



SPC  
Secretariat  
of the Pacific  
Community

# Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change



## Summary for Pacific Island Countries and Territories

# **Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change**

## **Summary for Pacific Island Countries and Territories**

By

Johann D Bell, Johanna E Johnson, Alex S Ganachaud,  
Peter C Gehrke, Alistair J Hobday, Ove Hoegh-Guldberg,  
Robert Le Borgne, Patrick Lehodey, Janice M Lough,  
Tim Pickering, Morgan S Pratchett and Michelle Waycott



© Copyright Secretariat of the Pacific Community 2011

All rights for commercial / for profit reproduction or translation, in any form, reserved. SPC authorises the partial reproduction or translation of this material for scientific, educational or research purposes, provided that SPC and the source document are properly acknowledged. Permission to reproduce the document and/or translate in whole, in any form, whether for commercial / for profit or non-profit purposes, must be requested in writing. Original SPC artwork may not be altered or separately published without permission.

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories

1. Fishery management — Oceania. 2. Marine ecosystem management — Oceania. 3. Climatic changes — Oceania. 4. Aquaculture – Management – Oceania

I. Bell, Johann D. II. Johnson, Johanna E. III. Ganachaud, Alexandre S. IV. Gehrke, Peter C. V. Hobday, Alistair J. VI. Hoegh-Guldberg, Ove VII. Le Borgne, Robert VIII. Lehodey, Patrick IX. Lough, Janice M. X. Pickering, Timothy XI. Pratchett, Morgan S. XII. Waycott, Michelle XIII. Title XIV. Secretariat of the Pacific Community

639.20995 AACR2  
ISBN: 978-982-00-0508-2

**Please cite this publication as:**

Bell JD, Johnson JE, Ganachaud AS, Gehrke PC, Hobday AJ, Hoegh-Guldberg O, Le Borgne R, Lehodey P, Lough JM, Pickering T, Pratchett MS and Waycott M (2011) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories. Secretariat of the Pacific Community, Noumea, New Caledonia.

Cover photo: Wave breaking over a coral reef at Wallis Island by Franck Mazeas. Cover design by Carla Appel.

The views expressed in this publication do not necessarily reflect those of the Secretariat of the Pacific Community or other participating organisations. This publication has been made possible in large part by funding from the Australian Agency for International Development (AusAID).

Published by the Secretariat of the Pacific Community, Noumea, New Caledonia  
BP D5, 98848 Noumea Cedex, New Caledonia  
(Email: [spc@spc.int](mailto:spc@spc.int))

Also available at <http://www.spc.int/climate-change/fisheries/assessment>

Printed in New Zealand by Stredder Print Ltd, Auckland, 2011

# Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories

## Authors' affiliations

### **Johann D Bell**

*Secretariat of the Pacific Community,  
Noumea, New Caledonia*

### **Johanna E Johnson**

*C<sub>2</sub>O Consulting, and National Marine Science  
Centre, Southern Cross University,  
Coffs Harbour, Australia*

### **Alexandre S Ganachaud**

*Institut de Recherche pour le Développement,  
Noumea, New Caledonia*

### **Peter C Gehrke**

*Snowy Mountains Engineering Corporation,  
Brisbane, Australia*

### **Alistair J Hobday**

*Climate Adaptation Flagship, CSIRO Marine  
and Atmospheric Research, Hobart, Australia*

### **Ove Hoegh-Guldberg**

*Global Change Institute and ARC Centre of  
Excellence for Coral Reef Studies, University of  
Queensland, St Lucia, Australia*

### **Robert Le Borgne**

*Institut de Recherche pour le Développement,  
Noumea, New Caledonia*

### **Patrick Lehodey**

*Collecte Localisation Satellites, Space  
Oceanography Division, Ramonville, France*

### **Janice M Lough**

*Australian Institute of Marine Science,  
Townsville, Australia*

### **Timothy D Pickering**

*Secretariat of the Pacific Community, Suva, Fiji*

### **Morgan S Pratchett**

*ARC Centre of Excellence for Coral Reef Studies,  
James Cook University, Townsville, Australia*

### **Michelle Waycott**

*School of Marine and Tropical Biology, James  
Cook University, Townsville, Australia*

## Foreword

The bonds between the people of the Pacific and their fisheries are extraordinary. Fish and shellfish are common in Pacific folklore and nowhere else do so many countries and territories depend as heavily on fisheries for economic development, food security and livelihoods. These unique relationships underpin the directive of Pacific Islands Forum Leaders to ‘develop and implement national and regional conservation and management measures for the sustainable utilisation of fisheries resources’ – a priority of the Pacific Plan.

Rapid population growth in many Pacific Island countries and territories demands new approaches to the sustainable use of natural resources for economic, human and social development. A recent study entitled ‘The Future of Pacific Island Fisheries’ by the Forum Fisheries Agency and Secretariat of the Pacific Community is a valuable guide to optimising the benefits from fisheries and aquaculture. However, achieving these benefits over the long term will depend on our ability to recognise and respond to the many drivers affecting the production and use of fish and shellfish.

There is now little doubt that the impact of climate – already an important driver of fisheries and aquaculture production – is likely to increase in the years ahead. To respond effectively, we need to know the vulnerability of the sector to the changing climate and how best to adapt.

To provide the region with this information, the Secretariat of the Pacific Community has published the peer-reviewed book, *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*, with generous support from the Australian Agency for International Development (AusAID). The purpose of this summary is to present the main results from the regional vulnerability assessment as they apply to each country and territory, making the information easily to use.

The practical adaptations, policies and investments described here are needed to maintain the economic and social benefits of fisheries and aquaculture in the face of climate change. They are essential planning tools. I recommend them to all stakeholders in the fisheries and aquaculture sectors of Pacific Island countries and territories, and their development partners.



**Dr Jimmie Rodgers**  
*Director-General*  
*Secretariat of the Pacific Community*

<b>Contents</b>	<b>Page</b>
<b>Preface</b> .....	vii
<b>Acknowledgements</b> .....	viii
<b>1. Introduction</b> .....	1
<b>2. Summaries for each country and territory</b> .....	7
<b>2.1</b> American Samoa.....	7
<b>2.2</b> Cook Islands.....	21
<b>2.3</b> Federated States of Micronesia.....	35
<b>2.4</b> Fiji.....	49
<b>2.5</b> French Polynesia.....	63
<b>2.6</b> Guam.....	77
<b>2.7</b> Kiribati.....	89
<b>2.8</b> Marshall Islands.....	101
<b>2.9</b> Nauru.....	113
<b>2.10</b> New Caledonia.....	125
<b>2.11</b> Niue.....	139
<b>2.12</b> Commonwealth of the Northern Mariana Islands.....	149
<b>2.13</b> Palau.....	161
<b>2.14</b> Papua New Guinea.....	175
<b>2.15</b> Pitcairn Islands.....	191
<b>2.16</b> Samoa.....	197
<b>2.17</b> Solomon Islands.....	211
<b>2.18</b> Tokelau.....	227
<b>2.19</b> Tonga.....	237
<b>2.20</b> Tuvalu.....	251
<b>2.21</b> Vanuatu.....	263
<b>2.22</b> Wallis and Futuna.....	277
<b>3. Adaptations and supporting policies</b> .....	287
<b>4. Gaps in knowledge</b> .....	309
<b>5. Investments required</b> .....	317
<b>6. Technical summaries</b> .....	325
<b>6.1</b> General approach and use of climate models.....	325
<b>6.2</b> Observed and projected changes in surface climate of the tropical Pacific {Chapter 2}.....	329
<b>6.3</b> Observed and projected changes to the tropical Pacific Ocean {Chapter 3}.....	334

<b>6.4</b>	Vulnerability of open ocean food webs in the tropical Pacific to climate change {Chapter 4}.....	343
<b>6.5</b>	Vulnerability of coral reefs in the tropical Pacific to climate change {Chapter 5}.....	349
<b>6.6</b>	Vulnerability of mangroves, seagrasses and intertidal flats in the tropical Pacific to climate change {Chapter 6}.....	354
<b>6.7</b>	Vulnerability of freshwater and estuarine habitats in the tropical Pacific to climate change {Chapter 7}.....	360
<b>6.8</b>	Vulnerability of oceanic fisheries in the tropical Pacific to climate change {Chapter 8}.....	363
<b>6.9</b>	Vulnerability of coastal fisheries in the tropical Pacific to climate change {Chapter 9}.....	367
<b>6.10</b>	Vulnerability of freshwater and estuarine fisheries in the tropical Pacific to climate change {Chapter 10}.....	371
<b>6.11</b>	Vulnerability of aquaculture in the tropical Pacific to climate change {Chapter 11}.....	375
	<b>References</b> .....	383
	<b>Abbreviations</b> .....	385

## Preface

It is now clear that the global community must do more than plan how to reduce global warming – we must learn to adapt to the inevitable increases in the temperature and acidification of the oceans while we rein in emissions of greenhouse gases. Adaptation has been a focus of recent international climate change negotiations and strong pledges have been made to help developing countries respond to the climate-related changes ahead.

Australia is well aware of the potential effects on yields from agriculture and fisheries likely to occur as a result of climate change. We are deeply committed to helping our Pacific neighbours understand their vulnerability to these changes and how best to respond. Together, we must find ways to maintain the quality of life for all people in the region as the impacts of climate change intensify.

The onus is on everyone involved to make the best use of the technical and financial support available for adaptation. The process should begin with thorough assessments of the vulnerability of the resources that underpin national economies, food security and livelihoods. Only then can sensible adaptations be identified and implemented in a timely and cost-effective way.

The comprehensive analysis provided in the book entitled *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change* now provides the region with the understanding needed, and the adaptations, policies and investments recommended to reduce the likely impacts of climate change on fisheries and aquaculture. It also gives the sector a roadmap for capitalising on the opportunities expected to arise from the changing climate.

This summary, which is a companion to the book, provides this vital information in an accessible form for each Pacific Island country and territory. It will be a valuable planning tool for policy makers, communities and their development partners.

Importantly, the summary is designed so that it can be updated regularly, given that much uncertainty still surrounds climate change projections. Reassessments of projected changes to surface climate, the tropical Pacific Ocean, fish habitats and fish stocks will be needed every 5-7 years to check whether adaptations to maintain the economic and social benefits from the sector are on track or should be realigned. Australia looks forward to contributing to this process.



**The Hon Kevin Rudd MP**

*Minister for Foreign Affairs  
Australia*



## Acknowledgements

This book is the product of a partnership that started between the Australian Agency for International Development (AusAID) and the Secretariat of the Pacific Community (SPC), and then grew to embrace contributions from 36 institutions. The late Gordon Anderson, in his role as the AusAID Pacific Fisheries Programme Development Adviser, was the first person to actively promote the need for a comprehensive assessment of the vulnerability of fisheries and aquaculture in the tropical Pacific. Generous support from AusAID's International Climate Change Adaptation Initiative and strong commitment from the executive team at SPC provided the opportunity to bring this important vision to fruition.

We thank the many other scientists who contributed to writing the chapters of the book *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change* from which this summary was drawn. The heads of fisheries departments in Pacific Island countries and territories, and our fellow members of the technical working group created to guide the project, provided valuable advice on how to compile this summary to meet the needs of policy makers and other stakeholders.

Several other people helped produce this summary. Carla Appel and Boris Colas did a masterful job with the layout to make the technical information easy to digest. Céline Barré was instrumental in deciding how best to present the information and checked the entire content of the summary. Angela Templeton provided valuable editorial advice, Peter Williams and Colin Millar helped summarise the recent tuna catches and Jeff Maynard and Lindsay Chapman assisted with the proof reading. Senior fisheries staff from across the region provided much-appreciated feedback on the proposed content and format of the draft sections for Pacific Island countries and territories at the 7<sup>th</sup> SPC Heads of Fisheries Meeting.

Finally, we acknowledge the modelling groups at the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the World Climate Research Programme's (WCRP) Working Group on Coupled Modelling (WGCM), for their roles in making available the WCRP CMIP3 multi-model dataset. Their work underpins the vulnerability assessments for fish habitats, fish stocks, and fishing communities and enterprises summarised here.

## 1. Introduction

Throughout the tropical Pacific, fisheries and aquaculture make vital contributions to economic development, government revenue, food security and livelihoods (Chapter 1). In recent years, licence fees from distant water fishing nations (DWFNs) have provided 3–40% of government revenue for seven Pacific Island countries and territories (PICTs), and fishing by national industrial fleets and/or fish processing have contributed 3–22% of gross domestic product (GDP) in five PICTs<sup>i</sup> (Chapter 12). Small-scale coastal fisheries have also provided 2–17% of GDP in five PICTs<sup>i</sup>.

The contributions of fisheries to the formal economies of PICTs are matched by the role fisheries and aquaculture play in helping to provide good nutrition and livelihoods across the region (Chapter 12). Fish<sup>i</sup> is a cornerstone of food security for the people of the tropical Pacific – fish provide 50–90% of animal protein in the diet of coastal communities across a broad spectrum of PICTs, and national fish consumption per person in many PICTs is more than 3–4 times the global average<sup>2</sup>. In rural areas, much of this fish (60–90%) is caught by subsistence fishing. Many people in the Pacific also catch and sell fish – an average of 47% of households in representative coastal communities in 17 PICTs derive either their first or second income in this way<sup>3</sup>. Industrial fishing and processing operations provide more than 12,000 jobs<sup>4</sup>, and aquaculture employs more than 6000 people in pearl and shrimp farming and supplies another 10,000 households with fish to eat or sell<sup>4</sup> (Chapter 11).

As a consequence of such benefits, the Pacific Plan<sup>5</sup> recognises that development of PICTs is linked to the effective management of fish, and the habitats that support them – *‘development and implementation of national and regional conservation and management measures for the sustainable use of fisheries resources’* is a priority of the Plan. Responsible and effective stewardship of the region’s fisheries resources has also been reinforced by the Pacific Island Forum Leaders’ *‘Vava’u Declaration’*<sup>ii</sup>. The recent *‘Future of Pacific Island Fisheries’* study<sup>6</sup> outlines the various drivers affecting the sector, and the actions that need to be taken to optimise the economic and social benefits of fisheries and aquaculture for PICTs.

Climatic variation, which is known to have profound effects on the distribution and abundance of fish and the productivity of aquaculture both in the tropical Pacific (Chapters 8–11) and elsewhere in the world (Chapter 1), is expected to grow in importance as a driver of the sector. Pacific Island countries and territories need to know whether future changes in climate and acidification of the ocean are likely to derail the plans being developed to optimise the great economic and social benefits they receive from fisheries and aquaculture.

To answer this important question, the Secretariat of the Pacific Community (SPC) coordinated a comprehensive assessment of the vulnerability of tropical Pacific fisheries and aquaculture to climate change<sup>7</sup>. The assessment included the full range

i Fish is used in the broad sense to represent both fish and invertebrates.

ii [www.forumsec.org.fj/pages.cfm/documents/forum-resolutions](http://www.forumsec.org.fj/pages.cfm/documents/forum-resolutions)

of oceanic, coastal and freshwater fisheries, and aquaculture activities, that occur in PICTs and spanned the area from 130°E to 130°W and 25°N to 25°S. The assessment was based on the analyses described below.

- Observed and projected changes to surface climate and the tropical Pacific Ocean.
- Effects of changes to the surface climate and ocean on the marine and freshwater ecosystems (fish habitats) that support fisheries and aquaculture in the region.
- Direct effects of changes to surface climate and the ocean, and the indirect effects of changes to fish habitats, on the distribution and abundances of the fish and invertebrate stocks underpinning oceanic, coastal and freshwater fisheries and aquaculture in the tropical Pacific.
- Implications of climate change for contributions by fisheries and aquaculture to the economic development and government revenue of PICTs, and the food security and livelihoods of their people.
- Adaptations and suggested policies to minimise the threats and capitalise on the opportunities expected to occur as a result of the changing climate.
- Gaps in knowledge that need to be filled to improve confidence in assessments of vulnerability and the research needed to provide this information.
- Investments required to launch priority adaptations and fill gaps in knowledge.

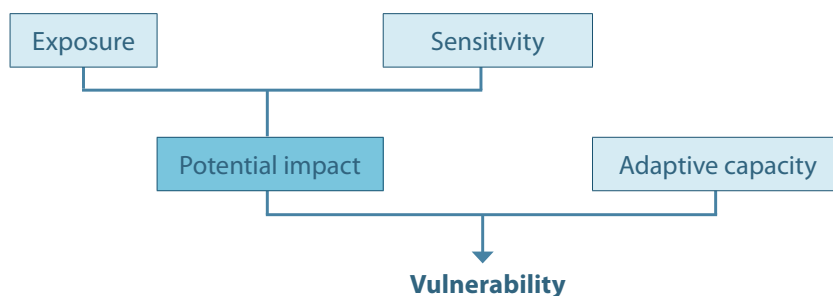
The vulnerability assessments for natural resources, economies, food security and livelihoods were made for representative low (B1) and high (A2) emissions scenarios from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4)<sup>8</sup> for two future timeframes, 2035 and 2100. Under the B1 scenario, the concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere is projected to reach 400–450 ppm by 2035, and 500–600 ppm by 2100. Concentrations of CO<sub>2</sub> are also projected to be 400–450 ppm by 2035 under the A2 scenario, but increase to 750–800 ppm under A2 by 2100<sup>9</sup> {Chapter 1}<sup>10</sup>.

Because global CO<sub>2</sub> emissions currently exceed those projected by the A2 emissions scenario<sup>iii</sup>, and because PICTs are also interested in their vulnerability in the near to mid term, we also assessed the implications of climate change for contributions by fisheries and aquaculture to economies and communities for the A2 scenario in 2050<sup>iv</sup>.

The vulnerabilities of fish habitats and stocks, and the economic and social benefits of fisheries and aquaculture, were based on the widely accepted framework adopted by the IPCC, and several other initiatives aimed at assessing vulnerability to climate change (Figure 1.1) {Chapter 1}. The framework assesses vulnerability as a function of exposure, sensitivity and adaptive capacity.

iii See [www.esrl.noaa.gov/gmd/ccgg/trends/#mlo\\_growth](http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_growth) for the latest trends in the growth of CO<sub>2</sub> emissions.

iv Projections for the A2 emissions scenario in 2050 were made by using model outputs for the B1 emissions scenario in 2100 as a surrogate for A2 in 2050 {Chapter 1}.

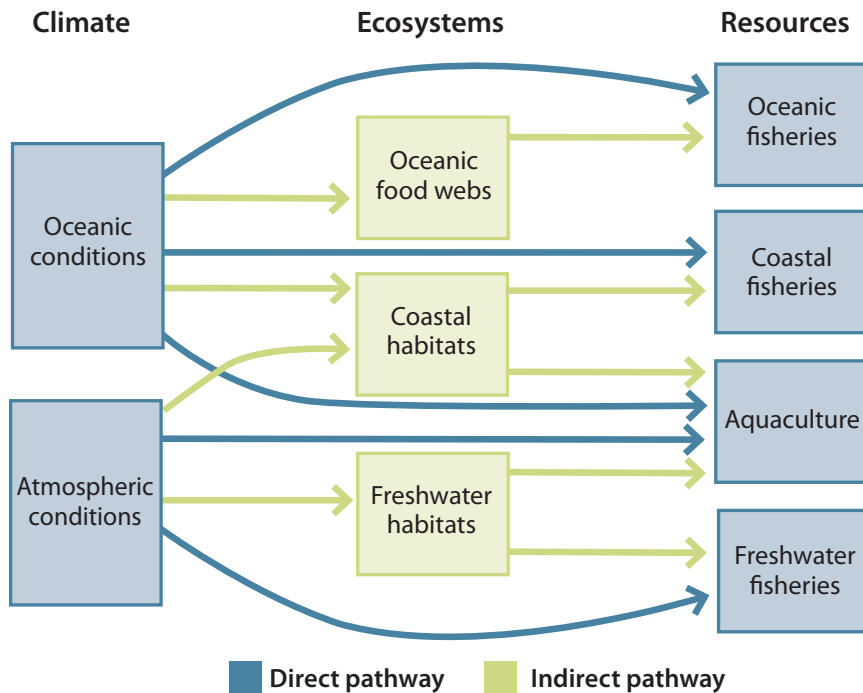


**Figure 1.1** Framework used to assess the vulnerability of fisheries and aquaculture in the tropical Pacific to climate change. Adapted from Schroter and ATEAM Consortium (2004)<sup>25</sup>.

Using this framework, the projected changes in atmospheric (surface climate) and oceanic conditions under the four combinations of emissions scenarios (B1 and A2) and timeframes (2035 and 2100) (hereafter referred to simply as four scenarios)<sup>v</sup> were cascaded along two pathways (Figure 1.2). In one pathway, the projected changes to surface climate {Chapter 2}<sup>11</sup> and the tropical Pacific Ocean {Chapter 3}<sup>12</sup> were used to define the ‘direct’ exposure of fish stocks supporting fisheries and aquaculture to climate change and ocean acidification. In a second pathway, the vulnerability assessments for the ecosystems underpinning fisheries and aquaculture {Chapters 4–7}<sup>13–16</sup> were used to determine the ‘indirect’ exposure of fish stocks. Estimates of the direct and indirect exposure of stocks were then integrated to make separate vulnerability assessments for oceanic, coastal and freshwater fisheries, and aquaculture, under each of the four scenarios defined above {Chapters 8–11}<sup>17–20</sup>. Next, the projected changes to fish stocks and aquaculture production were used to identify (1) the threats posed by climate change to plans to optimise the sustainable benefits from fisheries and aquaculture for economic development, government revenue, food security and livelihoods; and (2) opportunities to enhance these plans {Chapter 12}<sup>21</sup>.

The final step in the assessment was to recommend practical adaptations and suggested supporting policies to reduce the threats and capitalise on the opportunities. These adaptations and policies are not limited to dealing with the projected effects of a changing climate, however. Wherever possible, ‘win-win’ solutions have been identified that address the effects of (1) other factors affecting the benefits derived from fisheries and aquaculture production in the near term (e.g. population growth); and (2) climate change in the long term {Chapter 13}<sup>22</sup>.

<sup>v</sup> Note that due to the similar projections for CO<sub>2</sub> emissions under the B1 and A2 scenarios in 2035, they have usually been considered together throughout this summary.



**Figure 1.2** The two pathways used to develop scenarios for the exposure of the various fisheries resources and aquaculture in the tropical Pacific to climate change.

This ‘Summary for Pacific Island countries and territories’ has been designed to present the key findings of the vulnerability assessment in a way that is useful for all stakeholders in the fisheries and aquaculture sector.

**Section 2** summarises the following key information for each PICT:

- The existing features of surface climate and tropical Pacific Ocean in the vicinity of the country or territory, and the projected changes to surface climate and the ocean under the B1 and A2 emissions scenarios in 2035 and 2100.
- The importance of oceanic fisheries, coastal fisheries, freshwater and estuarine fisheries (if appropriate) and aquaculture to the country or territory. For each resource, this information includes the value and volume of recent production, the extent of the habitats supporting production, projected alterations to these habitats under climate change, and the projected changes to fish catches or aquaculture production due to the direct and indirect effects of climate change.
- The present contributions of fisheries and aquaculture to economic development and government revenue, food security and livelihoods, and the implications of climate change for these economic and social benefits.

- Recommended adaptations and suggested supporting policies to (1) reduce the threats of climate change to the future contributions by fisheries and aquaculture to economic development and government revenue, food security and livelihoods; and (2) capitalise on any opportunities.

In the interests of keeping the summary for each PICT short, the adaptations and policies are described only briefly in **Section 2** and links are provided to the detailed descriptions of adaptations and suggested policies in **Section 3**.

**Section 4** outlines the gaps in knowledge that remain to be filled to enable the region to assess the vulnerability of fisheries and aquaculture to climate change with more confidence. This section also summarises the research needed to fill the gaps.

**Section 5** summarises the investments required to launch the adaptations recommended for the fisheries and aquaculture sector across the region, and progressively fill the gaps in knowledge.

**Section 6** provides brief descriptions of the modelling done to produce this vulnerability assessment {Chapter 1} and the main projected changes to surface climate {Chapter 2}, the tropical Pacific Ocean {Chapter 3}, fish habitats {Chapters 4–7}, fish stocks {Chapters 8–10} and aquaculture {Chapter 11}. As shown in Figure 1.2, this information has been cascaded throughout the assessment to identify (1) the implications of climate change for the contributions of fisheries and aquaculture to economic development and government revenue, food security and livelihood opportunities for PICTs; and (2) the appropriate adaptations and supporting policies.

**Sections 6.2** and **6.3** contain information on surface climate and the tropical Pacific Ocean essential for interpreting the summaries for each country and territory, and should be read before proceeding to **Section 2**.

Throughout this summary, cross references to the relevant chapters of the full vulnerability assessment<sup>7</sup> have been provided in curly brackets – { } – so that readers can find the details of the analyses on which the conclusions have been based. Cross references to other parts of the summary are also provided in normal brackets. Other references have been kept to a minimum and listed at the end of this volume.

Likelihood and confidence values have been attributed to the projected effects of climate change on surface climate, the ocean, fish habitats, fisheries and aquaculture in the summaries for each country and territory using the key below.

