

Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change

Edited by Johann D Bell, Johanna E Johnson and Alistair J Hobday



© 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.

The copyright for individual chapters is held by the respective authors or the institutions to which they are affiliated.

The photographs in this book cannot be reproduced without the permission of the individual photographers or photographic agencies credited.

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change

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. Hobday, Alistair J. IV. Title. V. Secretariat of the Pacific Community.

639.20995 AACR2
ISBN: 978-982-00-0471-9

Please cite this publication as:

Bell JD, Johnson JE and Hobday AJ (2011) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia.

Please cite individual chapters as (e.g.):

Lough JM, Meehl GA and Salinger MJ (2011) Observed and projected changes in surface climate of the tropical Pacific. In: JD Bell, JE Johnson and AJ Hobday (eds) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia.

Cover photo: Wave breaking over a coral reef at Wallis Island by Franck Mazeas. Cover design and layout 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)

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

Editors

Johann D Bell

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

Johanna E Johnson

C₂O Consulting, Coffs Harbour, Australia

Alistair J Hobday

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

Contributors

Tim JH Adams

*Nauru Fisheries and Marine Resources
Authority, Nauru*

Valérie Allain

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

Edward H Allison

The WorldFish Center, Penang, Malaysia

Serge Andréfouët

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

Neil L Andrew

The WorldFish Center, Penang, Malaysia

Michael J Batty

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

Johann D Bell

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

Laurent Bopp

*Laboratoire des Sciences du Climat et de
l'Environnement/Institut Pierre Simon Laplace,
Gif sur Yvette, France*

David T Boseto

*Texas A&M University, College of Science and
Technology, Corpus Christi, USA*

Tom D Brewer

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

Rich W Brill

*Cooperative Marine Education and Research
Program (NMFS-NEFSC), Virginia Institute of
Marine Science, Gloucester Point, USA*

Béatrice Calmettes

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

Lindsay Chapman

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

Joshua E Cinner

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

Catherine Collier

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

Jeff Dambacher

*CSIRO Mathematics, Informatics and Statistics,
Hobart, Australia*

Brian Dawson

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

Sena De Silva

*Network of Aquaculture Centers in Asia-Pacific,
Bangkok, Thailand*

Luc Della Patrona

*Institut Français de Recherche pour
l'Exploitation de la Mer,
Noumea, New Caledonia*

Andreas Demmke

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

Guillermo Diaz-Pulido

*Griffith School of Environment,
Griffith University, Nathan, Australia*

Joanna C Ellison

*School of Geography and Environmental
Studies, University of Tasmania, Australia*

Katharina E Fabricius

*Australian Institute of Marine Science,
Townsville, Australia*

Boga S Figa

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

Kim Friedman

*Secretariat of the Pacific Community, Noumea,
New Caledonia and Department of Environment
and Conservation, Western Australia*

Alexandre S Ganachaud

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

Peter C Gehrke

*Snowy Mountains Engineering Corporation,
Brisbane, Australia*

Robert Gillett

*Gillett, Preston and Associates Inc,
Suva, Fiji*

Nicholas AJ Graham

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

Shane P Griffiths

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

Cathy A Hair

*Northern Fisheries Centre, James Cook
University, Cairns, Australia*

John Hampton

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

Mark A Hemer

*Wealth from Oceans Flagship, CSIRO Marine
and Atmospheric Research, Hobart, Australia*

Alistair J Hobday

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

Ove Hoegh-Guldberg

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

Tatiana Ilyina

*Max Planck Institute for Meteorology,
Hamburg, Germany*

Johanna E Johnson

C₂O Consulting, Coffs Harbour, Australia

Jeff P Kinch

*Secretariat of the Pacific Regional
Environmental Programme, Apia, Samoa and
National Fisheries College,
Kavieng, Papua New Guinea*

Mecki Kronen

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

Jens C Kruger

Secretariat of the Pacific Community, Suva, Fiji

Rebecca J Lawton

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

Christophe Maes

Laboratoire d'Études en Géophysique et
Océanographie Spatiales/Observatoire Midi-
Pyrénées, Toulouse, France

Franck Magron

Secretariat of the Pacific Community,
Noumea, New Caledonia

Paul A Marshall

Great Barrier Reef Marine Park Authority,
Townsville, Australia

Richard J Matear

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

Len J McKenzie

Primary Industry and Fisheries, Queensland
Department of Employment, Economic
Development and Innovation, Cairns, Australia

A David McKinnon

Australian Institute of Marine Science,
Townsville, Australia

Gerry A Meehl

National Centre for Atmospheric Research,
Boulder, USA

Jane E Mellors

Primary Industry and Fisheries, Queensland
Department of Employment, Economic
Development and Innovation, Cairns, Australia

CV Mohan

Network of Aquaculture Centers in Asia-Pacific,
Bangkok, Thailand

Philip L Munday

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

Simon Nicol

Secretariat of the Pacific Community,
Noumea, New Caledonia

James C Orr

Laboratoire des Sciences du Climat et de
l'Environnement/Institut Pierre Simon Laplace,
Commissariat à l'Énergie Atomique,
Saclay, France

Claude E Payri

Institut de Recherche pour le Développement,
Noumea, New Caledonia

Michael J Phillips

The WorldFish Center, Penang, Malaysia

Timothy D Pickering

Secretariat of the Pacific Community, Suva, Fiji

Silvia Pinca

Secretariat of the Pacific Community,
Noumea, New Caledonia

Elvira S Poloczanska

Climate Adaptation Flagship, CSIRO Marine
and Atmospheric Research, Brisbane, Australia

Ben Ponia

Ministry of Marine Resources Cook Islands,
Rarotonga, Cook Islands

Hans O Pörtner

Alfred-Wegener-Institute,
Bremerhaven, Germany

Morgan S Pratchett

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

Bo Qiu

Department of Oceanography, University of
Hawaii, Honolulu, USA

Chris Reid

Forum Fisheries Agency,
Honiara, Solomon Islands

Anthony J Richardson

Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, Hobart, Australia and University of Queensland, St Lucia, Australia

Ken R Ridgway

CSIRO Marine and Atmospheric Research, Hobart, Australia

Len Rodwell

Forum Fisheries Agency, Honiara, Solomon Islands

M Jim Salinger

University of Auckland, Auckland, New Zealand

Anne-Maree Schwarz

The WorldFish Center, Honiara, Solomon Islands

Alex Sen Gupta

University of New South Wales, Kensington, Australia

Inna Senina

Collecte Localisation Satellites, Space Oceanography Division, Ramonville, France

Marcus J Sheaves

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

John Sibert

Institute of Marine and Atmospheric Research, University of Hawaii, Honolulu, USA

Paul C Southgate

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

Craig R Steinberg

Australian Institute of Marine Science, Townsville, Australia

Antoine Teitelbaum

Secretariat of the Pacific Community, Noumea, New Caledonia

James P Terry

National University of Singapore, Singapore

Aline D Tribollet

Institut de Recherche pour le Développement, Noumea, New Caledonia

Aliti Vunisea

Secretariat of the Pacific Community, Pohnpei, Federated States of Micronesia

Jacob Wani

National Fisheries Authority, Port Moresby, Papua New Guinea

Michelle Waycott

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

Arthur Webb

Secretariat of the Pacific Community, Suva, Fiji

Susan E Wijffels

CSIRO Marine and Atmospheric Research, Hobart, Australia

Ashley J Williams

Secretariat of the Pacific Community, Noumea, New Caledonia

Shaun K Wilson

Department of Environment and Conservation, Western Australia

Jock W Young

Wealth from Oceans Flagship, CSIRO Marine and Atmospheric Research, Hobart, Australia

Foreword

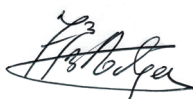
The bonds between the people of the Pacific and their fisheries are extraordinary. Fish and shellfish are common in Pacific folklore and nowhere else do so many countries and territories depend as heavily on fisheries for economic development, food security and livelihoods. These unique relationships underpin the directive of Pacific Island 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. This book, written with generous support from the Australian Agency for International Development (AusAID), brings together valuable contributions from scientists and fisheries managers from 36 institutions around the world to provide this vital information.

The fact that the main findings are mixed – there are likely to be winners and losers – underscores the importance of this vulnerability assessment. Practical adaptations, policies and investments are now needed to reduce the threats of climate change to the many fisheries and aquaculture activities that are part of the economic and social fabric of the region. Adaptations, policies and investments are also needed to capitalise on the opportunities. These essential planning tools are described in the last chapter – I recommend them to all stakeholders and their development partners.

This book is much more than a comprehensive assessment of the vulnerability of tropical Pacific fisheries and aquaculture to climate change. It is also a valuable resource for anyone wanting to learn about the diverse oceanic, coastal and freshwater fisheries and aquaculture activities of the Pacific Islands region, and the environmental conditions and habitats that support them.



Dr Jimmie Rodgers
Director-General
Secretariat of the Pacific Community

Contents	Page
Preface	ix
Acknowledgements	x
Chapter 1 Pacific communities, fisheries, aquaculture and climate change: An introduction.....	1
Chapter 2 Observed and projected changes in surface climate of the tropical Pacific.....	49
Chapter 3 Observed and expected changes to the tropical Pacific Ocean.....	101
Chapter 4 Vulnerability of open ocean food webs in the tropical Pacific to climate change.....	189
Chapter 5 Vulnerability of coral reefs in the tropical Pacific to climate change.....	251
Chapter 6 Vulnerability of mangroves, seagrasses and intertidal flats in the tropical Pacific to climate change.....	297
Chapter 7 Vulnerability of freshwater and estuarine fish habitats in the tropical Pacific to climate change.....	369
Chapter 8 Vulnerability of oceanic fisheries in the tropical Pacific to climate change.....	433
Chapter 9 Vulnerability of coastal fisheries in the tropical Pacific to climate change.....	493
Chapter 10 Vulnerability of freshwater and estuarine fisheries in the tropical Pacific to climate change.....	577
Chapter 11 Vulnerability of aquaculture in the tropical Pacific to climate change.....	647
Chapter 12 Implications of climate change for contributions by fisheries and aquaculture to Pacific Island economies and communities.....	733
Chapter 13 Adapting tropical Pacific fisheries and aquaculture to climate change: Management measures, policies and investments.....	803
Glossary	877
Glossary of symbols	899
Index	905
Abbreviations	921
List of referees	925

Preface

To be provided by

Hon Kevin Rudd
Minister for Foreign Affairs
Australia

Acknowledgements

This book is the product of remarkable teamwork – 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 intellectual contributions from authors at 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.

The Secretariat of the Pacific Community and the editors are grateful to the 85 authors who accepted the invitation to contribute their expertise to this assessment. We also thank the members of the technical working group, and the advisory committee, comprising representatives from French Polynesia, Solomon Islands and Vanuatu, who provided guidance throughout the project. Special thanks are due to the institutions that made the time of their senior staff available to lead the writing of several chapters (Australian Institute of Marine Science, Collecte Localisation Satellites, Institut de Recherche pour le Développement, James Cook University and Snowy Mountains Engineering Corporation). We also appreciate the valuable contribution made by the internationally recognised scientists and managers (listed at the end of the book) who provided the peer reviews of each chapter.

Many other people helped turn the text from the expert authors into a book. Catherine Collier and Aroon Edgar found effective ways to illustrate key points with attractive conceptual diagrams based on symbols from The Integration and Application Network. Carla Appel and Boris Colas did a masterful job with the layout to make the large volume of technical information easy to digest. Angela Templeton provided valuable editorial advice from the earliest stages and Astrid Baker carried out copy editing assisted by Julian Heinz. Céline Barré helped finesse the layout of all chapters, checked the references and meticulously corrected page proofs. Nathalie Wiegandt, Christophe Boe, Julie Vasello and Patricia Demmke helped with the great variety of tasks involved with the project, including organising meetings of the technical working group, corresponding with authors and word processing draft manuscripts. Trevor Viney and Ange Marelli Ballou made arrangements to acquire the many photographs and Fiona Paladini helped publicise the photo competition to select the cover image. Jeff Maynard did the final checking of the entire book, Sherrey Quinn compiled the index, Robert Le Borgne assisted with the glossary of terms and Lindsay Chapman reviewed the final wording of several chapters.

The people who kindly helped authors to produce or improve their contributions are listed here by book chapter. Chapter 1: Tim Lawson, Peter Terawasi, Apolosi Turaganiva and Peter Williams. Chapter 2: Julie Arblaster, Kevin Hennessy, Felicity McAllister, Alex Sen Gupta and Tim Simmonds. Chapter 3: Jérôme Lefèvre. Chapter 4: Christophe Menkes and Martine Rodier. Chapter 5: Sophie Dove. Chapter 6: Michael Batty, Tim Adams, Claire Garrigue, Jeff Kinch, Kelvin Passfield, Chris Roelfsema and Satja Sauni. Chapter 7: Patricia Demmke, Frank Pezold, Scott Pontifex and Jodie Thomas. Chapter 8: Don Bromhead, Jesus Jurado-Molina and Shelton Harley. Chapter 9: Aymeric Desurmont, Jeff Leis, Lyndon Llewellyn, Shilpa Kumar Roine and Colin Wen. Chapter 10: Frank Pezold and Jodie Thomas. Chapter 12: James Hemphill, Nicola Kingston, Tim Lawson, Colin Millar, Warwick Nash, Peter Terawasi, Nathalie Wiegandt and Peter Williams. Chapter 13: Sandra Bernklau, Michel Blanc, Tea Braun, Eric Clua, Patricia Demmke, Bob Gillett, Elise Huffer, Robert Jimmy, Brigitte Leduc, Seema Naidu, Jason Rubani, Hugh Walton, Arthur Webb, Meryl Williams and Stephen Yen Kai Sun.

Authors who contributed to Chapters 5–7 and 9–11 sincerely thank the customary owners of coastal and freshwater resources and the governments of Pacific Island countries and territories for their cooperation in facilitating and encouraging their research. The access provided by the resource owners assisted the authors to acquire knowledge used in this assessment on coastal and freshwater fish habitats and fish stocks, and coastal and freshwater aquaculture.

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, and the support provided for these datasets by the Office of Science, US Department of Energy, enabled the authors of Chapters 2 and 3 to assess the projected effects of climate change on the surface climate and ocean of the tropical Pacific.

