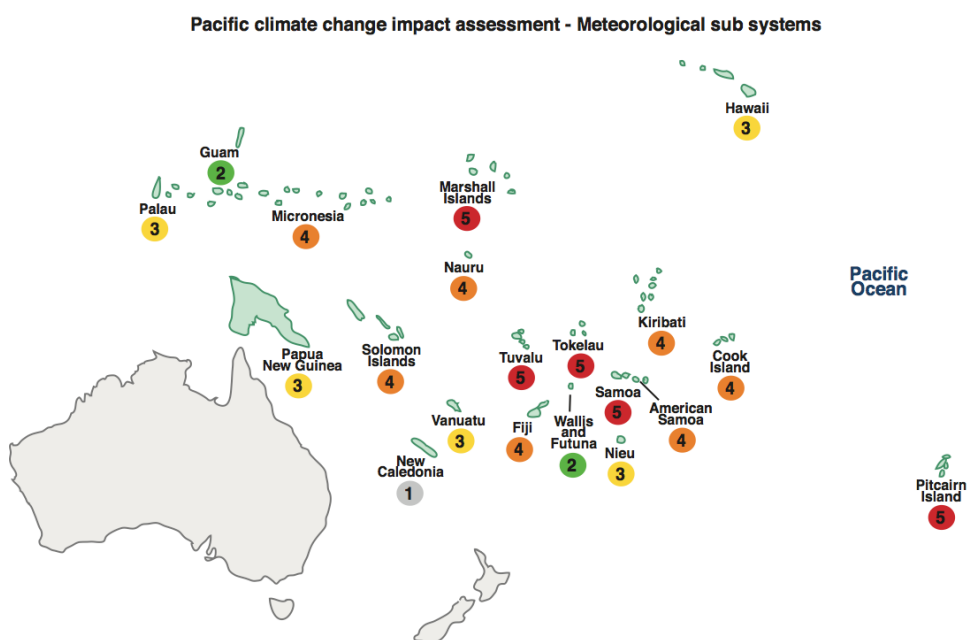


Figure 4.8: Scaling map for the impacts to meteorological sub-systems

4.3.9. Government policy and processes results

There were no specific climate change impact events provided for government and policy. This does not reflect that there are no explicit impact events for the government and policy sub system. It can be assumed that this may have been assessed as a total sub system. I.e. all impacts to government and policy sub system as a whole.

The climate impacts assessment results for the government & policy sub system included PNG, Fiji and Micronesia reporting a Category 5 impact rating against government policy and processes due to climate change. Ten countries (59%) reported a moderate to major impact to government policy and processes. The Pitcairn Islands, Guam and Hawaii reported a minor level 2 impact in this sub-system Category.

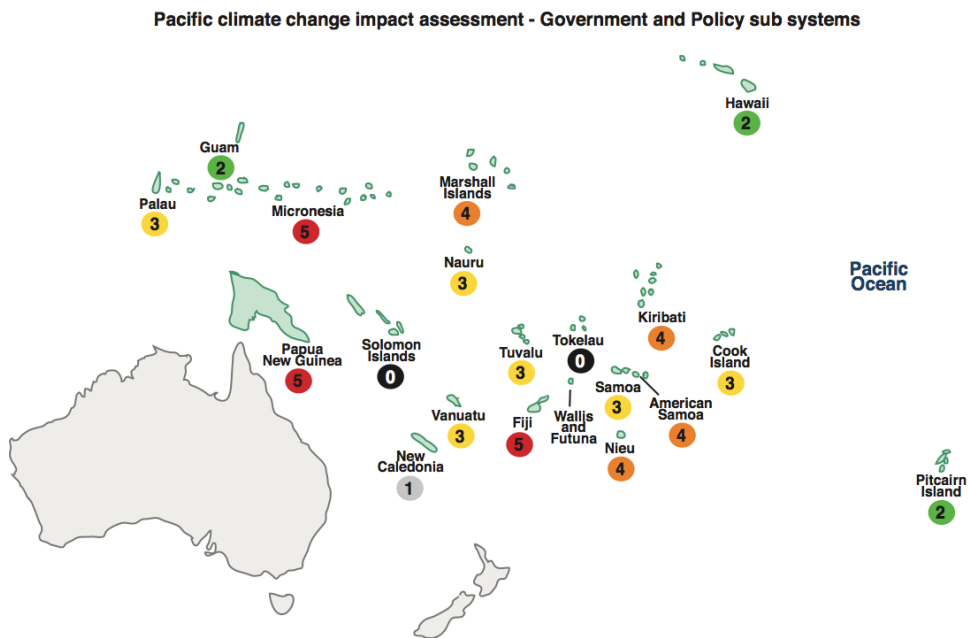


Figure 4.9: Scaling map for the impacts to government policy and process sub-systems

4.4. RESULTS OF SYSTEM ASSESSMENTS

The second section of the survey asked respondents to rank systems in order (1 being most important) as to which systems they perceive to be most important to their country in relation to exposure to climate change impacts. The systems that were assessed were ecological, human, physical and other (respondents were asked to identify other systems). The rationale for the survey request was to possibly derive weightings for systems and sub systems that could assist in weighting the scale. These were subsequently not utilised in the scale development. However, in future any further design development of the scale could utilise these results to develop some form of weighting for sub systems. This may

improve the validity of the scale but this hypothesis would need to be proven .

Tables 4.3 and 4.4 below summarise the assessments by percentage and counts respectively of the system assessment. Within the results in Table 4. 3 and Table 4. 4, approximately 60% (12) of respondents rated human systems as most important to their country as far as climate change impact is concerned. In addition, over half (11) of respondents rated physical systems as least important to them in relation to climate change impacts. Ecological systems were assessed as 1-50% (10), 2-25% (5), and 3-15% (3). There were two recordings of zero value for importance of ecological systems. Human systems were assessed as 1-60% (12), 2-30% (6), and 3-nil. There was 1 zero recorded for human systems. Physical systems were assessed as 1–15% (3), 2–20% (4) and 3–55% (11). There were two recordings of zero ratings for physical systems.

Table 4.4 outlines the counts by country for system importance assessments. In addition, it provides the median and mode for each system. The majority of countries ranked ecological systems (median 1. 5 and mean 1) and human systems (median 1. 4 and mean 1) as the most important in relation to climate change impacts. Physical systems recorded a median of 3 and a mean of 2. 3. Within ecological systems, Niue, the Pitcairn Islands and American Samoa recorded a ranking of 3. This is contrary to 75% (15) of the other respondents and is outside of the mean (1. 5) and median (1) for ecological systems.

Within human systems, Wallis and Futuna recorded the only 3 ranking. This is contrary to 90% (18) of the other respondents and is outside of the mean (1. 4) and median (1) for human systems. Within physical systems Papua New Guinea, Micronesia and Tuvalu recorded the 1 rankings. This is contrary to 75% (15) of the other respondents and is outside of the mean(2. 3) and median(3) for physical systems.

Some countries have ranked all three as '1' where others have not (PNG, Micronesia and Tuvalu). As a result, the rankings are not mutually exclusive. They may not have fully understood what the process required them to do here. There were some countries that recorded a rating of zero against systems and it is assumed that they did not correctly understand this section of the survey. This included Western Samoa and the Cook Islands.

Table 4.3: Summary table of counts in relation to importance of systems in relation to climate change impacts by percentage

Ranking	0	1	2	3
Ecological	10 %	50%	25%	15%
Human	5%	60%	30%	5%
Physical	10%	15%	20%	55%

Table 4.4: Summary table of counts in relation to importance of systems in relation to climate change impacts

Ranking	0	1	2	3	Total
Ecological	2	10	5	3	20
Human	1	12	6	1	20
Physical	2	3	4	11	20

Table 4.5: Count of Importance of systems in relation to climate change impacts by country

Country	Ecological	Human	Physical
American Samoa	3	1	2
Cook Islands	0	1	0
Fiji	2	1	3
Guam	1	2	3
Hawaii	1	2	3

Country	Ecological	Human	Physical
Kiribati	1	1	2
Marshall Islands	2	1	3
Micronesia	1	1	1
Nauru	2	1	3
New Caledonia	1	2	3
Niue	3	1	2
Palau	1	2	3
Papua New Guinea	1	1	1
Pitcairn Islands	3	2	3
Solomon Islands	1	2	3
Tokelau	2	1	3
Tuvalu	1	1	1
Vanuatu	2	1	3
Wallis and Futuna	1	3	2
Western Samoa	0	0	0
Mean	1.5	1.4	2.3
Median	1	1	3
Mode	1	1	3

4.5. RESULTS OF SUB-SYSTEM ASSESSMENTS

The third section of the survey asked respondents to rank systems in order (1 being most important and 8 the least important) as to which Sub-systems they perceive to be most important to their country in relation to climate change impacts. The Sub-systems that were assessed included marine and terrestrial, water, tourism, socio economic, culture, health, food and agriculture, meteorological.

Table 4.6 provides a count of the result assessments. Table 4.7 summarises the assessments by percentage of respondent's ratings to which Sub-systems are most important to them in relation to climate change impacts. Within the results in Table 4.6, 47% of respondents rate health as the most important sub-system followed by water (42%), food and agriculture (37%), terrestrial and marine (32%), culture (21%), socio economic (16%), meteorological (11%) and then tourism (5%). Overall, it seems that human aspects and associated food and rate as more important to the Pacific Island nations than more physical aspects such as socio economic and tourism Sub-systems.

Table 4.7 also outlines the mean, median and mode scores of each sub-system as follows:

- terrestrial and marine (mean = 2. 8, median = 3, mode = 1)
- water (mean = 2. 2, median = 2, mode = 1)
- tourism(mean = 5. 4, median = 7, mode = 8)
- socio-economic (mean = 3. 6, median = 3, mode = 2)
- culture (mean = 4. 3, median = 4, mode = 6)
- health(mean = 2. 7, median = 1. 5, mode = 1)
- food and agriculture(mean = 2.6 median = 2, mode = 1)
- meteorological (mean = 3. 8, median = 4, mode = 2).

The results indicate that health, water and food and agriculture are regarded as more important sub-systems for Pacific Islands in relation to climate change impacts. Tourism (39% of respondents ranking 8) and culture (11% of respondents ranking 8) ranked the lowest sub-systems. This may be due to higher adaptive capacity in both these sub-systems.

The assessment rankings for sub-systems do not appear to be mutually exclusive. For example, Micronesia ranked 5 items as the most important. In addition, others also ranked some sub-systems with the same ranking including Papua New Guinea, Tuvalu, Pitcairn Islands and Kiribati. It should be noted that zeros represent a nil response and have been removed from

the percentages in Table 4. 6. This includes responses from Western Samoa and partial responses from Wallis and Futuna. There was no reason provided or sought as to why these survey questions were not completed by those countries.

<i>Table 4.6: Analysis of sub-system importance in relation to climate change by country</i>								
Country	Terrestrial and marine	Water	Tourism	Socio economic	Culture	Health	Food and agriculture	Meteor- ological
American Samoa	5	2	8	3	6	7	1	4
Cook Islands	3	1	2	3	3	1	1	2
Fiji	3	2	3	2	1	4	4	4
Guam	1	3	7	2	8	4	5	6
Hawaii	2	1	8	4	5	7	6	3
Kiribati	1	1	3	2	2	1	1	2
Marshall Islands	4	3	8	6	7	1	2	5
Micronesia	1	2	2	1	1	1	1	2
Nauru	4	1	8	5	7	3	2	6
New caledonia	3	1	8	4	6	5	2	7
Nieu	4	1	8	7	6	5	2	3
Palua	3	2	7	6	8	1	5	4
Papua New Guinea	1	1	3	1	1	1	1	1
Pitcairn Islands	3	5	2	4	2	2	4	5
Solomon Islands	2	3	7	4	6	3	1	5
Tokelau	5	4	8	7	6	1	3	2
Tuvalu	1	1	1	1	1	1	1	1
Vanuatu	7	5	4	2	3	1	5	6
Wallis and futuna	1	3	No response	No response	3	2	No response	No response
Western Samoa	0	0	0	0	0	0	0	0

<i>Table 4.7: Count of sub-system importance in relation to climate change by country</i>								
Sub systems analysis	Terrestrial and marine	Water	Tourism	Socio economic	Culture	Health	Food and agriculture	Meteorological
Mean	1.4	1.3	2.2	1.8	1.9	0.9	1.2	1.5
Median	3	3	5.5	4	3	1	2.5	3.5
Mode	1	1	8	7	6	1	1	1
Percentage who ranked as 1	16%	16%	6%	11%	11%	26%	17%	11%
Percentage who ranked as 2	5%	5%	6%	6%	5%	11%	6%	6%
Percentage who ranked as 3	11%	11%	6%	0%	11%	5%	6%	6%
Percentage who ranked as 4	5%	5%	6%	11%	0%	0%	6%	6%
Percentage who ranked as 5	5%	11%	0%	0%	0%	5%	11%	11%
Percentage who ranked as 6	0%	0%	0%	6%	16%	0%	0%	6%
Percentage who ranked as 7	5%	0%	11%	11%	0%	0%	0%	0%
Percentage who ranked as 8	0%	0%	11%	0%	5%	0%	0%	0%
Sub system percentages	1	2	3	4	5	6	7	8
Terrestrial and marine	16%	5%	11%	6%	5%	0%	6%	0%
water	16%	5%	11%	6%	11%	0%	0%	0%
Tourism	5%	5%	6%	6%	0%	0%	11%	11%
socio economic	11%	5%	0%	11%	0%	5%	11%	0%
culture	11%	5%	11%	0%	0%	16%	0%	6%
Health	26%	11%	6%	0%	5%	0%	0%	0%
Food and agriculture	16%	5%	6%	6%	11%	0%	0%	0%
Meteorological	11%	5%	6%	6%	11%	5%	0%	0%

4.6. USABILITY ISSUES

For now, it is assumed that the users found the use of the Scale simple as the author did not receive any queries from any of my 18 respondents asking how to use the scale for assessment purposes. Usability of the scale would be the subject of further studies and a subsequent survey. In addition, New Caledonia seemed to have trouble using the scale for assessment purposes as they reported one ratings for every sub system. The study did not evaluate this response further and assumed it was related to user misunderstanding. The only other minor issue was language related. The respondent for Wallis and Futuna could not understand English well. As a result the author created a French translation of the survey to which they completed assessments for only three sub systems. There was no follow up to ascertain why Wallis and Futuna only partially completed the survey.

4.7. SUMMARY OF RESULTS

The results of the Pacific Islands climate change impacts survey 2011 show that tourism and culture sub-systems are reported to be the least impacted by climate change. Meteorological, food and agriculture and water sub-systems are the most severely impacted sub-systems in the Pacific region in 2011.

In total, the survey recorded 171 Scale assessments across 9 sub-systems. Of the 171 counts, eight were level 1 count by New Caledonia and should be excluded and regarded as erroneous. Of the remainder of 163 counts 75 counts were scaled at a major (level 4) or severe (level 5) impact rating. This equates to 46% of all responses across the 9 sub-systems in 20 countries across the Pacific undergoing a severe or major impact due to climate change in 2011. The findings are in agreement with other climate change impact assessments on the region completed to date. This will be discussed in the next chapter. It is concluded that a simple Scale can be

utilised effectively to measure climate change impacts for the Pacific region.

Chapter 5: Discussion of Results

A simplified climate change scale model was introduced in Chapter 3 and is designed to assess and communicate climate change impacts for a region. Subsequent to the design of the Simplified qualitative climate change scale for assessing and communicating climate change impacts, a survey of 20 Pacific Island nations was undertaken to assess if the Scale is easy to use for professionals who are responsible for reporting climate change impacts for their country. The results of those climate change impact assessments as part of the survey are detailed in Chapter 4.

In this chapter we discuss what these results mean in the context of a simplified Scale for measuring and communicating climate change impacts. To re-iterate, the main goal of this research was to design a simplified Scale for measuring climate change impact for a region. A secondary goal was to test if the Scale was easily usable for assessment of climate change impacts for a region.

Within the research there are some limitations and constraints that are important to understand. Firstly, the research assumes that all climate impact events within each sub-system are attributed to climate change due to global warming. Secondly, the research does not survey the public or policymakers to as to how effective the results and presentation of the results are in communicating climate change impacts. Therefore, it can only be assumed that, as there is only one number and a brief definition for that scale number that it would be easy for a member of the public or a policymaker to understand. Lastly, the lists of climate change events that were provided for each sub-system as part of the survey are not a definitive list. The list was only a sample of events from a number of reports (Mimura 2007; Preston 2009; Hay 2003) .

The Scale assessment would have a higher level of confidence if the climate change impact events list was fully complete and agreed by professional

who complete the assessment. It is feasible that a different set of climate change events could be created for a different region specific. This would then allow the Scale to be utilised in different regions. This issue is discussed in more detail later in this chapter. This chapter will commence with a discussion on findings during the research around lack of focus on current impacts from the science community and policymakers. It will then look at some of the lessons learned during the design of the scale. The research will review current climate change impacts in the Pacific and what implications the results of the survey may have had. Then the chapter will look at some alternate application of the Scale. Finally, we will look at how the Scale could be improved in future.

This section of the research focuses on findings during the literature review. The literature reviewed analysed literature and methods of existing climate scales and indexes. It also covered scaling methods and climate change impacts in the Pacific region including the small island countries of the Pacific. One of the main findings during the literature review was that there was no current simplified scale for measuring climate change impacts. This in essence became the motivation for developing a scale as outlined in Chapter 3 of this research.

The motivation for this research came about because prima facie most discussion on popular media and within the scientific community was in relation to future state climate models and future state vulnerability to climate change. This was validated during completion of the literature review as there was little material discovered which actually discussed current climate change impacts. Within the popular media and public opinion we can conclude that bias of public perception of climate change is negative and sceptical of the science behind climate change (Bentley 2012). Similar experiences are documented in texts such as *Why we disagree about climate change* (Hulme 2009) and *Climate change and the media* (Boyce, 2009). These texts also explain possible rationales for human

behaviour in relation to climate change. The matter of popular public opinion on climate change and media influence on public opinion is not the subject of this research. However, it is important to raise the issue in the context of a need to better communicate climate change to the public.

In addition, adverse public reaction could be due to the fact that climate change is seen as a distant event (Bentley 2012). If the focus was more on current climate change impact it may be that public opinion may shift to become less sceptical. There is clear evidence of current impact from climate change in the Pacific region. The results of the assessments in the survey support this. The survey that was distributed to 20 Pacific Island nations was utilised by professionals. How can it be that so many people from so many diverse countries who are mutually exclusive and in some cases separated by great distances, report major climate change impacts to their sub-systems already occurring? Climate change is impacting the Pacific Island region as confirmed by reports including the *Intergovernmental Panel on Climate Change (IPCC) 4th assessment report* chapter on small islands and *Climate variability and change and sea level rise in the Pacific islands region* (Hay 2003).

This was validated by completion of the Pacific Islands climate change impact survey 2011. The next section will look at what the results of that survey means, comparing its other studies of climate change impact on the Pacific region.

This section will look at what the results of the survey. It will not provide a detailed analysis of the results. For a detailed analysis of the results refer to Chapter 4. This section will also make an assessment of how accurate results were against other climate change impact studies that have been completed to date at a summary level. The discussion will focus on the overall impact of climate change across Pacific small island countries. Pacific region climate impact summaries will be extracted from the following three reports:

1. Climate variability and change and sea level rise in the Pacific Islands region (Hay 2003.)
2. Small Islands chapter 16 of the Intergovernmental Panel on Climate Change (IPCC)4AR 2007 (Mimura 2007)
3. *Climate change in the Pacific: Scientific assessment and new research report 2012* – The Pacific Climate change Science program (CSIRO and The Australian Bureau of Meteorology 2011).

The summary views on climate change impact within the Pacific will be compared with the overall results obtained from the climate change impact survey results detailed in chapter 4 of this research. An overall assessment will then be made as to the effectiveness of the results obtained by using the simplified climate change impact scale constructed within this research.

5.1. PACIFIC ISLANDS CLIMATE CHANGE IMPACTS SURVEY 2011 – IMPACT SUMMARY

The Pacific Islands climate change impacts survey 2011 (the survey) described in this thesis was undertaken in 2011. The main aim of the survey was to test the effectiveness for users in assessing climate change impacts over sub-systems utilising the derived simplified climate change impact scale. The survey distributed to 20 Pacific Island nations.

The main findings in relation to climate change impacts from the survey results were, approximately 20% of respondents recorded a severe impact to **marine and terrestrial sub-systems**. 30% of respondents recorded a major impact to marine and terrestrial sub-systems. The remaining 50% of respondents have indicated a moderate level of impact to marine and terrestrial sub-systems. In total, all respondents have indicated a moderate or greater level of impact to marine and terrestrial sub-systems due to climate change impact.

Within **water sub-systems**, 37% of respondents recorded a major impact due to climate change. 21% of respondents indicated a severe impact. 26 % indicated a moderate impact and 11% indicated a minor impact to water sub-systems. The key point of note is that 63% of respondents indicated a moderate or major impact on water sub-systems in their countries. Combined with marine and terrestrial results it seems that both fresh and ocean water systems are under major to severe forcing's due to climate change throughout the Pacific region.

Within **tourism sub-systems** most countries reported minor and negligible impacts (47%). No countries reported a severe impact to tourism sub-systems due to climate change at this stage. 11% of respondents reported a major impact, and 26% reported a negligible category 1 impact level on tourism sub-systems. The results indicate that tourism sub-systems are the least impacted by climate change currently in the Pacific region.

In response to **cultural impacts**, only one-fifth of respondents (21%) recorded a negligible impact and 37% reported moderate impacts.

Within **health sub-systems** 79% reported a moderate major impact due to climate change. 11% reported a minor impact rating of 2.

Within **social-economic sub-systems** there were 37% of respondents recorded a moderate impact. 21% reported negligible to minor impacts. In contrast, 42% reported a major to severe impact to this sub-system.

Within the **food and agricultural sub-systems** 10% of respondents reported a minor or negligible impact. The remainder (90%) reported a moderate to severe impact due to climate change. Of these 26% recorded a severe category 5 impact on food and agricultural sub-systems. In conjunction with meteorological sub-systems this represents the highest number of respondents with a category 5 impact level. Note that there are severe impacts to both water and marine terrestrial sub-systems, which are key inputs to food and agricultural sub-systems in the Pacific region.

Approximately, 25% of respondents recorded a severe category 5 rating for **meteorological sub-systems**. A further 35% of respondents recorded a major category 4 rating. There were 5% negligible ratings for meteorological sub-systems.

Lastly, **government and policy sub-systems** reported a mainly minor to moderate impact for 59% of respondents. 41% of respondents recorded a major to severe rating for government and policy sub-systems.

In summary, over the nine sub-systems assessed there was an average of level 3-5 impact ratings for climate change impact in the Pacific region. This represents a moderate to severe impact from climate change based on anecdotal and expert knowledge assessments utilising the simplified climate change scale.

5.2. *CLIMATE VARIABILITY AND CHANGE AND SEA LEVEL RISE IN THE PACIFIC ISLANDS REGION* REPORT – IMPACT SUMMARY

This report (Hay 2003) assessed the impacts on natural and human systems in 2002. In assessing impacts in the report utilise a number of methodologies including experimentation, modelling, use of empirical analogues, expert judgement, and use of anecdotal information. There are already major stresses such as warm water resources dating as far back as the 1982-83 ENSO event. The report states that extreme weather events and climate variability are currently impacting on the few countries in the Pacific Island region for water sub-systems. Agricultural production systems are already stressed as a consequence of our population densities and growth rates. Increasing population numbers, with climate change impacts, means that food security is a major concern. There are indications that changes in climatic conditions coupled with increases in unsustainable use by rendering terrestrial and freshwater ecosystems vulnerable in the longer term. During the 1997 to 1998 El Niño extensive wildfires occurred in many Pacific Island countries, including Samoa and Fiji. This impacted

grasslands and forest composition and biodiversity. Globally, sea level has been rising over the last 100 years or so in many parts of the Pacific have already experienced relative sea level rise. Some of the direct impacts on socio economic and cultural sectors from sea level rise include:

- damage to coastal protection works, causeways, roads and other coastal infrastructure;
- destruction or degradation of crops as a result of seawater intrusion;
- contamination of fresh groundwater supplies;
- increased disease risk;
- storm damage and incidence of storms in areas that currently experienced few such storms, such as French Polynesia and Tokelau;
- erosion of beaches and coast undermining important facilities e. g, hospitals, airfields, storage facilities and graveyards;
- loss of tourism, recreation and cultural resources; and
- habitat degradation and harvest restrictions.

The report states that many of the impacts above are already impacting island populations. Countries are already experiencing disruptive changes consistent with many of the anticipated consequences of global climate change, including extensive coastal erosion, droughts, coral bleaching, more widespread and frequent occurrence of mosquito borne diseases and higher sea levels making some soils to saline for cultivation of traditional crops. This evidence provides compelling intangible indications of the seriousness of global warming impact. The adverse consequences of climate change are already an unfortunate reality for many Pacific Island inhabitants.

5.3. *IPCC 4TH ASSESSMENT REPORT* - CHAPTER 16 SMALL ISLANDS-IMPACT SUMMARY

‘Small Islands’ was the 16th chapter of the IPCC 4AR(Mimura 2007). In relation to current climate change impacts and at or before 2007 the

report stated that on some islands, especially those at higher latitudes, warming has already led to the replacement of some local species (high confidence). Trends in extreme temperature across the South Pacific for the period 1961 to 2003 showed increases in the annual number of hot days and warm nights, with decreases in annual number of cool days and cold nights, particularly in the years after the onset of El Niño. The report indicates an increase in tropical cyclone activity in the South Pacific east of 160°, especially in years associated with El Niño events. There is a more than doubling in the number of category 4 and 5 storms in the South-West Pacific from the period 1975 to 1989.

The report indicates that the overall average mean relative sea level rise around the whole region of the Pacific at 0.77mm per year. SEAFRAME stations in the Pacific indicate an average rate of sea level rise is currently 1.6mm per year. Many small islands are experiencing the water stress at the current levels of rainfall input.

Poor water quality is affecting human health and carries waterborne diseases. Water quality is linked to climate variability and change. The report states that islands are sensitive to climate change and sea level rise, and adverse consequences of climate change and variability are already a reality for many inhabitants of small islands. The report also indicates decline in the momentum for vulnerability and impact research and only cite a few recent investigations of climate change impacts on small islands.

5.4. *CLIMATE CHANGE IN THE PACIFIC: SCIENTIFIC ASSESSMENT AND NEW RESEARCH – IMPACT SUMMARY*

This report (Australian Bureau of Meteorology and CSIRO 2011) was sanctioned in response to identified information gaps, research priorities, and observational data for Pacific Islands. The report was completed by the Pacific climate change science program, which is a collaborative research

partnership between several Australian government agencies, East Timor and 14 Pacific Island countries.

In relation to climate change impacts within the Pacific region the report states that temperature records from Pacific Island observation station show a clear signal of warming over the past 50 years, with most stations warming at a rate between 0.8 and 0.2°C per decade over this time; consistent with global trends. Rainfall across the region has increased and decreased in response to natural climate variability. There are no significant trends in the overall number of tropical cyclones, or in the number of intense tropical cyclones, in the South Pacific Ocean over the period 1981 to 2007.

Sea surface temperatures in the region have generally warmed since 1950. This warming has been partially attributed to increases in the concentration of greenhouse gases. The western tropical Pacific Ocean has become significantly less salty over recent decades. Conversely, regions to the East have generally become saltier. Together, these changes suggested intensification of the hydrological cycle. A distinctive pattern of intensified surface warming and sub-surface cooling, within a depth of 200m is evident over the past 50 years in the Pacific Ocean climate model suggest this pattern is consistently human induced change.

Sea level has risen globally in the Pacific region over recent decades. The report states that sea levels are also increasing, primarily as a result of increases in mean sea level. The acidity level of ocean waters is increasing due to the increased uptake of carbon dioxide due to higher atmospheric concentrations that have resulted from human activities.

Anecdotally, people in the region are reporting climate change impacts, including more saltwater intrusions, changes in seasonal climate cycles, and more frequent droughts, fires, mudslides and coral bleaching. However, little research has been conducted to quantify the

relative importance of human induced change and natural variability as causes of the observed trends in the Pacific region. The report provides evidence that local perceptions are that changing weather and climate has occurred over the past decade more than at any other time in human memory. Partner country representatives living on the Pacific Islands described local perceptions of climate change in their countries. These included:

- shifts in seasonal patterns of rainfall and tropical cyclones;
- more frequent and extreme rainfall causing flooding and mudslides;
- more drought and fires;
- more hot days;
- lower crop productivity;
- spread of weeds, pests and diseases;
- more coral bleaching; and
- more storm surges, coastal erosion and saltwater contamination of freshwater springs and taro swamps.

Many Pacific Islanders believe the impacts of climate change are being exacerbated by increased population and development, waste management and land degradation.

The report also mentions that some regional scale changes in the Pacific have been partly attributed to human activities such as the weakening of the Walker circulation and the warming in the Pacific mean surface temperature. However, it also mentions the researchers are attempting to determine whether the changes perceived by people in the islands are real, and if so, to qualify the relative contributions from human and natural climate influences.

5.5. EFFECTIVENESS OF THE SCALE

This research project initially set out to answer a number of research questions as outlined in section 1.3 Aims and scope. The discussion that

follows will evaluate how effective the scale was in answering the research questions.

The project primarily aimed to create a simplified qualitative scale for assessing and communicating climate change impacts that could improve communication of climate change to the public. The scale was able to elicit an assessment of climate change from experts in 18 countries. The results of the assessment indicate a moderate to severe impact on climate change is already occurring across the Pacific region. The results of the assessments indicate that most sub-systems across nearly 20 small island countries are being impacted by climate change.

To compare validity of the impact assessment using the scale three detailed scientific reports of climate change impacts in the Pacific region were reviewed and compared. These reports validated that there is strong evidence of high impacts of climate change being experienced across varying sub-systems in Pacific countries. The evidence in these reports is in some instances from recorded data sets and in others from anecdotal accounts. None of the three reports contained a comprehensive assessment of the overall impact of climate change due to lack of data. It can be concluded that the survey provides a more comprehensive view overall of the impacts of climate change across a diverse number of systems than any of the three reports reviewed.

All reports are in agreement that the Pacific Island region is currently being moderately to severely affected by climate change. As a result, it can be concluded that the scale has effectively measured climate change impact indicatively across the Pacific region.

Secondly, the research looked to apply a risk based approach. This was achieved by utilising the AS/NZS Risk management standard 2004 and evolving a basic qualitative scale. It can only be assumed that the scale was easy to use for assessment as there were only two countries (New

Caledonia and Wallis and Futuna) that produced inadequate assessment results.

As there was no survey undertaken of users of the scale output, namely the public and policymakers, the research cannot conclude if:

- the scale output would be suitable for the general public and policymakers;
- the scale was simple to understand;
- the scale made it easy to understand results of assessments of climate change impacts.

In addition, the research established:

- a primary motivation for improving communication of climate change impacts, in Section 1.2 problem statement;
- that there were no existing measures for assessing and communicating climate change impacts in a simple way.

5.6. EXTENDED APPLICATIONS FOR USE OF A SIMPLIFIED IMPACT SCALE

We have seen in the last section how the simplified climate change scale was utilised to effectively assess current climate change impacts in the Pacific region. The Pacific region was chosen because it is currently highly vulnerable to stresses attributed to climate change forcing's (Hay 2003).

Table 5.1: Sample climate change event data set for health sub-systems in Pacific Small Islands Countries Region

Includes impacts such as:	<ul style="list-style-type: none"> • Increased evidence of vector-borne diseases • Increased incidence of water- and/or food-borne diseases
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	<ul style="list-style-type: none"> • Increased incidence of tropical diseases including malaria, dengue fever, Ross river fever, filariasis, schistosomiasis, diarrhoeal disease, heat stress, skin diseases, acute repository infections and asthma • Increased incidence in mental disorders • Increase in morbidity and mortality from extreme weather events e. g. drowning • Increased injuries form extreme weather events • Reduction in dietary diversity
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The simplified climate scale could also be utilised to understand current climate change impacts when there is no available impact data for a region. Additionally, the climate impact events can be explicit and targeted for different regions, as illustrated by the example of health sub-systems in the Caribbean (Table 5.2) as compared to what was used in the Pacific Islands climate change impact survey 2011 (Table 5.1). As is evident within the tables there are two separate sets of events for health impacts. Each impact event set differs depending on the region.

Table 5. 2 Sample climate impact event data set for health sub-systems in the Caribbean (Aron 2002)

Includes impacts such as:	<ul style="list-style-type: none"> • Vector-borne disease increases (Dengue fever, Malaria) • Increase in water-borne diseases • Increase in heat stress and deaths related to heat stress • Increase in asthma rates
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Using the scale for cross regional assessments and as a proxy measure when data is not available for a sub-system are two ways in which the simplified scale could be applied with minimal of effort. However, there are some improvements that could be undertaken to the scale as it stands to provide a higher level of confidence for users. In addition, if a portal solution was made available to users, assessments could be updated in shorter periods e.g. monthly. Output results could also be more

transparent using such a channel. These improvements are discussed in the next section.

Chapter 6: Conclusions

The research achieved the primary aim of the study which was to create a simplified qualitative scale for assessing climate change impacts. However, there was no assessment undertaken to assess if the public found the result output easy to understand.

It was clear from research that improvements in communication of climate change concepts to the public would improve public opinion and support of climate change. Simplified map presentations of results of impact assessments could assist in improvement of the perception that climate change is not a concept of the distant future but is actually happening now.

The research validates that there is no current simplified qualitative scale for measuring climate change impact. As a result of this finding a prototype simplified qualitative scale was developed using existing risk management frameworks. The scale was then utilised by subject matter experts to assess climate change impacts to nine sub systems across 18 Pacific Island countries. Impact assessment results were elicited with little issue on the usability aspects of the prototype scale. The assessment findings indicate a moderate to severe impact from climate change is already occurring across the Pacific region. This concurs broadly with the more scientific findings contained in three major climate change impact reports for the Pacific Islands in the last decade.

The main strength of the prototype scale is its ease of use for impact assessment and its ease of understanding the results if presented in a graphical map. The main weakness of the scale is that it is based on the expert assessors' perceptions and the completeness, applicability and consistency of the group of impact events that they are assessing. Some suggestions have been made in Section 6.1 below to address these weaknesses.

6.1. FUTURE WORKS AND IMPROVEMENTS TO THE SIMPLIFIED IMPACT SCALE

There are opportunities to further improve the prototype follows:

1. A weighting could be added to each climate change impact event to provide more accurate scaling and rely less upon expert perception as to what impact events are rated higher than others.
2. Obtain and ascertain usability feedback for users of the scale. This includes those who assess and those that interpret the output of the scale. This feedback would be useful to understand if the output of the scale was easy to understand for the public.
3. There is a more general question as to the veracity of the different individual evaluations completed by the respondents of the survey. The evaluations of climate change impacts are not necessarily an appraisal of the general state of the sub system, but a reflection on the particular or set of impact events. If the scale could develop a standard set of climate change impacts that could be utilised across regions could create the opportunity for consistent cross regional analysis of impacts.

4. A web information technology application could present assessment results and provide impact assessment information technology services based on a prototype scale assessment. Assessment results could be undertaken at regular intervals with updated and output on graphical maps for comparison of sub systems and regions. This would improve transparency and currency of the impact assessment result information. Additionally, standard climate impact event sets could be created and stored within an application database. The impact sets could be updated as required.

The opportunities for improvements are not within the scope of this thesis and would require further additional research.

References

Allaby M, A Dictionary of Ecology 2004, Oxford University Press, UK, 2004.

Aron JL, Corvalan CF, Philippeaux H.. 2003. Climate Variability and Change and Their Health Effects in the Caribbean: Information for Adaptation Planning in the Health Sector. Conference 21–22 May 2002; workshop 23–25 May 2002. Geneva:World Health Organization.

AS/NZS 4360 (2004). : Risk Management. Third Edition, Standards Australia/Standards New Zealand, Sydney, Australia, Wellington, New Zealand. www.standards.com.au

Australia. Bureau of Rural Sciences. and Australia. Dept. of Agriculture Fisheries and Forestry. (2004). Climate change : adaptation in agriculture. [Canberra], Bureau of Rural Sciences.

Australian and New Zealand Environment and Conservation Council. State of the Environment Reporting Task Force, Core Environmental Indicators For Reporting On The State Of The Environment, Canberra, 2000

Australian Bureau of Meteorology and CSIRO, 2011, climate change in the Pacific; scientific assessment and new research. Volume 1; regional overview, volume 2; country reports.

Australian Bureau of Meteorology and CSIRO, State of the Climate Report, Australia, 2012.

Australian State of the Environment Committee. , R. J. S. Beeton, et al. , Australia: State Of The Environment: Independent Report To The Australian Government Minister For The Environment And Heritage. Canberra, 2006

Baettig, M. B. , M. Wild, et al. , "A climate change index: Where climate change may be most prominent in the 21st century", Geophys. Res. Lett 34: 6, 2007.

Barnett, J., Lambert, S., Fry, I The Hazards of Indicators: Insights from the Environmental Vulnerability Index, Annals of the Association of American Geographers Vol. 98, Iss. 1, 2008

Bentley RA, Garnett P, O'Brien MJ, Brock WA (2012) Word Diffusion and Climate Science. PLoS ONE 7(11): e47966.
doi:10.1371/journal.pone.0047966

Boyce, T. and Lewis, J. 2009. *Climate change and the media*, New York: Peter Lang.

Bruce, S. Leedman, A. and Sims, J. The Australian National Agricultural Monitoring System – a national climate risk management application. Proceedings of the 13th Australian Agronomy Conference. 10-14 September 2006 Perth, Western Australia.

Budyko, M. I. (1958) The Heat Balance of the Earth's Surface, trs. Nina A. Stepanova, US Department of Commerce, Washington, D.D., 259 p.

De Vellis, R. F. , Scale Development : Theory And Applications, Sage, USA, 1991.

European Environment Agency (EEA)
Climate change, impacts and vulnerability in Europe 2012: an indicator-based report [Electronic resource]. - Copenhagen : European Environment Agency, 2012. - 300p. - EEA Report No. 12/2012 .

Garnaut, R. , The Garnaut Climate Change Review : Final Report, Cambridge University Press, Australia, 2008.

Global Environment Facility(GEF). GEF Benefits Index of Climate Change (GBICC) (Washington, DC: Global Environment Facility, undated), available on the Internet at: available at:
http://www.gefweb.org/uploadedFiles/Policies/Resource_Allocation_Framework/GEF-4_Indicative_Allocations/GBI_Climate_Change.pdf [accessed 17 February 2013]

Gleason, Karin L., Jay H. Lawrimore, David H. Levinson, Thomas R. Karl, David J. Karoly, 2008: A revised u.s. climate extremes index. *J. Climate*, **21**, 2124–2137.

Godfrey, Elaine (2008). "The Enhanced Fujita Tornado Scale". National Climatic Data Center.
<http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/educational/fujita.html> (Accessed 13 July 2009).

Gray, W. , Ibbitt, R. et al. , A Methodology To Assess The Impacts Of Climate Change On Flood Risk In New Zealand. Christchurch: 36, 2005

Hansen, J. , Sato, M. et al. , "A Common-Sense Climate Index: Is Climate Changing Noticeably?" Proceedings of the National Academy of Sciences of the United States of America, 95(8): 4113-4120, 1998.

Hay, J. E., Mimura M., Campbell J, Fifita S., Koshy K, McLean Roger F., Nakalevu T, Nunn P., de Wet N. (2003) Climate variability and change and sea-level rise in the Pacific Islands region-A resource book for policy and decision makers, educators and other stakeholders. South Pacific Regional Environment Programme and Japan Ministry for Environment Small Islands.

Hinkin, R. T., A review of scale development practices in the study of organisations. *Journal of Management*, Vol 21, No5, 1995.

Hulme, M. *Why We Disagree About Climate Change* (Cambridge Univ. Press, 2009).

Intergovernmental Panel on Climate Change. (2007). IPCC fourth assessment report climate change 2007. Geneva, Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A

Special Report of Working Groups I and II [Field, C. B. , V. Barros, T. F. , Stocker, D. , Qin, D. J. , Dokken, K. L. , Ebi, M. D. , Mastrandrea, K. J. , Mach, G. -K. , Plattner, S. K. , Allen, M. , Tignor, and P. M. Midgley (eds.)]. Cambridge University Press, UK, 2012, pp 582

Kocin, Paul J., Louis W. Uccellini, 2004: A Snowfall Impact Scale Derived from Northeast Storm Snowfall Distributions. Bull. Amer. Meteor. Soc., 85, 177–194.

Kowalzig, J. (2009). Comments by Jan Kowalzig at UNFCCC Climate change conference. Bonn, May, 2009. Retrieved from <http://www.preventionweb.net/english/professional/news/v.php?id=9876> [accessed 17 February 2013]

Leemans, Rik (1990). "Possible Changes in Natural Vegetation Patterns Due to a Global Warming". National Geophysical Data Center (NOAA).

Lewis, R. J. (2001). "The changing face of ciguatera." *Toxicon* **39**(1): 97-106.

Lorenzoni I., Nicholson-Cole S., Whitmarsh L. Barriers perceived to engaging with climate change among the UK public and their policy implications (2007) *Global Environmental Change*, 17 (3-4), pp. 445-459.

Lorenzoni I, Leiserowitz A, De Franca Doria M, Poortinga W, Pidgeon NF (2006) Cross-national comparisons of image associations with “global warming” and “climate change” among laypeople in the United States of America and Great Britain. *Journal of Risk Research* 9: 265–281. doi: [10.1080/13669870600613658](https://doi.org/10.1080/13669870600613658).

Manton, M. J. and J. D. Jasper (1998). Environmental indicators for national state of the environment reporting : the atmosphere. Canberra, Environment Australia, Dept. of the Environment.
Maplecroft. 2010. *Climate Change Risk Atlas 2011*. Bath, UK: Maplecroft.

Marshall, Timothy P. (2001). "Birth of the Fujita Scale". *Storm Track*. 24 (3): 6–10.

McSweeney, C. , M. New, et al. . (2008). UNDP Climate Change Country Profiles, University of Oxford

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem, 2007: Small islands. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687-716.

National Assessment Synthesis Team *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, Report for the US Global Change Research Program, Cambridge University Press, Cambridge UK, 620pp., 2001.

Nicholls, N. , M. R. Haylock, et al. . (2000). Climate extremes : indicators for State of the Environment monitoring. Canberra, A. C. T. , Environment Australia.

Peel, M. C. and Finlayson, B. L. and McMahon, T. A. (2007). "Updated world map of the Köppen–Geiger climate classification". *Hydrol. Earth Syst. Sci.* 11: 1633–1644.

Peterson, T. C. , "Climate Change Indices. " *World Meteorological Organisation* 54(2): , 2005, pp 83-86.

Peterson, T. C. , C. Folland, et al. . (2001). Report on the activities of the working group on climate change detection and related rapporteurs: 143.

Pongracz, R. and Bartholy, J. "Extreme Climate Analysis Using Extreme Index Time Series For The Central/Eastern European Region. " *Geophysical Research* 8(08552), 2006.

Preston, B.L. and Stafford-Smith, M. (2009). *Framing vulnerability and adaptive capacity assessment: Discussion paper*. CSIRO Climate Adaptation Flagship Working paper No. 2.
<http://www.csiro.au/org/ClimateAdaptationFlagship.html>

Programme. , UNEP.(2004). Environmental Indicators South Pacific. Klong Luang, Pathumthani, Resource centre for Asia and Pacific.

Programme. , W. C. D. a. M. (2007). Joint CCL/CLIVAR/JCOMM Expert team on Climate Change Detection and Indices. Geneva. WCDMP No. 64

Richter, C.F., 1936. "An instrumental earthquake magnitude scale", *Bulletin of the Seismological Society of America* 25, no., 1-32.

Saucier, Walter J. *Principles of Meteorological Analysis*. The University of Chicago Press,. 1955

Schwab, D.P.(1980). Construct validity in organisation behaviour. P 3-43 in B/M. Staw and L.L. Cummings(Eds), *Research in organisation behaviour*, Vol 2 .Greenwich,CT:JAI press.

Secretariat of the Pacific Regional Environment Programme. Pacific Islands Framework For Action on Climate Change 2006-2015. 2nd edition,(2005). available at: <http://www.sprep.org/attachments/Publications/PIFACC-ref.pdf> [accessed 17 February 2013]

State of the Environment Committee, Independent Report to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities, DSEWPAC, Canberra, 2011.

Steffen, W. , England, M. and Karoly, D. Climate Commission: A year in review(2011).Climate Commission.

Stevens, S. S. (1946). "On the Theory of Scales of Measurement". Science 103 (2684): 677–680.

Tharenou, P. , Donohue, R. et al. , Management Research Methods, Cambridge University Press, Australia, 2007.

Thorntwaite, C.W. (1948). "An Approach Toward a Rational Classification of Climate". Geographical Review 38 (1): 55–94.

Union of concerned scientists. (2000). Global Warming: Early Warning signs. Exploring climate change impacts. Cambridge, MA. : 30., available at; http://www.geol.sc.edu/cbnelson/scienceweb/UpwardBound/climate_change_guide.pdf [accessed 17 February 2013]

University of Copenhagen Synthesis Report from Climate change Global Risks, Challenges & Decisions. Copenhagen 2009. 2nd edition, available at: <http://climatecongress.ku.dk/pdf/synthesisreport> [accessed 17 February 2013]

UN General Assembly, *United Nations Millennium Declaration, Resolution Adopted by the General Assembly* , 18 September 2000, A/RES/55/2, available at: <http://www.unhcr.org/refworld/docid/3b00f4ea3.html> [accessed 17 February 2013]

UN General Assembly, *United Nations 2005 World summit outcome, Resolution Adopted by the General Assembly* , 15 September 2005, A/60/L.1, available at: <http://www.who.int/hiv/universalaccess2010/worldsummit.pdf> [accessed 17 February 2013]

United Nations. International Meeting to Review the Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States 2005. Mauritius Declaration. 14 January 2005, A/CONF.207/L.6 (consolidated), available at: <http://www.un.org/special-rep/ohrrls/sid/MIM/A-conf.207-L.6-Mauritius%20Declaration.pdf> [accessed 17 February 2013]

United Nations Environment Programme Regional Resource Centre for Asia and the Pacific. Environmental Indicator's. (2004).

United Nations. Economic and social survey of Asia and the Pacific. Surging ahead in uncertain times. New York. (2007)

United Nations Framework Convention on Climate Change. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. FCCC/CP/2009/11 30 March 2010 [Accessed 12 May 2010]

P. J. Watson (2011) Is There Evidence Yet of Acceleration in Mean Sea Level Rise around Mainland Australia?. *Journal of Coastal Research*: Volume 27, Issue 2: pp. 368 – 377.

Williams, Jack (May 17, 2005). "Hurricane scale invented to communicate storm danger". Retrieved from- <http://www.usatoday.com/weather/hurricane/whscale.htm> [Accessed 13 July 2009]

World Meteorological Organization. Guide To Climatological Practices. 3rd edition, 2011

Appendix: Pacific Islands Climate Change Impact Survey 2011

Pacific Islands Climate change impacts survey 2011

Introduction

I am a researcher at the University of Southern Queensland, Toowoomba 4350, QLD, Australia within the Department of Biology & Physical Sciences and the Australian Centre for Sustainable Catchments. My research goal is to develop a simplified scale to measure the current impact of climate change in the Pacific region. To achieve this I require a high level understanding of the current impact of climate change across natural and human systems in the Pacific region. Your assistance in completion of this survey is invaluable in the development of the climate impact scale.

Background

Climate change is regarded as one of the greatest policy challenges ever faced by governments and policymakers. To understand and compare the impact of climate change between regions requires a clear and consistent measure. To date there is no one simplified scale for measuring climate change impact for policymakers and the general public. This survey will support the development of such a scale to measure climate change impacts specifically within the Pacific region. As a result it will provide the opportunity for improved policy decisions around provision of resources for mitigation and adaptation in the Pacific region. The survey was designed utilising methodology contained within the Australian risk management standard AS/NZS 4360:2004. All questions relate to Pacific region impacts of climate change.

The results of the survey and the eventual scale will be shared with survey participants as well as major aid providers and insurance organisation's including the World Bank, the Asian Development Bank, Ausaid, NZAID, UNDP, Munich Re insurance, AON insurance, and International Institute for Environment and Development. To date these organizations have shown some level of interest in the simplified climate change impact scale concept. A simplified scale could be utilised in future to assist in assessment of climate change impacts and prioritise aid money for competing climate adaptation projects.

Survey instructions

The survey should take no more than approximately 15 minutes to complete.

Note that I am looking for only an indicative rating. Please feel free to share the survey within your individual climate change committee/team/department if impact areas are covered by different people.

If you could please respond to the following questions by shading an impact rating against each question and provide specific details(if time permits) where appropriate. A definition of each of the impact ratings is provided in table 1. Examples of impact types² for each of the natural and human systems are provided under each question. If a listed impact is currently affecting your country please shade that impact. The list of systems, sub systems and impacts is not definitive and any suggested additions are welcome. **If you are unable to**

² **Impact sources:** 1- *Climate variability and change and sea-level rise in the Pacific islands region-A resource book for policy and decision makers, educators and other stakeholders. South Pacific Regional Environment Programme and Japan Ministry for Environment.* 2- *Small Islands, Climate change 2007: Impacts, Adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. 2007.*

complete due to time constraints it would be greatly helpful if you could provide either another point of contact or reference to reports and/or documents upon which I could act as a proxy and answer the survey questions for your country.

Please return the completed survey by **as soon as possible** to;

Mark Macfarlane

c/o Ms Debbie White

Department of Biology & Physical Sciences and the Australian Centre for Sustainable Catchments.

University of Southern Queensland, Toowoomba 4350, QLD, Australia

Or email to markmacf@grapevine.net.au

The survey questions

1-What is the current impact of climate change in your region on **“terrestrial and marine ecosystems”**?

1	2	3	4	5
Includes impacts like....	Loss of diversity in fish species(e.g. migration and distribution of species) Loss in diversity of coastal birds Degradation of coral reefs Bleaching of coral reefs Marine ecosystems compromised Rise in non-indigenous invasive species Increasing coastal erosion Reduction in country/island size Increasing beach erosion Loss in diversity of species Increased periodic flooding from sea Permanent inundation from sea Reduced forest area Loss of mangrove areas Reduction in turtle nesting habitats Chronic island erosion Increased species extinctions Loss of biodiversity Increase in ciguatera outbreaks Loss of tropical rainforest Loss of savannah area Loss of wetlands Loss in native coastal woodlands Changes in wave climate and ocean circulation Increasing ocean acidification Increasing sea surface temperature Ongoing and continual rise in sea levels Seepage of saline water through rivers during dry seasons(increasing soil salt level)			

	Increasing grassland and savannah fires Increasing changes in species habitats
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2- What is the current impact of climate change in your region on **“water”**?

1	2	3	4	5
Includes impacts like....	Water resources compromised e.g. water tables rising to surface and reduction due to evapotranspiration. Reduction in water supply (reduction in freshwater lenses) Seawater intrusion into freshwater lenses Contamination of fresh groundwater supplies Soil salinization Replacement of potable water supply			

3- What is the current impact of climate change in your region on **“tourism”**?

1	2	3	4	5
Includes impacts like....	Reduced tourism revenue			

4- What is the current impact of climate change in your region on **“socio-economic factors”**?

1	2	3	4	5
Includes impacts like....	Infrastructure and facilities damage (e.g. government services, coastal protection works, causeways, roads, airports, ports.) Settlement damage Energy disruptions - utilities (power and water), fossil fuels, fuelwood. Island abandonment Socio-economic well being compromised Transport interruptions increasing due to natural factors (e.g. closure of roads, airports, ports, marine resources and bridges) Communication interruptions Increasing economic losses as a percentage of GDP Loss of productivity in main economic sectors Achieving poor sustainability levels Migration away from climate change impact areas Increasing poverty Reduction in housing material availability (e.g. sago,			

	bamboo, grass thatching et al.)
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5- What is the current impact of climate change in your region on **“Culture”**?

1	2	3	4	5
Includes impacts like....	Loss of cultural heritage and/or spiritual sites National sovereignty undermined Loss of subsistence and traditional technologies, indigenous skills and knowledge and community structures.			

6- What is the current impact of climate change in your region on **“Health”**?

1	2	3	4	5
Includes impacts like....	Increased evidence of vector borne diseases Increased incidence of water and/or food borne diseases Increased incidence of tropical diseases including malaria, dengue fever, Ross river fever, filariasis, schistosomiasis, diarrhoeal disease, heat stress, skin diseases, acute repository infections and asthma. Increased incidence in mental disorders Increase in morbidity and mortality from extreme weather events e.g. drowning. Increased injuries form extreme weather events Reduction in dietary diversity			

7- What is the current impact of climate change in your region on **“Food and agriculture”**?

1	2	3	4	5
Includes impacts like....	Reduction in food security Lower subsistence food yields Decline in total fish stocks Lower Subsistence farming yields Lower commercial farming yields lower Reduction in soil fertility and/or nutrient availability Degradation of soils Reduction in land use Increase in agricultural pests(e.g. unwelcome insects) Increase in unwelcome weed species Higher soil temperatures Increased destruction and degradation of key crops(sugarcane, yams, taro and cassava)			

8- What is the current impact of climate change in your region on the **“Meteorological factors”**?

1	2	3	4	5
Includes impacts like....	Increase in number of tropical cyclones Increase in average intensity of tropical cyclones Extended drought conditions Increasing drought frequency Increased precipitation volume and intensity Increased daily temperature extremes Increased incidence and severity of floods Increasing ENSO extremities Increasing quasiperiodicity in ENSO Increase in number and severity of storm surges Increasing evapotranspiration rates Increasing incidence of mudslides			

9- What is the current impact of climate change in your region on **“Government policy/processes”**?

1	2	3	4	5
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Table 1: Impact ratings

A rating of	Scale	Means that the occurrence of the impact
Severe	5	<ul style="list-style-type: none"> Threatens the survival of the country. Has extreme impacts on the viability of the country/island; Or has extreme impact on natural or human systems of the country/island.
Major	4	<ul style="list-style-type: none"> Threatens the survival or continued effective function of a natural or human system of the country/island. Has a major impact on the governments strategic objectives; Or have a major impact on natural or human systems of the country/island.
Moderate	3	<ul style="list-style-type: none"> Does not threaten natural or human systems, but would mean that the system could be subject to significant maintenance or changed ways of operation. Moderately impacts on the governments strategic/operational objectives; or Have a moderate impact on the natural or human systems of the country/island.
Minor	2	<ul style="list-style-type: none"> Threatens the efficiency or effectiveness of some aspect of natural or human systems but can be managed by adaptation actions. Minor impact on the governments strategic/operational objectives; or Has a minor impact on natural or human systems of the country/island.

Negligible	1	<ul style="list-style-type: none"> Results in impacts that can be dealt by routine adaptation actions.
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10-Please rank the systems in numerical order (with 1 being most important) as to which you perceive to be more important to your country/island and provide any additional comment you may feel is required.

System	Rank	Comment
Ecological		
Human		
Physical		
Others not listed		

11-Please rank the sub systems in numerical order (with 1 being most important) as to which you perceive to be more important to your country/island and provide any additional comment you may feel is required.

Sub system	Rank	Comment
Terrestrial and marine ecosystems		
water		
Tourism		
Socio economic		
Cultural		
Health		
Food and Agriculture		
Meteorological		