



ARC Centre of Excellence  
**Coral Reef Studies**

Annual Report 2013





Front cover photo: Ed Roberts  
Inside cover photo: Ove Hoegh-Guldberg  
Back cover photo: Tom Bridge



ARC Centre of Excellence  
**Coral Reef Studies**

## Annual Report 2013





# Contents

<b>2</b>	<b>AIMS</b>	<b>20</b>	<b>PROGRAM 4: GENETIC, MOLECULAR AND PHYSIOLOGICAL PROCESSES</b>	<b>50</b>	<b>ARTICLE – THE CONDITION AND STABILITY OF REEF FISH ASSEMBLAGES IN THE CHAGOS ARCHIPELAGO</b>
<b>3</b>	<b>VISION</b>	<b>22</b>	<b>PROGRAM 5: RESILIENCE OF LINKED SOCIAL-ECOLOGICAL SYSTEMS</b>	<b>52</b>	<b>NATIONAL BENEFIT CASE STUDY 2 – INDIGENOUS HIGH SCHOOL STUDENTS PREPARE FOR CAREERS IN MARINE SCIENCE</b>
<b>3</b>	<b>OVERVIEW</b>	<b>24</b>	<b>PROGRAM 6: CONSERVATION PLANNING FOR A SUSTAINABLE FUTURE</b>	<b>54</b>	<b>ARTICLE – TOO HOT FOR SEA TURTLES?</b>
<b>4</b>	<b>DIRECTOR'S REPORT</b>	<b>26</b>	<b>PROGRAM 8: GENOMICS AND META-GENOMICS OF CORAL REEFS</b>	<b>58</b>	<b>PUBLICATIONS</b>
<b>6</b>	<b>GOVERNANCE</b>	<b>28</b>	<b>ARTICLE – GREAT BARRIER REEF: WORLD HERITAGE IN DANGER?</b>	<b>74</b>	<b>PERFORMANCE MEASURES</b>
<b>8</b>	<b>MEMBERSHIP</b>	<b>30</b>	<b>GRADUATE TRAINING</b>	<b>78</b>	<b>FINANCIAL STATEMENT</b>
<b>10</b>	<b>RESEARCH PROGRAM LEADERS</b>	<b>40</b>	<b>NATIONAL AND INTERNATIONAL LINKAGES</b>	<b>79</b>	<b>FINANCIAL OUTLOOK</b>
<b>12</b>	<b>BUSINESS LEADERS</b>	<b>44</b>	<b>MEDIA AND PUBLIC OUTREACH</b>	<b>80</b>	<b>ACKNOWLEDGEMENTS</b>
<b>14</b>	<b>RESEARCH FELLOW PROFILE – DR JODIE RUMMER</b>	<b>48</b>	<b>NATIONAL BENEFIT CASE STUDY 1 – CORAL REEF GOVERNANCE AND MANAGEMENT</b>		
<b>15</b>	<b>GRADUATE PROFILE – SANDRA BINNING AND DOMINIQUE ROCHE</b>				
<b>16</b>	<b>PROGRAM 1: EVOLUTIONARY AND ENVIRONMENTAL CHANGE</b>				
<b>18</b>	<b>PROGRAM 2: UNDERSTANDING AND MANAGING CORAL REEF BIODIVERSITY</b>				



## Aims

The aims of the Australian Research Council (ARC) Centre of Excellence for Coral Reef Studies are:

- 1. Research**  
The Centre's research is world-best, innovative, and highly relevant to coral reef management, adaptive governance and policy development.
- 2. Research Training and Professional Education**  
The Centre attracts and trains outstanding coral reef scientists at all stages of career, to build human capacity and expertise in coral reef science world-wide.
- 3. End-user and Community Linkages**  
Transfer and exchange of knowledge, technologies and research outcomes by the Centre promotes co-operation and improves the management of coral reefs.
- 4. National and International Linkages**  
The ARC Centre, through its networks and activities nationally and internationally, creates a global hub for coral reef science collaborations.
- 5. Management and Governance**  
Centre management is collaborative, co-operative, multi-institutional, communicative and continuously improving.
- 6. Commercial Activities**  
Commercial activities and research contracts undertaken by the ARC Centre extend knowledge transfer, nationally and globally.



An underwater photograph of a coral reef. The water is clear and blue. In the foreground, there is a large, textured rock covered in various types of coral, including branching and brain corals. The background shows more coral structures and the open water of the reef.

# Vision

Providing global leadership in the provision of scientific knowledge necessary for sustaining the ecosystem goods and services of the world's coral reefs.

# Overview

The ARC Centre of Excellence for Coral Reef Studies was established in July 2005 under the ARC Centres of Excellence Program. Headquartered at James Cook University, the ARC Centre partnership includes the Australian Institute of Marine Science (AIMS), the Australian National University (ANU), the Great Barrier Reef Marine Park Authority (GBRMPA), the University of Queensland (UQ), and the University of Western Australia (UWA). In 2013, the Centre has collaborative links to 342 institutions in 49 countries.

Major research themes include adaptation to climate change, understanding and managing biodiversity, marine reserves, fisheries biology, genomics, conservation planning, social studies, and governance and policy – in short, the basic and applied science that underpins the sustainable delivery of goods and services from the world's coral reefs.

# Director's Report



Welcome to the annual report of the Australian Research Council's *Centre of Excellence for Coral Reef Studies*. In the dying days of 2013, we were delighted to receive news that our Centre has received a second cycle of funding, an award of \$28 million for 2014-2020. Our Centre's goal is to provide and communicate

the scientific knowledge that underpins sustainable use of the world's coral reefs. The new Centre will be up and running before mid-year, launching a fresh set of research programs, recruiting new people and expertise, and embarking on an enhanced range of new activities. One major activity will be the new Centre's first annual symposium, scheduled for 3<sup>rd</sup> and 4<sup>th</sup> July, at the Australian Academy of Science's Shine Dome, in Canberra.

The Centre's research has contributed in many ways since 2005 to scientific knowledge, reef management, training and outreach. The impact of our research is exemplified by our National Benefit Case Studies, which we present in each year's annual report (pp48-52). In this, our final report for 2005-2013, it is timely to document some of the ARC Centre's achievements since its inception eight years ago. Commencing in 2005 with 19 Chief Investigators, the Centre's membership now stands at 66 Chief Investigators and Research Fellows. Importantly, the success of our Research Programs is characterised by collaboration across university nodes and disciplines, with shared supervision of PhD students, multi-institutional research projects and co-funded Research Fellows (pp16-27). This integration has increased with the growing maturity of the ARC Centre, as evidenced by the very high incidence of co-authored publications across a broad range of disciplines.

Our postgraduate cohort has increased from 66 in 2005 to almost 200 in 2013 (p30). During our first funding cycle we have trained a total of 418 postgraduate students. Our graduates occupy many research positions and many are also contributing to management, non-government organisations and government agencies in Australia and in many countries around the world. Over the coming years we will further reinforce our position as the world's largest provider of graduate training in coral reef research.

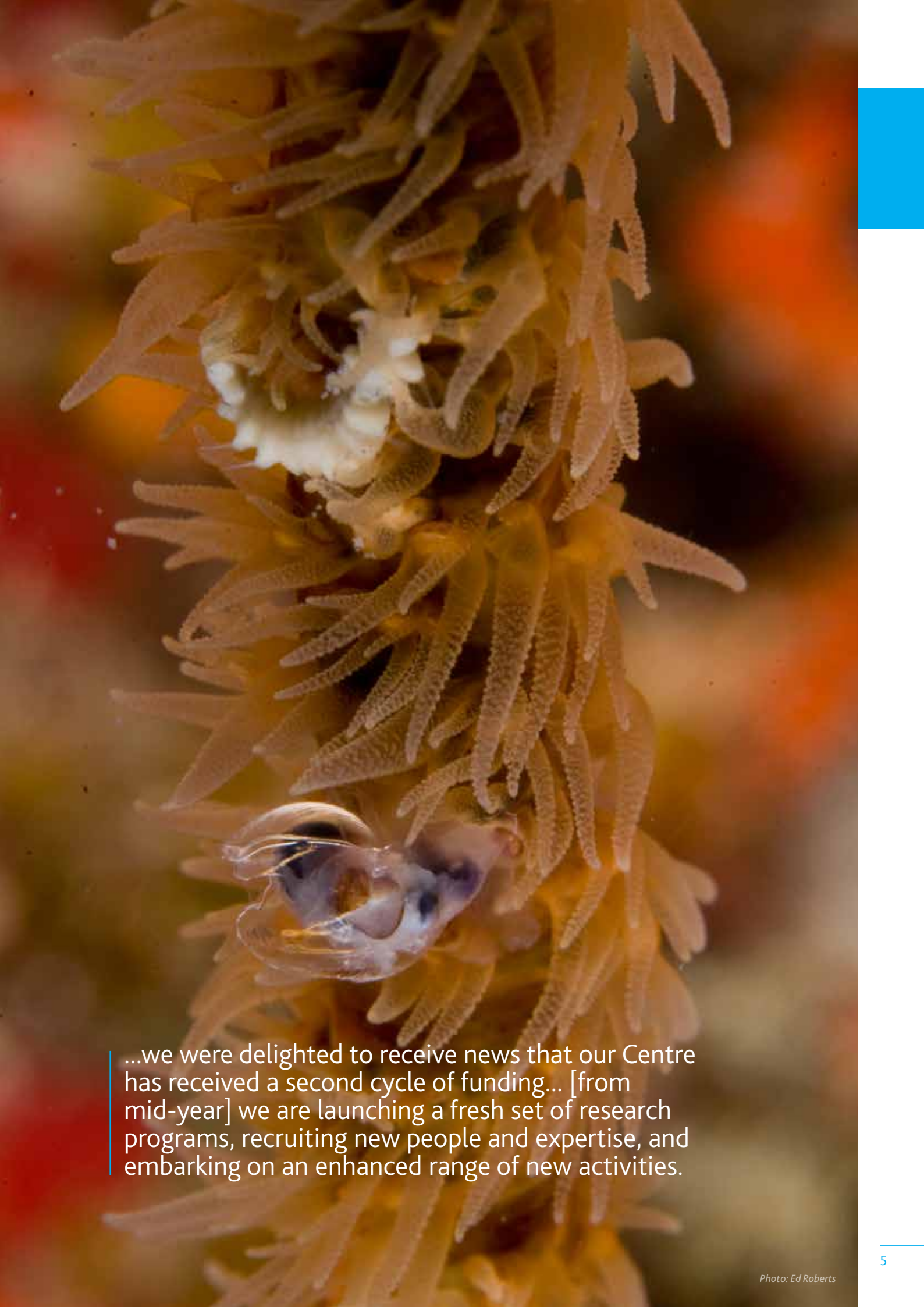
Internationalisation has been a growing theme over the eight years of the Centre, with a growing international postgraduate and postdoctoral population, a global array of field sites, and partner organisations and collaborators in >100 countries. The ARC Centre convened the *12th International Coral Reef Symposium* in Cairns, Queensland in July 2012, attracting over 2,000 delegates from around the world. In 2013, our postgraduate students come from 41 countries and over 50% of our research fellows have come to Australia from 12 overseas countries. The Centre has field sites throughout tropical Australia, and across the maritime nations of the tropical world - including the western Indian Ocean, the Red Sea, Coral Triangle, western Pacific Ocean, French Polynesia and the Caribbean.

In 2014, we will expand or launch for the first time productive partnerships with many overseas organisations, including WorldFish in Malaysia, the Center for Ocean Solutions at Stanford University, the French-led Groupement de Recherche International (Biodiversity of Coral Reefs), and the King Abdullah University of Science and Technology in Saudi Arabia. These partnerships will be characterised by joint postdoctoral fellows, secondments, joint research projects and regular cross-institutional visits. The success of our internationalisation strategy is clearly evident from our annual publication output. In 2013, we published 351 articles involving 1,171 co-authors from 342 institutions in 49 countries around the world (p58).

Lastly, I'd like to express my gratitude to our many friends around the world for their contributions to an outstanding year, to the Centre's Advisory Board, and our research partners and end-users (particularly the *Australian Institute for Marine Science*, the *Great Barrier Reef Marine Park Authority*, the *Center for Ocean Solutions*, the *Beijer Institute for Ecological Economics*, and *WorldFish*). I am especially grateful to our Centre's talented administrative team – Jenny Lappin, David Yellowlees, Olga Bazaka, Rose-Marie Vasiljuk, Janet Swanson, Louise Lennon, Karen van Staden and Hayley Ware - for their Trojan work in preparing for our next cycle of activities from 2014 onwards.

**Terry Hughes**  
*Director*





...we were delighted to receive news that our Centre has received a second cycle of funding... [from mid-year] we are launching a fresh set of research programs, recruiting new people and expertise, and embarking on an enhanced range of new activities.

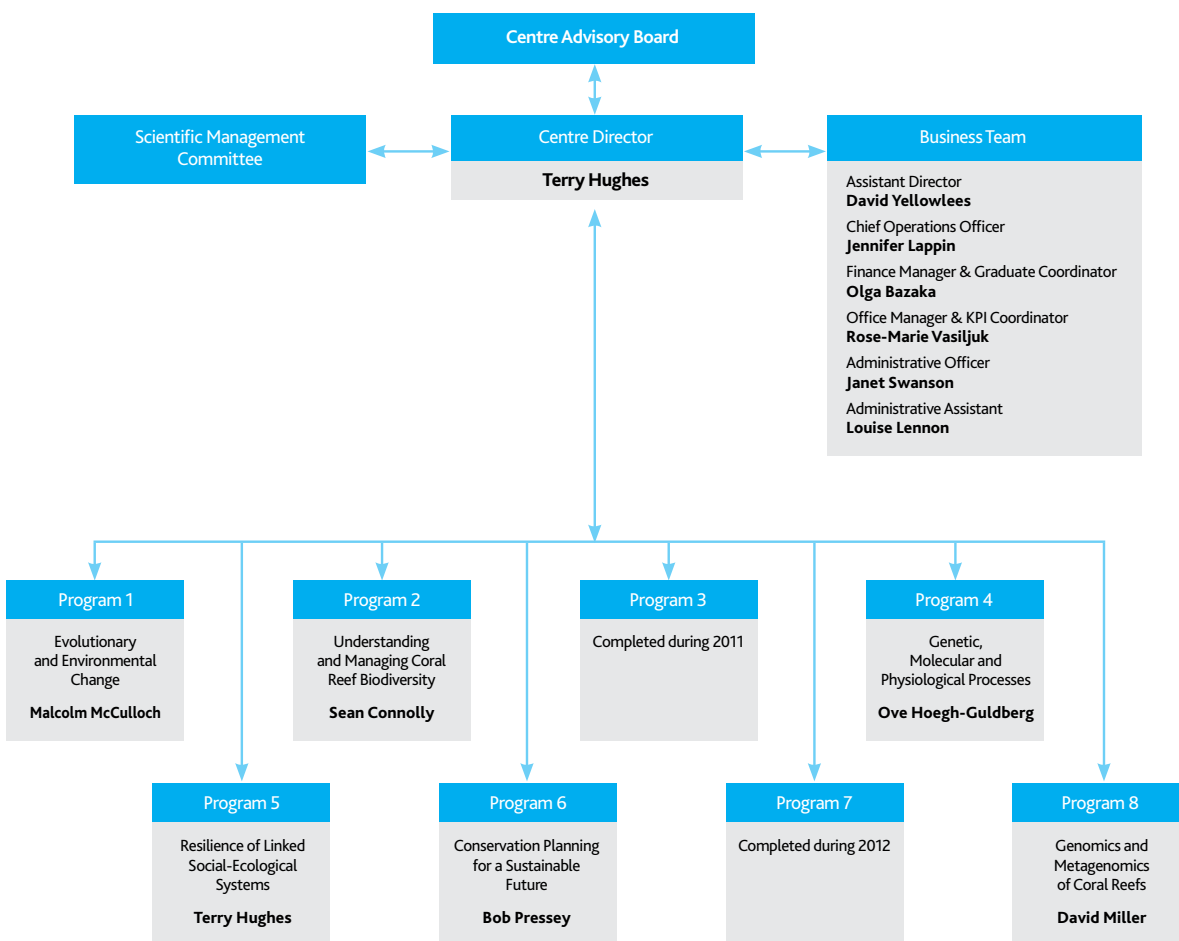
# Governance

The Centre of Excellence has a responsive and effective governance structure that engages key stakeholders in the Centre's planning and management processes. The Centre is administered by James Cook University with the Centre Director, Terry Hughes reporting directly to Professor Chris Cocklin, the Senior Deputy Vice-Chancellor with responsibility for Research and Innovation. Day-to-day operations are managed by the Chief Operations Officer, Jenny Lappin, in consultation with the Centre Director and Assistant Director, David Yellowlees.

The Centre's current governance structure and relationships are illustrated in the chart below. Centre Director, Terry Hughes, oversees the Centre's research programs and liaises on a regular basis with the two deputy directors Ove Hoegh-Guldberg and

Malcolm McCulloch. In 2013, Program 5 *Resilience of linked social-ecological systems* and Program 7: *Policy development, institutions and governance of coral reefs* were restructured into a single research program.

Chief Investigators in the Centre are located in three faculties at James Cook University, and at the Australian National University, the University of Queensland and the University of Western Australia. Partner Investigators are based at the Australian Institute of Marine Science, the Great Barrier Reef Marine Park Authority, and in overseas institutions. Adjunct researchers make a significant contribution to the Centre's research programs and are located in both national and international institutions.





## Centre Advisory Board

The Centre Advisory Board provides vision and high-level strategic advice to the Centre Director. It strengthens linkages between the ARC Centre, research partners, industry and government to advocate and promote the Centre, and improves linkages between the Centre and end-users to facilitate uptake and impact of research outcomes and exchange of ideas. The Centre Director and Chief Operations Officer provide the operational and management link between the Advisory Board and the Centre.

Membership of the ARC Centre Advisory Board reflects the Centre's strong international linkages and multi-disciplinary research activities. We are privileged to have had access to the expertise and experience of these leaders and others over the last eight years of the Centre and we extend our thanks to them for their advice and support. The Board met twice in Townsville in 2013, on 14<sup>th</sup> March and 9<sup>th</sup> October. The key focus of the Centre Advisory Board in 2013 was positioning of the Centre of Excellence to submit a successful proposal to the ARC for a further seven years of funding under the ARC Centres of Excellence program.

The Centre Advisory Board's membership comprises:

**Dr Brian Walker (Chair)**

*CSIRO Ecosystem Sciences*

**Dr Neil Andrew**

*Director, Pacific Region, WorldFish, Malaysia*

**John Gunn**

*Chief Executive Officer, Australian Institute of Marine Science*

**Professor Terry Hughes**

*Director, ARC Centre of Excellence*

**Andrew Skeat**

*General Manager, Great Barrier Reef Marine Park Authority*

**John Tanzer**

*Director, WWF Global Marine Program, Switzerland*

**Professor Mandy Thomas**

*Executive Dean, Creative Industries Faculty, Queensland University of Technology*

## Scientific Management Committee

The Centre's Scientific Management Committee (SMC) is responsible for operational management of the Centre and for planning and stewardship of its scientific research program. The SMC is chaired by eminent Israeli researcher, Professor Yossi Loya. Professor Loya has chaired the Committee since it was established in 2006 and we extend our thanks to him for his leadership, invaluable advice and support. Other members of the Committee are the leaders of each of the Centre's Research Programs, and Dr David Wachenfeld, the Director, Ecosystem Conservation and Sustainable Use at the Great Barrier Reef Marine Park Authority, the Centre's principal end-user in Australia. The Committee met five times in 2013, face-to-face or virtually, in April, July, August, October and November.

Scientific Management Committee Members are:

**Professor Yossi Loya (Chair)**

*The Raynor Chair for Environmental Conservation Research  
Tel Aviv University  
Israel*

**Dr David Wachenfeld**

*Director, Ecosystem Conservation and Sustainable Use  
Great Barrier Reef Marine Park Authority*

**ARC Australian Laureate Fellow Malcolm McCulloch FAA FRS**

*Leader, Research Program 1  
University of Western Australia*

**Professor Sean Connolly**

*Leader, Research Program 2  
James Cook University*

**ARC Australian Laureate Fellow Ove Hoegh-Guldberg FAA**

*Leader, Research Program 4  
University of Queensland*

**ARC Australian Laureate Fellow Terry Hughes FAA**

*Leader, Research Program 5  
James Cook University*

**Distinguished Professor Bob Pressey FAA**

*Leader, Research Program 6  
James Cook University*

**Professor David Miller**

*Leader, Research Program 8  
James Cook University*

# Membership

## Researchers

In 2013, the Centre's membership comprises 66 Chief Investigators and Research Fellows and 31 Partner Investigators, resident international scholars and adjunct researchers. This year, 19 of the Centre's Research Fellows are funded by ARC awards (Laureate, Future, DECRA, Super Science and Australian Research Fellows), three are Queensland Smart Futures Fellows, one is a Queensland Premier's Fellow and one is a Western Australian Premier's Fellow.

### Chief Investigators and Research Fellows

**Professor Terry Hughes**

*Centre Director*  
ARC Australian Laureate Fellow  
James Cook University

**Dr Tracy Ainsworth**

*ARC Super Science Fellow*  
James Cook University

**Dr Glenn Almany**

*ARC Future Fellow*  
James Cook University

**Dr Jorge Alvarez-Romero**

*Research Fellow*  
James Cook University

**Dr Amélie Augé**

*Research Fellow*  
James Cook University

**Dr Andrew Baird**

*ARC Future Fellow*  
James Cook University

**Professor David Bellwood**

*Chief Investigator*  
James Cook University

**Dr Anthony Bertucci**

*Super Science Fellow*  
James Cook University

**Dr Jessica Blythe**

*Research Fellow*  
James Cook University and  
WorldFish

**Dr Pim Bongaerts**

*Research Fellow*  
University of Queensland

**Dr Mary Bonin**

*Research Associate*  
James Cook University

**Dr Tom Bridge**

*Research Fellow*  
James Cook University and  
Australian Institute of Marine Science

**Dr Jana Brotánková**

*Research Associate*  
James Cook University

**Dr Joshua Cinner**

*ARC Australian Research Fellow*  
James Cook University

**Professor Sean Connolly**

*Chief Investigator*  
James Cook University

**Dr Ian Craigie**

*Research Associate*  
James Cook University

**Dr Viv Cumbo**

*Research Associate*  
James Cook University

**Dr Delphine Dissard**

*Research Fellow*  
University of Western Australia

**Assoc Professor Sophie Dove**

*Chief Investigator*  
University of Queensland

**Dr Simon Dunn**

*Research Fellow*  
University of Queensland

**Dr Louisa Evans**

*Research Fellow*  
James Cook University

**Dr Michael Fabinyi**

*Society in Science Research Fellow*  
James Cook University

**Dr James Falter**

*Research Fellow*  
University of Western Australia

**Dr Joana Figueiredo**

*Queensland Smart Futures Fellow*  
James Cook University

**Dr Ashley Frisch**

*Super Science Fellow*  
James Cook University

**Dr Mariana Fuentes**

*Super Science Fellow*  
James Cook University

**Dr Christopher Fulton**

*Chief Investigator*  
Australian National University

**Dr Nick Graham**

*Discovery Early Career Researcher Award (DECRA) Fellow*  
James Cook University

**Dr Alana Grech**

*Research Fellow*  
James Cook University

**Dr Alistair Harborne**

*Discovery Early Career Researcher Award (DECRA) Fellow*  
University of Queensland

**Dr Hugo Harrison**

*Research Associate*  
James Cook University

**Dr Christina Hicks**

*Research Fellow*  
James Cook University and Center for Ocean Solutions  
Stanford University, USA

**Professor Ove Hoegh-Guldberg**

*Deputy Director*  
*ARC Australian Laureate Fellow*  
*Queensland Smart State Premier's Fellow*  
University of Queensland

**Dr Andrew Hoey**

*Discovery Early Career Researcher Award (DECRA) Fellow*  
James Cook University

**Dr Michael Holcomb**

*Super Science Fellow*  
University of Western Australia

**Professor Geoffrey Jones**

*Chief Investigator*  
James Cook University

**Dr Sally Keith**

*Research Fellow*  
James Cook University

**Professor Michael Kingsford**

*Chief Investigator*  
James Cook University

**Dr Bill Leggat**

*Chief Investigator*  
James Cook University

**Dr Vimoksalehi Lukoscsek**

*Discovery Early Career Researcher Award (DECRA) Fellow and Queensland Smart Futures Fellow*  
James Cook University

**Professor Mark McCormick**

*Chief Investigator*  
James Cook University

**Professor Malcolm McCulloch**

*Deputy Director*  
*ARC Australian Laureate Fellow*  
*Western Australia Premier's Fellow*  
University of Western Australia

**Dr Vanessa Messmer**

*Research Fellow*  
James Cook University

**Professor David Miller**

*Chief Investigator*  
James Cook University

**Dr Aurélie Moya**

*Research Fellow*  
James Cook University

**Professor Peter Mumby**

*ARC Australian Laureate Fellow*  
University of Queensland

**Professor Philip Munday**

*ARC Future Fellow*  
James Cook University

**Professor John Pandolfi**

*Chief Investigator*  
University of Queensland

**Professor Morgan Pratchett**

*Queensland Smart Futures Fellow*  
James Cook University

**Professor Bob Pressey**

*Chief Investigator*  
James Cook University

**Dr Jairo Rivera Posada**

*Research Fellow*  
James Cook University and  
Australian Institute of Marine Science

**Dr Jodie Rummer**

*Super Science Fellow*  
James Cook University



**Professor Garry Russ**

*Chief Investigator*  
James Cook University

**Dr Eugenia Sampayo**

*Research Fellow*  
University of Queensland

**Dr Verena Schoepf**

*Research Fellow*  
University of Western Australia

**Dr Susanne Sprungala**

*Research Associate*  
James Cook University

**Dr Ruth Thurstan**

*Research Fellow*  
University of Queensland

**Dr Linda Tonk**

*Research Fellow*  
University of Queensland

**Dr Stefan Walker**

*Research Fellow*  
James Cook University

**Dr Sue-Ann Watson**

*Research Associate*  
James Cook University

**Dr Rebecca Weeks**

*Research Fellow*  
James Cook University

**Dr David Williamson**

*Research Fellow*  
James Cook University

**Professor Bette Willis**

*Chief Investigator*  
James Cook University

**Professor David Yellowlees**

*Chief Investigator*  
James Cook University

**Dr Ke Zhang**

*Research Associate*  
James Cook University

**Dr Zhenlin Zhang**

*Super Science Fellow*  
University of Western Australia

**Resident International Scholars****Dr Pip Cohen**

*Research Fellow*  
WorldFish, Malaysia

**Professor Bruno Lapeyre**

*Professor*  
Centre National de la Recherche Scientifique, France

**Dr Benjamin Mason**

*National Science Foundation  
International Research Fellow*  
USA

**Dr David Mills**

*Research Fellow*  
WorldFish, Malaysia

**Professor David Mouillot**

*Marie Curie Fellow*  
Montpellier University, France

**Partner Investigators and Adjunct Researchers****Dr Vanessa Adams**

Charles Darwin University

**Professor Serge Andréfouët**

Institut de Recherche pour le Développement,  
New Caledonia

**Professor Eldon Ball**

Australian National University

**Dr Line Bay**

Australian Institute of Marine Science

**Professor Linda Blackall**

Swinburne University of Technology

**Dr Guillermo Diaz-Pulido**

Griffith University

**Dr Leanne Fernandes**

Earth to Ocean Consultants

**Professor Carl Folke**

Stockholm University, Sweden

**Dr Sylvain Forêt**

Australian National University

**Dr Alison Green**

The Nature Conservancy

**Dr Richard Hamilton**

The Nature Conservancy

**Dr Anne Hoggett**

Lizard Island Research Station

**Professor Ronald Karlson**

University of Delaware

**Dr Alexander Kerr**

University of Guam, USA

**Maurice Knight**

World Wildlife Fund, Indonesia

**Professor Janice Lough**

Australian Institute of Marine Science

**Professor Yossi Loya**

Tel Aviv University, Israel

**Professor Tim McClanahan**

Wildlife Conservation Society,  
Kenya

**Dr Laurence McCook**

Great Barrier Reef Marine Park Authority

**Dr Mark Meekan**

Australian Institute of Marine Science

**Professor Serge Planes**

University of Perpignan

**Professor Robert Steneck**

University of Maine

**Dr Shunichi Takahashi**

Australian National University

**Professor John Tanzer**

World Wildlife Fund, Switzerland

**Professor Madeleine van****Oppen**

Partner Investigator, Australian Institute of Marine Science

**Dr David Wachenfeld**

Great Barrier Reef Marine Park Authority

**Mirjam Maughan**

James Cook University

**Mae Noble**

Australian National University

**Kai Rankenburg**

University of Western Australia

**Sophie Rankenburg**

University of Western Australia

**Dr Maya Srinivasan**

James Cook University

**Dr Annamieke Van Den Heuvel**

University of Queensland

**Dr Amelia Wenger**

James Cook University

**Matt Young**

James Cook University

**Business Team****Jennifer Lappin**

*Chief Operations Officer*  
James Cook University

**Professor David Yellowlees**

*Assistant Director*  
James Cook University

**Olga Bazaka**

*Finance Manager and Graduate Coordinator*  
James Cook University

**Nicola De Silva**

*Administrative Officer*  
University of Queensland

**Louise Lennon**

*Administrative Assistant*  
James Cook University

**Janet Swanson**

*Administrative Assistant*  
James Cook University

**Karen van Staden**

*Administrative Officer*  
University of Western Australia

**Rose-Marie Vasiljuk**

*Office Manager and KPI Officer*  
James Cook University

**Hayley Ware**

*Project Officer*  
University of Queensland

**Graduate Students (see page 33)****Research Support Staff****Giovanni Bernal Carrillo**

University of Queensland

**Aaron Chai**

University of Queensland

**Christopher Goatley**

James Cook University

**Dr Tatjana Good**

James Cook University

**Maria Gomez-Cabrera**

University of Queensland

**Stephen Hall**

James Cook University

**Mizue Hisano**

James Cook University

**Cindy Huchery**

James Cook University

# Research Program Leaders



## Professor Sean Connolly

Professor Sean Connolly, from James Cook University (JCU), is Leader of Program 2: *Understanding and managing coral reef biodiversity*. Sean combines mathematical and statistical modelling with fieldwork and laboratory experiments to study the dynamics of biological turnover at all scales, including ecophysiology, population dynamics, species interactions and biodiversity, and macroevolution. He received his doctorate in 1999 from Stanford University in California, USA, for research on the ecology of rocky shores. In 1999-2000, he was a postdoctoral Research Fellow at the University of Arizona, USA, where he examined global dynamics of marine biodiversity in the fossil record. In 2000, he was recruited to JCU to develop and lead a research program in ecological modelling applied to coral reefs. Sean has >70 publications in leading international journals, including 11 papers in *Science* or *Nature*, and he has supervised 25 postgraduate and Honours students. In 2008 he was awarded an ARC Australian Professorial Fellowship (2008-2012), and in 2009, the *Fenner Medal* of the Australian Academy of Science, which honours outstanding research in the biological sciences by a scientist under 40.



## Professor Ove Hoegh-Guldberg

Professor Ove Hoegh-Guldberg is one of two Deputy Directors of the ARC Centre and Leader of Program 4: *Genetic, molecular and physiological processes*. He is also the Director of the Global Change Institute at The University of Queensland. His research interests span a broad range of topics including marine biology, physiology, biochemistry and molecular biology of plant-animal symbioses, co-evolution, coral bleaching, ocean acidification and climate change. In 1999, he was awarded the University of NSW Eureka Prize for Scientific Research, for research by an Australian scientist under 40. Ove is an *ISI Highly Cited Researcher* and has published over 230 papers, including 18 in *Science* or *Nature*. He is currently Coordinating Lead Author for the 'Oceans' chapter within the Inter-governmental Panel on Climate Change (IPCC) 5th assessment report. He is well known as an advocate for science, particularly with coral reefs and their future in the face of rapid climate change. In 2008, Ove was awarded the prestigious Queensland Premier's Smart State Fellowship (2008-2013). In 2013 he was awarded an ARC Australian Laureate Fellowship and was elected a Fellow of the Australian Academy of Science.



## Professor Terry Hughes

Professor Terry Hughes is the Director of the ARC Centre of Excellence and Leader of *Program 5: Resilience of linked social-ecological systems*. He received his PhD in 1984 from Johns Hopkins University in Baltimore, USA and was an NSF Postdoctoral Fellow at the University of California, Santa Barbara before moving to Australia and James Cook University in 1990. Terry was elected a Fellow of the Australian Academy of Science in 2001 in recognition of "a career which has significantly advanced the world's store of scientific knowledge". In 2007, he was awarded the *Sherman Eureka Prize for Environmental Research*. In 2008, he was awarded the prestigious quadrennial *Darwin Medal* by the International Society for Reef Studies. From 2008-2010, he was a member of the ARC Advisory Council. Terry has broad research interests in ecology, marine biology and the social-ecological dynamics of coral reefs. As Centre Director, he provides academic leadership and is responsible for the strategic development of the Centre. He is an *ISI Highly Cited Researcher* with 24 papers in *Science* or *Nature*. He has been awarded three Federation/Laureate Fellowships by the Australian Research Council, from 2002-2017, and is a Fellow of the *Beijer Institute for Ecological Economics*, in Stockholm.





## Professor Malcolm McCulloch

Professor Malcolm McCulloch is one of the Centre's two Deputy Directors and Leader of Program 1: *Evolutionary and environmental change*. Malcolm was appointed as a Western Australian Premier's Fellow in 2009 and holds a senior Professorship in the School of Earth and Environment at The University of Western Australia. His research interests focus mainly on the recent geological record using isotopic and trace element geochemical methods to determine how climate and anthropogenic processes have influenced both past and present marine environments, with particular emphasis on coral reefs. Malcolm received his PhD from the Californian Institute of Technology (Caltech). In his early career he was a leader in crustal and mantle evolution and cosmochemistry, and has subsequently become a world leader in environmental geochemistry. He is an *ISI Highly Cited Researcher* having published over 260 scientific papers in leading international journals including 26 in *Science* or *Nature*. Malcolm has received a number of prestigious awards having been elected Fellow of The Royal Society (London), the Australian Academy of Science, the American Geophysical Union, the Geochemical Society and the Geological Society of Australia. He was awarded the *Jaeger Medal* for career excellence in the earth sciences from the Australian Academy of Science, and an Honorary Doctorate from Curtin University. In 2012, Malcolm was awarded an ARC Australian Laureate Fellowship.



## Professor David Miller

Professor David Miller is Leader of Program 8: *Genomics and metagenomics of coral reefs*. David studies the molecular biology of corals and other "simple" marine animals. His research interests span a broad range of topics from marine biology to genomics, and include the biochemistry and molecular biology of coral symbioses, the evolution of developmental mechanisms ("evo-devo"), immune system evolution, and the molecular bases of coral responses to stressors such as disease, ocean acidification and climate change. David obtained his PhD in genetics and biochemistry from the University of Kent (UK). He subsequently undertook post-doctoral research at the University of Bristol (UK) and then the University of Adelaide. David moved to James Cook University in 1984 and is currently a Professor in molecular genetics and genomics. David's main claim to fame is the discovery that "simple" animals such as corals have genomes as complex as those of man and other vertebrates, and his research highlighting the role of gene loss in shaping animal genomes. He plays a leading role in a number of genome projects on various lower animals, including the first coral genome project and the first all-Australian whole genome project, and is a regular commentator on animal genome evolution for a number of high profile journals.



## Professor Bob Pressey

Professor Bob Pressey is the leader of Program 6: *Conservation planning for a sustainable future*. Bob's research includes studies of biodiversity, geographic information systems, spatial modelling of species and human activities, software development, explicit frameworks for deciding on the location and timing of conservation investments, and the socio-economic issues involved in implementing conservation action. Prior to moving to James Cook University (JCU) he was a research scientist for the New South Wales National Parks and Wildlife Service for almost 20 years. During that time, Bob developed and applied leading-edge techniques in conservation planning, influencing policy and conservation practice. He is an *ISI Highly Cited Researcher* and has served on the editorial boards of leading conservation biology journals. Bob was awarded *The Royal Botanic Gardens' Eureka Prize* for Biodiversity Research in 2002, and the inaugural (2008) *Australian Ecology Research Award* from the Ecological Society of Australia. In 2009, he was awarded the title of Distinguished Professor at JCU. In 2010, he was elected as a Fellow of the Australian Academy of Science, for his contributions to the field of systematic conservation planning. His groundbreaking research on conservation planning was recognised in 2012 by his appointment to the WWF Australia's Eminent Scientists Group. Bob leads research projects in Australia, the Asia-Pacific region, Brazil, Costa Rica, Ecuador and Mexico.

# Business Leaders



## Jennifer Lappin

Jenny Lappin is the Chief Operations Officer of the ARC Centre of Excellence. Jenny has a Bachelor of Commerce degree from the University of Queensland and is a Certified Practising Accountant. She has over 20 years of senior management experience with responsibilities for strategic planning, finance, human resources, communications, events management, facilities development, business processes and policy development. Starting work as an accountant in Townsville she progressed her career in Sydney, Melbourne and London before returning to Australia. She worked as an academic in the Department of Commerce at James Cook University in 1988, moving to general financial management positions soon after. Following various leadership positions in finance, research, foreign aid projects and as an Executive Officer at JCU, she moved in October 2005 to the ARC Centre of Excellence to oversee, with the Centre Director, its establishment and development. Along with the Centre Director she regularly provides advice to other Centres of Excellence around the world in assisting with their establishment and development.



## Professor David Yellowlees

Professor David Yellowlees is the Assistant Director of the ARC Centre of Excellence and a Chief Investigator in Programs 4 and 8. Educated in Scotland as a biochemist, he has undertaken extensive research on the symbiosis between coral reef organisms, particularly in corals and tridacnid clams. His major interests have centred on the metabolic relationship between the symbiotic partners. His research on the acquisition of inorganic carbon, its photosynthetic fixation and transfer to the animal host forms the basis of much of our understanding of these organisms at the metabolic level. David has published over 80 papers in international journals. He has had a long career at James Cook University commencing in the Department of Chemistry and Biochemistry in 1971. After resigning as Head of the School of Pharmacy and Molecular Sciences at the beginning of 2007, he joined the staff of the Centre as its Assistant Director. He now applies many of those skills learned as Head of School to assist with the running of the Centre. In particular, he mentors the postdoctoral fellows, assists researchers with grant submissions and acts as the postgraduate liaison officer for the ARC Centre. He is a member of the JCU Research Committee and on the DVC's (Research and Innovation) Research Advisory Group.





“

Through our network of marine protected areas, Kubulau’s communities are working together to ensure the future of our fisheries, which will benefit future generations as well.

”

Ratu Vuki  
High Chief  
Kubulau District, Fiji (p25)

# Research Fellow Profile

## Dr Jodie Rummer

Jodie is originally from the USA and admits that growing up watching National Geographic and BBC specials while living in a land-locked State drove her ambition to pursue a career in marine biology. After moving to Florida, where she earned her Bachelor's and Master's degrees, she became especially interested in fish physiology; physiology, because it is a perfect balance of physics, chemistry, maths, and all of the biological disciplines; fish because of their diversity, and, because they possess a multitude of mechanisms for occupying vastly different types of aquatic environments.

Her interest in fish physiology took Jodie to Vancouver, Canada where she graduated with a PhD from the University of British Columbia for her work on the evolution of oxygen transport in fishes and on how they cope with environmental and exercise-induced stress. After a short post-doctoral fellowship in Hong Kong working on how fish respond to stress by changes in blood circulation, she moved to the ARC Centre in 2011 to take up an ARC Super Science Fellowship.

Jodie's strength in evolutionary and ecological physiology complements the ARC Centre's coral reef expertise. Using both field- and laboratory-based experiments, she employs geographic environmental gradients, such as the thermal gradient along the Great Barrier Reef, as analogues for future change, investigates the extreme performers within aquatic environments, and integrates conventional and innovative physiological, biochemical, and molecular techniques to gain insight into the various cellular and whole-organism responses of fish. Around the Centre, Jodie quickly became known for referring to her fish as "athletes".

Jodie has made several significant contributions to fish physiology. Her recent paper in *Science* (p21) details the evolution of enhanced oxygen delivery in fish where she characterised a physiological mechanism involving a unique version of the O<sub>2</sub>-transporting protein (haemoglobin) in the blood that allows fish to deliver oxygen to their tissues up to 25-times more efficiently than humans. When a fish is exposed to stress, such as intense exercise or elevated environmental CO<sub>2</sub>, these haemoglobins can almost double oxygen delivery. This study may help scientists predict whether fish can cope with the anthropogenic climate change in our oceans. This is a continuing theme in Jodie's research at the Centre.



Remarkably, Jodie has also discovered that some fish perform better – athletically – under high CO<sub>2</sub> conditions, which may reflect their evolutionary history and their habitat, and she thinks the mechanism behind this may be enhanced O<sub>2</sub> delivery. Thanks to funding from the National Geographic Society, Jodie has been investigating the effects of long-term exposure to elevated CO<sub>2</sub> in fishes living in natural CO<sub>2</sub> seeps in Papua New Guinea. These fish communities occupy reefs near cool volcanic seeps whose seawater chemistry is similar to that projected for the coming century. Nearby reefs unaffected by the CO<sub>2</sub> seeps are ideal controls.

Another aspect of Jodie's research is how elevated temperatures decrease fish performance and whether fish populations living near the equator may be more at risk.

Since joining the Centre, Jodie has discussed her findings at dozens of invited national and international speaking engagements. She has become a liaison point of contact for local and international Women in Science issues and is writing two chapters on communication and networking in a book on *Success Strategies for Women in Science*. She has published her work in top journals, and she has been able to initiate numerous successful collaborations both nationally and internationally, notably with fellow Centre member, Philip Munday.



## Sandra Binning and Dominique Roche



For this couple, teaming up to do research has some real practical advantages: working in waves can be extremely challenging. Because conducting detailed experiments and observations in wave-exposed habitats is so difficult, Sandra and Dom had to come up with new ways to study their subjects. At the University of Washington's Friday Harbor Marine Laboratories in the USA they learned novel techniques in fish physiology and kinematics. Armed with this new knowledge, they designed and built specialised aquaria fitted with underwater pumps and motors where they could create water conditions similar to those found on a reef crest. Dom has explored whether predators and prey fishes are similarly affected

Water flow plays a huge role in the ability of aquatic creatures to survive and flourish in natural habitats. Yet, we know very little about how these stressors affect more complex phenomena like predator-prey interactions, or whether individuals can adapt to turbulent conditions given enough time. These important questions formed the basis of Dom and Sandra's PhD projects at the ARC Centre's Australian National University (ANU) node.

In 2010, these intrepid Canadians moved half-way across the world to pursue their PhD studies in marine ecology in Australia. Canada may seem like a strange place to foster a love of coral reefs, but for Dom and Sandra, a passion for tropical fishes is what initially brought them together. Having met as undergraduate students in Canada during a tropical ecology field course, the two initially began exploring the underwater world as dive buddies, and were invited to participate on research cruises in the Caribbean and Eastern Pacific by the Smithsonian Tropical Research Institute. From there, they pursued the next step in their scientific training, and funding from both the ANU and the ARC Centre of Excellence for Coral Reef Studies turned their dreams of working on the Great Barrier Reef into reality.

by displacements caused by waves, and the energetic costs associated with swimming in complex water flows. In one experiment, Dom designed tanks where he could expose fish to different flow conditions and film their behaviour. In another, he programmed a motor to create waves of different amplitudes and measured the oxygen consumption rates of fish swimming at different speeds. His results show that body shape is a critical trait affecting whether fish behaviour is severely impacted by water flow, and that fish use a lot of energy to swim when fluctuations in water velocity are high.

Sandra has explored the long-term effects that exposure to waves has on fish fin shape and athleticism. She designed a series of wave tanks where she raised juvenile damselfish over a period of months to test their adaptation to different water flow conditions. She also created a "fish boot camp" where adults were trained to swim against a current for eight hours a day to test if exercise improved their athletic abilities. Her results show that fish, just like humans, do become more athletic when they are trained to swim in wavy conditions. However, some fin shapes are better for swimming than others, and in this regard, fish are evolutionary constrained by their body shape.

# Evolutionary and environmental change

## Researchers

**Malcolm McCulloch** (Program Leader)

**David Bellwood**

**Sean Connolly**

**Delphine Dissard** (Research Fellow)

**James Falter** (Research Fellow)

**Ove Hoegh-Guldberg**

(Research Fellow)

**Michael Holcomb** (Research Fellow)

**Michael Kingsford**

**Janice Lough**

**John Pandolfi**

**Eugenia Sampayo** (Research Fellow)

**Verena Schoepf** (Research Fellow)

**Ruth Thurstan** (Research Fellow)

**Zhenlin Zhang** (Research Fellow)

Program 1 focuses on developing a better understanding of the environments and processes that cause transitions in coral reef systems over a range of scales. Knowledge of the past history of coral reefs improves our ability to predict future influences of environmental variability, human impacts and climate change. Together with the Centre's ecological studies, this Program's research provides a unique perspective on community change that ranges from centuries to millennia.

Recent research in Western Australia, led by Program Leader Malcolm McCulloch has centred on the exceptionally strong ocean warming event that occurred along the WA coastline in the summer of 2010–2011. Coral reefs along this coastline experienced temperatures ~2–3°C warmer than typical summer maximum temperatures. These highly unusual temperatures caused extensive bleaching of corals that extended from the more northerly fringing reefs of Ningaloo, the offshore sub-tropical reefs of Abrolhos Island, down to the temperate corals found in the waters of Rottnest Island, offshore Perth, a distance of more than 1000 km.

In 2013, PhD students Taryn Foster and Sana Dandas at the UWA node addressed the recovery of reefs from the extreme 2010–2011 summer heating. An unexpected finding was the medium-term effect of heat stress on calcification rates of corals. After bleaching, greater rates of calcification occurred in the winter months rather than during the following two summers. In fact, only in 2012–13, is there evidence for resumption of the normal seasonal pattern of higher rates of calcification in summer. This work was complemented by similar studies undertaken by Program 1 in Cygnet Bay in the Kimberley, where despite much higher temperatures, rates of coral calcification are broadly similar to those from Ningaloo. This suggests an upper physiologically based limit to the rates of calcification that is largely independent of seasonal fluctuations in temperature regimes. Related studies were also undertaken by PhD student Jessie Short who has examined the effects of these unusually warm conditions on the interactions between crustose coralline algae and corals.

In another study, Research Fellows Zhenlin Zhang and Jim Falter showed how local atmospheric and oceanic forcing can exacerbate the effects of regional oceanic warming on the thermal stress levels experienced by corals on inshore reefs. The summer of 2010–2011 saw inshore reef temperatures at Coral Bay in Ningaloo Reef that were 1°C to 2°C higher than offshore sea surface temperatures and which were already 2°C to 3°C higher than their long-term climatological average due to regional ocean warming in recent decades. These conditions resulted in the historically unprecedented mass bleaching of coral in the enclosed lagoon of Coral Bay, in contrast to corals in nearby well-flushed reefs which experienced less severe conditions.

During 2013, Super Science Fellow Michael Holcomb has shown that the physiologically controlled process of pH up-regulation of corals is much more variable than initially thought, with different regions within a single coral polyp, up-regulating pH to different extents. Laterally growing regions of a coral colony show a reduced ability to up-regulate pH, and are in turn more sensitive to ocean acidification. Thus ocean-acidification has the potential to remodel the skeletal architecture of even low-sensitivity species. If these findings are common across a range of species, then coral cover from lateral growth is likely to be reduced under future conditions of ocean-acidification.

John Pandolfi and collaborators published a major paper in *Nature Climate Change* synthesizing all available studies of the response of marine organisms to contemporary climate change. The study was based on a unique meta-database of 1,735 marine biological responses to regional or global climate change. Over 80% of all observations of the geographic distribution, phenology, species composition, abundance, demography and calcification of species were consistent with the expected impacts of climate change. The results showed that rates of observed shifts in marine species' distributions and phenology are comparable to, or greater than, those for terrestrial systems. Other significant publications by Program 1 researchers in 2013 included new palaeoecological evidence of the historical collapse of corals at Pelorus Island, inshore Great Barrier Reef, following European settlement, published in the *Proceedings of the Royal Society*; and a synthetic review of the role of evolution and adaptation in the long-term response of marine organisms to climate change, published in *Ecology Letters*.



## Climate 'causing huge changes in ocean life'

Profound changes are taking place in marine life around the planet in response to global warming, an international team of scientists has found.

Marine species – including fish, shellfish, crustaceans, plankton, mangroves and seagrasses – are now shifting the areas they inhabit at an average rate of 72 kilometres per decade as a result of one degree of planetary warming.

Some species have moved up to 470 kilometres in a decade. This contrasts with an average 6 km movement by life on land. Most of the movement is towards the poles as sea life searches for cooler waters.

The team analysed 208 reports on marine life and fisheries, covering 857 different marine species or groups from around the world for changes in their normal distribution, abundance, breeding cycles, community composition, shell formation and age structure. It is the biggest marine study of its kind so far and fills an important gap in our understanding of global change.

"The results were quite a shock," says co-author Professor John Pandolfi. "We found that changes in sea life attributable to a one degree increase in the Earth's overall temperature appear much greater than those seen in life on land so far."

The oceans are estimated to have absorbed 80 per cent of the extra heat put into the Earth system by human use of fossil fuels, but have nevertheless warmed more slowly than the land owing to their huge

mass, he says.

"This makes the very large changes in the behaviour of sea life all the more surprising. We put it down mainly to the fact that marine organisms often produce substantial numbers of floating larvae that are easily dispersed by ocean currents."

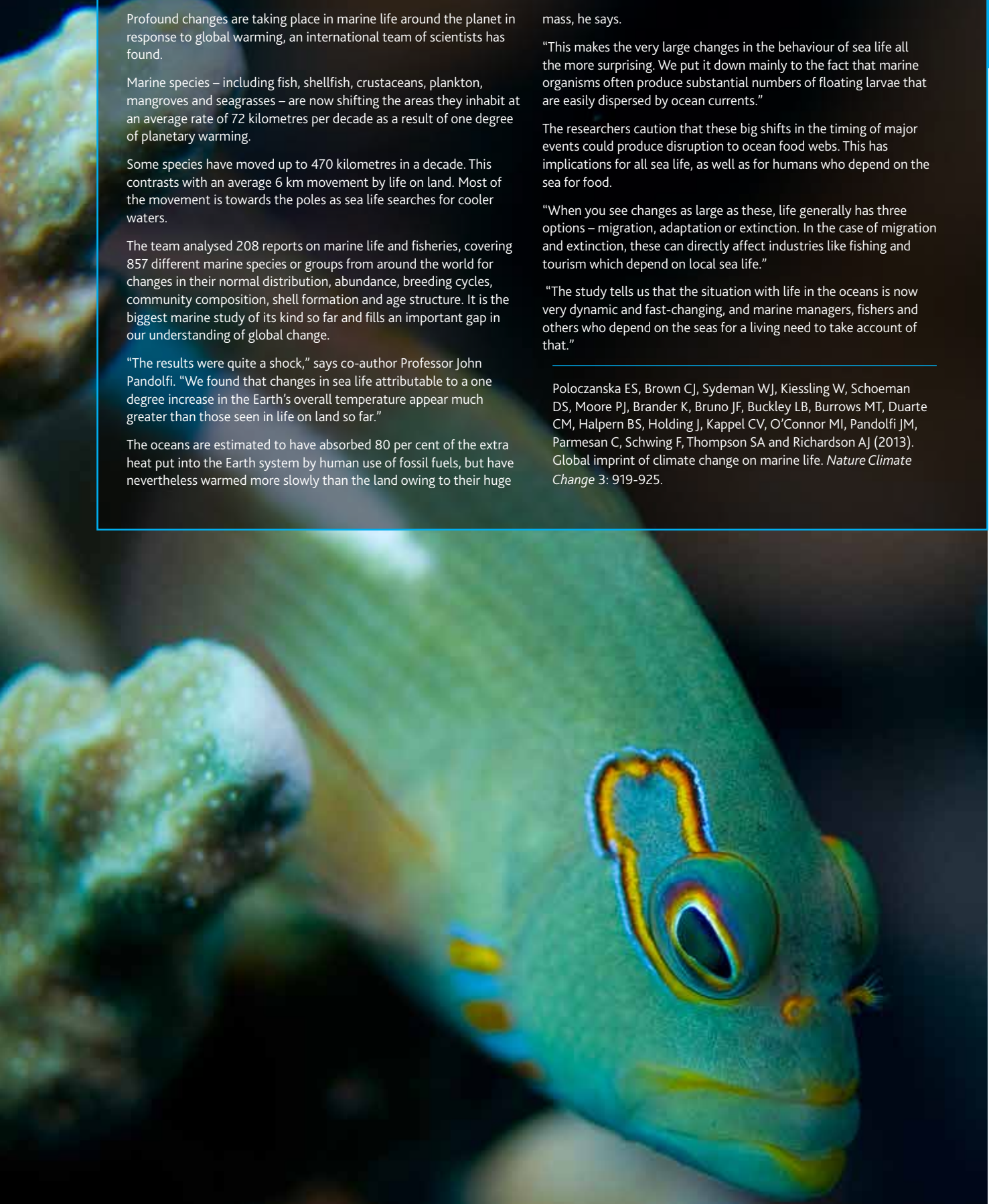
The researchers caution that these big shifts in the timing of major events could produce disruption to ocean food webs. This has implications for all sea life, as well as for humans who depend on the sea for food.

"When you see changes as large as these, life generally has three options – migration, adaptation or extinction. In the case of migration and extinction, these can directly affect industries like fishing and tourism which depend on local sea life."

"The study tells us that the situation with life in the oceans is now very dynamic and fast-changing, and marine managers, fishers and others who depend on the seas for a living need to take account of that."

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Poloczanska ES, Brown CJ, Sydeman WJ, Kiessling W, Schoeman DS, Moore PJ, Brander K, Bruno JF, Buckley LB, Burrows MT, Duarte CM, Halpern BS, Holding J, Kappel CV, O'Connor MI, Pandolfi JM, Parmesan C, Schwing F, Thompson SA and Richardson AJ (2013). Global imprint of climate change on marine life. *Nature Climate Change* 3: 919-925.



# Understanding and managing coral reef biodiversity

## Researchers

**Sean Connolly** (Program Leader)  
**Glenn Almany** (Research Fellow)  
**Andrew Baird** (Research Fellow)  
**David Bellwood**  
**Mary Bonin** (Research Associate)  
**Tom Bridge** (Research Fellow)  
**Vivian Cumbo** (Research Associate)  
**Joana Figueiredo** (Research Fellow)  
**Ashley Frisch** (Research Fellow)  
**Chris Fulton**  
**Nick Graham** (Research Fellow)  
**Alistair Harborne** (Research Fellow)  
**Hugo Harrison** (Research Associate)  
**Andrew Hoey** (Research Fellow)  
**Terry Hughes** (Research Fellow)  
**Geoffrey Jones**  
**Sally Keith** (Research Fellow)  
**Michael Kingsford**  
**Vimoksalehi Lukoschek**  
 (Research Fellow)  
**Laurence McCook**  
**Mark McCormick**  
**Mark Meekan**  
**Vanessa Messmer** (Research Fellow)  
**Peter Mumby** (Research Fellow)  
**Philip Munday** (Research Fellow)  
**John Pandolfi**  
**Serge Planes**  
**Jairo Rivera Posada** (Research Fellow)  
**Morgan Pratchett** (Research Fellow)  
**Jodie Rummer** (Research Fellow)  
**Garry Russ**  
**Robert Steneck**  
**Ruth Thurstan** (Research Fellow)  
**Stefan Walker** (Research Fellow)  
**David Williamson** (Research Fellow)  
**Bette Willis**

Program 2 aims to understand the mechanisms and processes that maintain coral reef biodiversity, using a combination of mathematical modelling, fieldwork, and laboratory studies. Consequently, this multi-disciplinary Program informs knowledge-based management of biodiversity, resulting in environmental, social, and economic benefits to tropical maritime nations. Coral reef biodiversity underpins the critically important functions and services performed by

reef ecosystems, such as sustaining the productivity of fish stocks on which many tropical nations depend for their food security and future development.

In 2013, the potential impact of climate change on coral reefs was a major theme for a number of Program 2 researchers. For instance, Super Science Fellow Jodie Rummer found that reef fish living at the equator are highly vulnerable to warming temperatures, while fish at higher latitudes have more scope to adjust to ocean warming. PhD student Neil Chan, working with Sean Connolly, found that the effects of ocean acidification on coral growth are less pronounced than previously claimed, indicating that there is still time to act to prevent major loss of coral reefs on a global scale.

Understanding the functioning of coral reef ecosystems is essential to anticipating ecological change, and to reversing or ameliorating undesirable changes on coral reefs, such as overgrowth by seaweeds. Nick Graham, David Bellwood, Terry Hughes, and Josh Cinner, in a paper in *Frontiers in Ecology and the Environment*, drew on examples from other ecosystems, and from the social sciences, to identify ways that coral reef managers might reverse phase shifts from coral to seaweed-dominated reefs. Peter Mumby's research team reported, in *Current Biology*, on the roles that local conservation management and global greenhouse gas reduction play in maintaining the ability of reefs to continue growing; they found that both local and global actions were essential to securing future reef function.

Garry Russ and collaborators Rene Abesamis and Angel Alcala made key breakthroughs in 2013 in their long-term program of using no-take marine reserves as fisheries management and conservation tools in the Philippines. Almost 40 years after the first marine reserve was established in the southern Philippines (1974), this team for the first time used genetic parentage analysis to establish preliminary reef fish larval connectivity patterns among an existing network of marine reserves. Geoff Jones, Serge Planes and co-workers applied

this approach in Kimbe Bay Papua New Guinea, showing both self-recruitment in small isolated marine reserves and larval connectivity among reserves over 100 km apart. Similarly Geoff, David Williamson and Hugo Harrison tracked coral trout larvae dispersing from protected areas on the Great Barrier Reef. These findings have particular significance to the communities of fishers along these different coastlines.

2013 also saw some important advances in our understanding of how marine reserves work. DECRA Fellow, Nick Graham and, adjunct researcher, Tim McClanahan found major differences between the food web structures of coral reef "wilderness areas", compared to protected reefs embedded within exploited reef systems. Joana Figueiredo, Andrew Baird, and Sean Connolly found that coral populations have a much greater capacity to replenish themselves, instead of relying on immigrants from far away reefs, than previously thought. Indeed, reef systems remote from regional scale degradation by human activity, such as those in Western Australia, are able to recover from major disturbances, such as bleaching events, despite their isolation from coral broodstock on other reefs, as shown in a 2013 *Science* paper by Andrew Baird, Morgan Pratchett, and colleagues (see opposite).

Researchers in Program 2 also made numerous important contributions in 2013 to coral reef policy and conservation at State, Commonwealth, and international levels. For example, Peter Mumby's research on parrotfishes was extensively cited in a lawsuit between Earth Justice and the US government, which led to the US developing a more extensive fishery management plan for parrotfishes.

Program 2 researchers received several awards and honours during 2013. Philip Munday was awarded a top tier ARC Future Fellowship. Ashley Frisch was awarded a Churchill Fellowship, and Program Leader Sean Connolly was a finalist for the Scopus Young Researcher of the Year Award.



## Remote reefs can be tougher than they look

Isolated coral reefs can recover from catastrophic damage as effectively as those with nearby undisturbed neighbours, a long-term study by marine biologists from the Australian Institute of Marine Science (AIMS) and the ARC Centre of Excellence for Coral Reef Studies has shown.

Australia's largest oceanic reef system, Scott Reef, is relatively isolated, sitting out in the Indian Ocean some 250 km from the remote coastline of north Western Australia. Prospects for the reef looked gloomy when in 1998 it suffered catastrophic mass bleaching, losing around 80% of its coral cover. The study shows that it took just 12 years to recover.

The study challenges conventional wisdom that suggested isolated reefs were more vulnerable to disturbance, because they were thought to depend on recolonisation from other reefs. Instead, the scientists found that the isolation of reefs allowed surviving corals to rapidly grow and propagate in the absence of human interference.

Spanning 15 years, data collected and analysed by the researchers shows how after the 1998 mass bleaching the few remaining corals provided low numbers of recruits for Scott Reef. On that basis recovery was projected to take decades, yet within 12 years the cover and diversity of corals had recovered to levels similar to those seen pre-bleaching.

"The initial projections for Scott Reef were not optimistic," says Dr James Gilmour "because, unlike reefs on the Great Barrier Reef, there

were few if any reefs nearby capable of supplying new recruits to replenish the lost corals at Scott Reef."

"However, the few small corals that did settle at Scott Reef had excellent rates of survival and growth, whereas on many nearshore reefs high levels of algae and sediment, and poor water quality will often suppress this recovery."

"We know from other studies that the resilience of reefs can be improved by addressing human pressures such as water quality and overfishing," says Dr Gilmour. "So it is likely that a key factor in the rapid recovery at Scott Reef was the high water clarity and quality in this remote and offshore location."

In their publication the team also draws attention to the important role played by climate change in the longer-term prospects for coral reefs, as Prof Morgan Pratchett explains.

"While it is encouraging to see such clear recovery, we need to be mindful of the fact that the coral recovery at Scott Reef still took over a decade. If, as the climate change trend suggests, we start to see coral bleaching and other related disturbances occurring more frequently, then reefs may experience a ratcheting down effect, never fully recovering before they suffer another major disturbance."

Gilmour, JP, Smith, LD, Heyward, AJ, Baird, AH and Pratchett, MS (2013). Recovery of an isolated coral reef system following severe disturbance. *Science* 340: 69-71.





# Genetic, molecular and physiological processes

## Researchers

**Ove Hoegh-Guldberg** (Program Leader)

**Tracy Ainsworth** (Research Fellow)

**Pim Bongaerts** (Research Fellow)

**Tom Bridge** (Research Fellow)

**Sophie Dove**

**Simon Dunn** (Research Fellow)

**Bill Leggat**

**David Miller**

**Philip Munday** (Research Fellow)

**Jodie Rummer** (Research Fellow)

**Linda Tonk** (Research Fellow)

**Madeleine van Oppen**

**Sue-Ann Watson** (Research Associate)

**Bette Willis**

**David Yellowlees**

Understanding molecular and genetic mechanisms as well as ecological dynamics provides powerful insight into the drivers of change on coral reefs. This approach is central to Program 4's research activities and has become even more important as Centre researchers work to project how reefs will change in the future.

In 2013, Sophie Dove and colleagues published the first of a series of papers from a mesocosm experiment on Heron Island Research Station designed to explore past, present and future ocean temperatures and chemistries. One of the key discoveries was that decalcification of coral reefs escalates as we head toward 'business-as-usual' CO<sub>2</sub> emission trajectories. Their paper published in *Proceedings of the National Academy of Science*, also revealed major impacts on typical coral reef communities resulting from projected changes in ocean temperature, pH and carbonate ion concentrations.

During 2013, Tom Bridge (joint postdoctoral fellow with AIMS) and Pim Bongaerts continued their focus on mesophotic reefs. Along with Terry Hughes and colleague John Guinotte from US National Oceanographic and Atmospheric Administration, they published, in *Nature Climate Change*, a Commentary on the importance of deep reefs for

management and conservation. Pim and Tom continue their exploration of the genetic connectivity of coral populations across depth gradients with the goal of evaluating whether or not mesophotic reefs might act as refuges against climate change.

Bette Willis and colleagues focused on three interconnected themes: coral disease ecology and disease drivers on the Great Barrier Reef, coral-*Symbiodinium* and coral-bacterial symbioses in coral health, and the role of dispersal in reef interconnectivity and resilience. The discovery by PhD student Jean-Baptiste Raina that the coral host can synthesise the climate-active molecule DMSP, which plays a critical role in the response of corals to thermal stress was published this year in *Nature*. A synthetic overview of influence of climate change on marine infectious diseases, and the implications for management and society was published in *Annual Review of Marine Science*, part of Program 4's contribution to the international Research Coordination Network for Infectious Marine Diseases. Also in 2013, an experimental study by former PhD student Emily Howells, demonstrating that historical thermal regimes define the limits to acclimatisation of the coral-*Symbiodinium* holobiont, was published in *Ecology*.

In 2013, Jodie Rummer characterised the biochemical mechanism for enhanced O<sub>2</sub> delivery in fish, which includes the unique pH-sensitive haemoglobin found only in fish, and the enzyme carbonic anhydrase. During a mild acidosis, such as when environmental CO<sub>2</sub> concentrations are elevated or during exercise, this mechanism can double tissue O<sub>2</sub> delivery. This discovery, published in *Science*, sheds insight into the evolution of one of the most successful groups of vertebrates: the fishes.

Simon Dunn has continued to explore the cellular and metabolic regulation of cnidarian-algal symbiosis with a current focus on lipogenesis. Linda Tonk published an online database of multiple genetic markers to aid identity of *Symbiodinium*

species associated with invertebrate host organisms across the Great Barrier Reef.

During 2013, Tracy Ainsworth and Bill Leggat continued to focus on bacterial associations with corals using a combination of transcriptomics along with parallel analysis using proteomics and metabolomics. PhD student Ben Gordon and Bill Leggat published the first method for the extraction and analysis of the metabolite profile of coral and their associated dinoflagellates. Using this technique they determined that significant changes in the metabolic interaction between coral and *Symbiodinium* occur after the holobiont is subjected to only one day of elevated temperature or CO<sub>2</sub>. This work is now being used to develop biomarkers for stress in the coral holobiont that are of potential use for management. Gordon, Leggat and Ainsworth have extended this research at the Australian Synchrotron, where they have been imaging changes in coral-*Symbiodinium* metabolism following exposure to elevated temperatures. This is the first study of its type and will significantly improve our understanding of how the coral holobiont functions.

Madeleine van Oppen continues her work on the evolutionary biology of reef-building corals, posing the important question as to whether or not evolutionary processes can keep pace with the current rapid rate of climate change. Anthony Bertucci has been assembling, with Sylvain Forêt, the transcriptome from the world's largest solitary coral, *Heliofungia actiniformis*, in order to study the differential expression of genes in the different tissue layers of reef-building corals.

In 2013, Program 4 Leader Ove Hoegh-Guldberg was elected as a Fellow of the Australian Academy of Science joining Terry Hughes, Malcolm McCulloch and Bob Pressey who were elected in previous years. Ove is Coordinating Lead Author to Chapter 30 ('Oceans') of the upcoming IPCC 5<sup>th</sup> Assessment Report.



## How fish won the oxygen war

A missing link in the story of how the fishes triumphed over toxic oceans and past climate changes has been revealed by an international team of scientists.

The key to the evolutionary success of fish – and their possible survival in future – may lie with a molecule that they ultimately bequeathed to humans: hemoglobin, the carrier of oxygen from our lungs to all other organs.

In a paper in the journal *Science*, Dr Jodie Rummer of the ARC Centre of Excellence for Coral Reef Studies and colleagues from the University of British Columbia report a groundbreaking discovery about how fish manage to survive in hostile water conditions.

"Four hundred million years ago the oceans were not what they are today. They were low in oxygen, high in CO<sub>2</sub> and acidic," says Dr Rummer. "Yet the fishes not only survived in these unpromising circumstances, they managed to thrive. Their secret weapon was a system for unloading oxygen from the hemoglobin in their blood, whenever the going got really tough."

"Hemoglobin in the blood takes up oxygen in the gills of fish. It then carries it round the body to the heart, muscles and organs until it encounters tissues that are highly active and producing a lot of CO<sub>2</sub>. The acid is the signal for the hemoglobin to unload as much of its oxygen as possible into the tissues," she explains.

"These early fish managed to develop a way to maximize the delivery of oxygen, even when the water they lived in was low in it. They had a phenomenal capacity for releasing oxygen just when needed: it was one of the big secrets of their evolutionary success, to the extent they now make up half the vertebrates on the planet."

The fish system is many times more efficient than the one inherited by humans (as our amphibian ancestors branched away from higher fishes around 350-400 million years ago when the hemoglobin system was still in its early stages of development), but its discovery may lead to new ways of understanding and tackling conditions influenced by oxygen levels in the body.

"Also, we feel that if we can understand how fish coped with low-oxygen, high CO<sub>2</sub>, acidic waters in the past, it will give us some insight into how they might cope with man-made climate change which appears to be giving rise to such conditions again," Dr Rummer says.

Rummer JL, McKenzie DJ, Innocenti A, Supuran CT and Brauner CJ (2013). Root effect hemoglobin may have evolved to enhance general tissue oxygen delivery. *Science* 340: 1327-1329.



# Resilience of linked social-ecological systems

## Researchers

**Terry Hughes** (Program Leader)  
**Andrew Baird** (Research Fellow)  
**David Bellwood**  
**Jessica Blythe** (Research Fellow)  
**Joshua Cinner** (Research Fellow)  
**Louisa Evans** (Research Fellow)  
**Michael Fabinyi** (Research Fellow)  
**Nick Graham** (Research Fellow)  
**Laurence McCook**  
**John Pandolfi**  
**Bob Pressey** (Research Fellow)  
**Ke Zhang** (Research Fellow)

Program 5 focuses on resilience – the capacity of people, economies and coral reef ecosystems to cope with and adapt to change and surprises. Its objective is to undertake research and develop new tools that improve the governance and management of natural systems and enhance their capacity to sustain human and natural capital. Program 5’s multi-disciplinary research combines expertise on coral reef biology, management, governance, economics and the social sciences. The Program has three themes: Understanding the dynamics of complex systems, Adapting and responding to environmental change, and Managing for resilience.

In 2013, Centre Director Terry Hughes began the second year of his ARC Laureate Fellowship, and was awarded a prestigious Einstein Professorship from the Chinese Academy of Science (CAS), one of 20 globally across all sciences. As part of this award, the Chinese Academy of Sciences will host Hughes for a lecture tour in 2014, and the Centre of Excellence will mentor and train two CAS-sponsored visiting fellows. Hughes gave a series of invited lectures and keynote talks in Australia, South Africa, and Jamaica, and also led a series of papers on regime shifts and multi-scale governance challenges, including a paper in *Conservation Biology* on the “wicked problem” of China’s disappearing coral reefs.

Mike Fabinyi conducted ongoing fieldwork in Beijing on the international trade in seafood products. A key and surprising result from Mike’s research is that there is actually a recent decline in the demand for shark fins, but this is not the result of conservation campaigns seeking to raise consumer awareness about the sustainability of shark finning. Instead, Mike’s interviews with the owners of the luxury restaurants, where shark fin soup is served as part of prestigious banquets, revealed two key reasons for declining demand: a crackdown on government corruption (misappropriated funds were often used to sponsor lavish banquets for party officials); and an increase in food safety scandals which resulted in consumers lacking confidence in the authenticity and quality of shark fins. Mike presented his research at invited seminars in Australia, New Zealand, and Singapore.

Louisa Evans received a *Collaborating Across Boundaries* grant that enabled her to collaborate with colleagues from the JCU Business School to improve understanding of how to foster effective leadership in nature conservation. Louisa also collaborated with colleagues from WorldFish (Malaysia), the University of Dar Es Salaam (Tanzania), and the University of East Anglia (UK) to study how institutional strengthening could help reduce destructive dynamite fishing used on the coast of East Africa.

During the year, Centre researchers collaborated on a series of interdisciplinary articles about governing coral reefs in a changing world. Nick Graham, Terry Hughes and David Bellwood published a high-profile study in *Frontiers in Ecology and the Environment* that examined how the scientists and managers could reverse phase shifts in coral reefs. Josh Cinner led a study in *PLoS One* that examined the social and ecological vulnerability of coastal communities in Kenya to the impacts of climate change. Louisa Evans

and collaborators published a study in *Human Ecology* on using scenarios to understand adaptation options on the Great Barrier Reef.

Program 5 recruited several stellar new Research Fellows in 2013, but also said goodbye to some of our Early Career Fellows who moved to faculty positions in Australia and overseas. We are most recently joined by Dr Jessica Blythe, who took up a joint position with the ARC Centre and WorldFish in 2013. Originally from Newfoundland, Canada, Jessica is a social scientist who uses qualitative and quantitative research methodologies to explore the vulnerability of coastal communities to the impacts of climate change. Christina Hicks handed in her PhD thesis in mid-2013 and immediately took up an Early Career Research Fellowship position co-funded by Stanford University and the ARC Centre. In her new position, Christina will examine how rigorous social science can help inform the application of an ecosystem services approach to managing coral reefs. Early in 2013, Natalie Ban took up a faculty position at the University of Victoria (Canada) while Louisa Evans moved to a faculty position at Exeter University in the UK in December 2013. Louisa and Natalie will continue to collaborate with Centre researchers on a range of interdisciplinary working groups scheduled for 2014.



## Community power 'can rescue failing fish stocks'

Using genetic 'fin-printing', an international team of scientists has gathered the first clear proof that small traditional fishing grounds that are effectively managed by local communities can help re-stock both themselves and surrounding marine areas. The finding has big implications for hundreds of millions of people around the world who depend on coral reefs for food and livelihood.

"This is a really important finding, because it shows that small community-run fisheries can preserve their fish stocks – and can boost fish stocks in a surrounding radius of 30 kilometres or more," says Dr Glenn Almany of the ARC Centre of Excellence for Coral Reef Studies.

"It's proof that traditional local fishery management pays off – and that is particularly critical in countries around the world where government fisheries schemes are lacking or poorly enforced. Some of this traditional marine management has operated for centuries. We're providing the hard scientific evidence that it works," says Dr Richard Hamilton from The Nature Conservancy.

Local fisheries in neighbouring countries such as Indonesia, Philippines, Malaysia, Papua New Guinea, Solomon Islands and East Timor feed hundreds of millions of people and are under growing stress from development, overfishing and climate change.

Working with local fishers on Manus Island, Papua New Guinea, the team took fin samples from a spawning aggregation of coral trout in a tiny marine reserve, then collected similar samples from juvenile fish up to 33 kilometres away to see how many were the offspring of the parent group, using DNA parentage analysis.

They found 17-25 per cent of all juveniles collected in the managed area were from this particular group of parent fish, as were 6-17 per cent of all juvenile groupers caught in four neighbouring fishery areas.

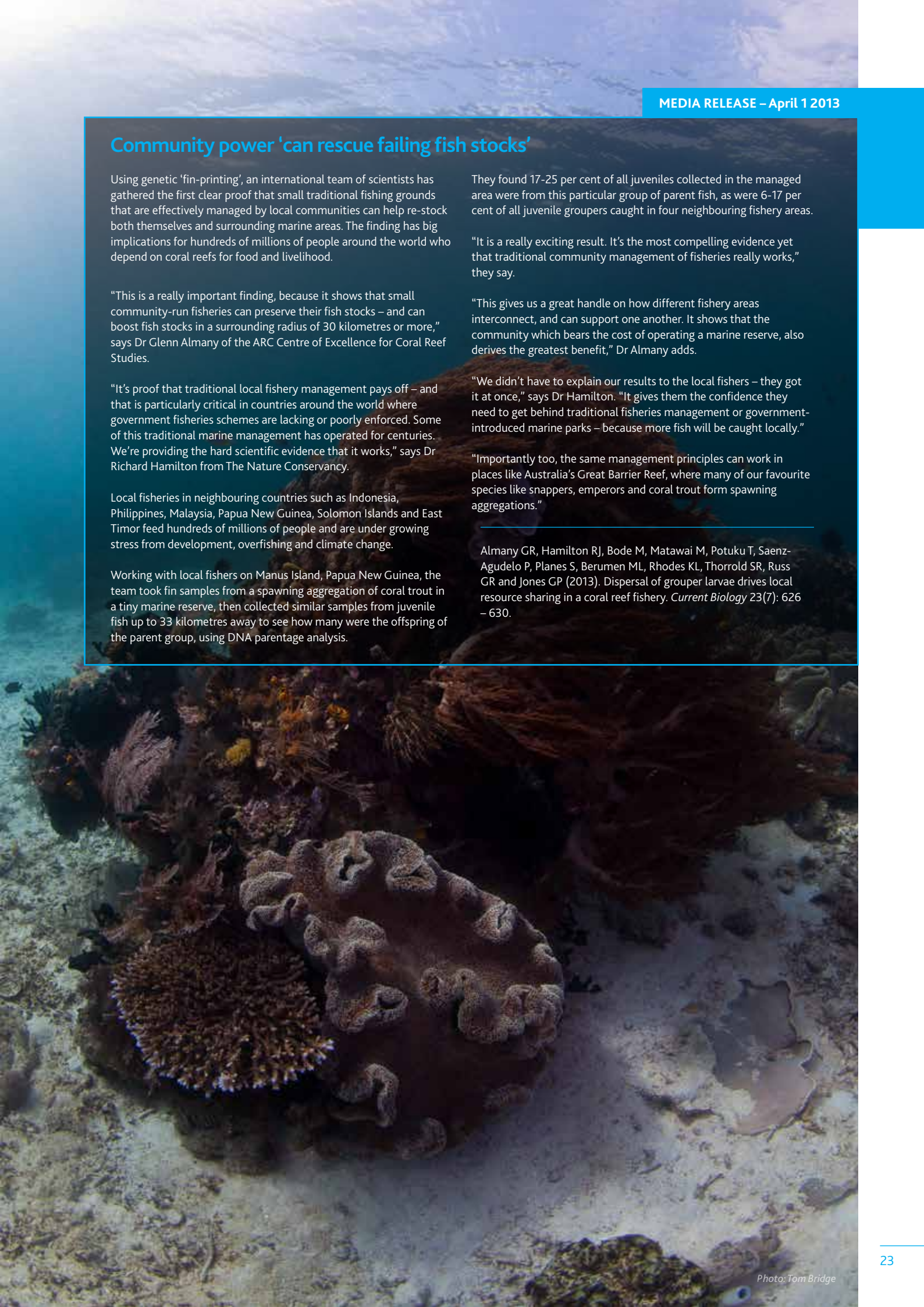
"It is a really exciting result. It's the most compelling evidence yet that traditional community management of fisheries really works," they say.

"This gives us a great handle on how different fishery areas interconnect, and can support one another. It shows that the community which bears the cost of operating a marine reserve, also derives the greatest benefit," Dr Almany adds.

"We didn't have to explain our results to the local fishers – they got it at once," says Dr Hamilton. "It gives them the confidence they need to get behind traditional fisheries management or government-introduced marine parks – because more fish will be caught locally."

"Importantly too, the same management principles can work in places like Australia's Great Barrier Reef, where many of our favourite species like snappers, emperors and coral trout form spawning aggregations."

Almany GR, Hamilton RJ, Bode M, Matawai M, Potuku T, Saenz-Agudelo P, Planes S, Berumen ML, Rhodes KL, Thorrold SR, Russ GR and Jones GP (2013). Dispersal of grouper larvae drives local resource sharing in a coral reef fishery. *Current Biology* 23(7): 626 – 630.



# Conservation planning for a sustainable future

## Researchers

**Bob Pressey** (Program Leader)  
**Glenn Almany** (Research Fellow)  
**Jorge Álvarez-Romero** (Research Fellow)  
**Amélie Augé** (Research Fellow)  
**Jana Brotánková** (Research Associate)  
**Ian Craigie** (Research Associate)  
**Mariana Fuentes** (Research Fellow)  
**Alana Grech** (Research Fellow)  
**Laurence McCook**  
**Rebecca Weeks** (Research Fellow)

Program 6 focuses on spatial solutions to diverse resource management problems, involving the design of conservation areas and application of management actions. Systematic conservation planning provides a rigorous approach to decision-making that increasingly synthesises advances in biology, geography, economics, the social sciences, and spatial modelling to minimise the loss of biodiversity and ecosystem services, while also maximizing the benefits to resource users. The goal of Program 6 is to conduct research, in collaboration with local communities, that develops practical solutions to management problems while promoting the persistence and sustainable use of natural resources. This approach places a high value on engagement with local communities, managers and policy makers, government agencies and non-government organisations.

In 2013, Program 6's activities are spread across and around Australia, through the Coral Triangle and Oceania, and further afield in Mexico, the USA, Brazil, Costa Rica and East Africa. Research topics are grouped under seven broad themes: Planning for a changing world, Integrated land-sea planning, The value of information, People and conservation, Decision support systems, Linking plans to effective actions, and Measuring conservation outcomes.

Across the Coral Triangle, Program 6 members continue, through their research, to develop and strengthen collaborations with government agencies and non-government organisations, with PhD projects underway in the Philippines, Indonesia, and Papua New Guinea. In the Philippines, Vera Horigue evaluated the management performance of marine protected area (MPA) networks. She is currently working with the Philippine MPA Support Network to improve the design and management of networks. Vera's research on the management performance of networks was presented in the Coral Triangle Initiative Philippines Forum in August 2013. Georgina Gurney has been collaborating with the Wildlife Conservation Society in North Sulawesi, Indonesia, to assess the social impact of a network of community-based MPAs. Mélanie Hamel's research in Papua New Guinea is developing a detailed typology of the Madang Lagoon's coral reefs and other associated marine habitats to be used in future conservation planning research. As a whole-of-region contribution, Rebecca Weeks was a member of the primary MPAs resource team involved in drafting the Coral Triangle Marine Protected Area System (CTMPAS) Framework and Action Plan. The CTMPAS Framework and Action Plan is the first joint policy product on MPAs for the Coral Triangle Initiative on Coral Reefs Fisheries and Food Security. It provides information for the six Coral Triangle countries to understand the opportunities, options, and actions needed to find new regional solutions to the challenges around managing coastal resources and fisheries.

Climate change is another research focus of Program 6. Mariana Fuentes and colleagues, in a paper published in 2013 in *Global Climate Change*, analysed the resilience of 58 marine turtle management

units and identified the 13 most vulnerable sites which are distributed around all three major ocean basins. Mariana is also assessing the impacts of climate change on marine turtles in Brazil and this year she also commenced a collaboration with the SILVIS lab at the University of Wisconsin focusing on marine turtle nesting sites in the USA.

In a comprehensive paper in *Frontiers in Ecology and the Environment*, headed by former Program 6 research fellow Natalie Ban, Centre researchers suggested that linking conservation planning to a social-ecological systems (SES) framework can lead to a more thorough understanding of human-environment interactions. Other papers of note from Program 6 in 2013 included a study led by Alana Grech and published in *Marine Pollution Bulletin* on guiding principles for ports and shipping in the Great Barrier Reef; a new modelling study examining the exposure of coastal ecosystems to flood plumes, led by Jorge Álvarez-Romero (*Journal of Environmental Management*), and a risk analysis of systems for environmental governance which focused on the Great Barrier Reef (*Environmental Research Letters*).

Program 6 researchers received several awards during 2013 and Research Fellow Alana Grech was recruited to a faculty position at Macquarie University. Mariana Fuentes was the recipient of a prestigious fellowship from the *Science without Borders* program to pursue her work on sea turtles in Brazil. Bob Pressey was a recipient of an Australia-India visiting fellowship from the Australian Academy of Science aimed at establishing collaborative research in India. As part of this new partnership, Kartik Shanker from the Indian Institute of Science visited the Centre in 2013 to develop new projects with Program 6 researchers.



## Science and tradition secure a fishier future for Fiji

In a world where fish catches are collapsing around the globe, Fijian fish are on the comeback trail thanks to a remarkable blend of centuries-old tradition and the latest science.

The communities of Kubulau – pronounced Kumbulau – have extended their network of marine protected areas (MPAs) to cover almost half their traditional fisheries area using a mix of traditional and “western” management styles.

“The practice of establishing a tabu – which places temporary bans on fishing in certain areas – goes back hundreds of years in Fijian history,” says Dr Rebecca Weeks from the ARC Centre of Excellence for Coral Reef Studies at James Cook University. “But growing populations, modern fishing methods, increasing water pollution, climate change and deforestation have seen fish stocks dwindle.”

“By working together to create a network of tabu areas, and adding some large, permanently closed MPAs, the communities in Kubulau are making sure that their management efforts are better able to address the problem of sustainable fishing in the 21<sup>st</sup> century.”

In July 2011, Dr Weeks and her colleague, Dr Stacy Jupiter, facilitated a workshop for local fishers and community leaders, following which the communities of Kubulau added five new MPAs to their existing network. Three villages significantly increased the size of their MPAs, and 500 metre buffer zones were added to the three permanent reserves for the district.

“Considering that the target for protection of marine habitats under the Convention on Biological Diversity’s new strategic plan is only 10 per cent, the communities of Kubulau are setting a leading example

in helping Fiji meet its international commitments,” explains Dr Weeks.

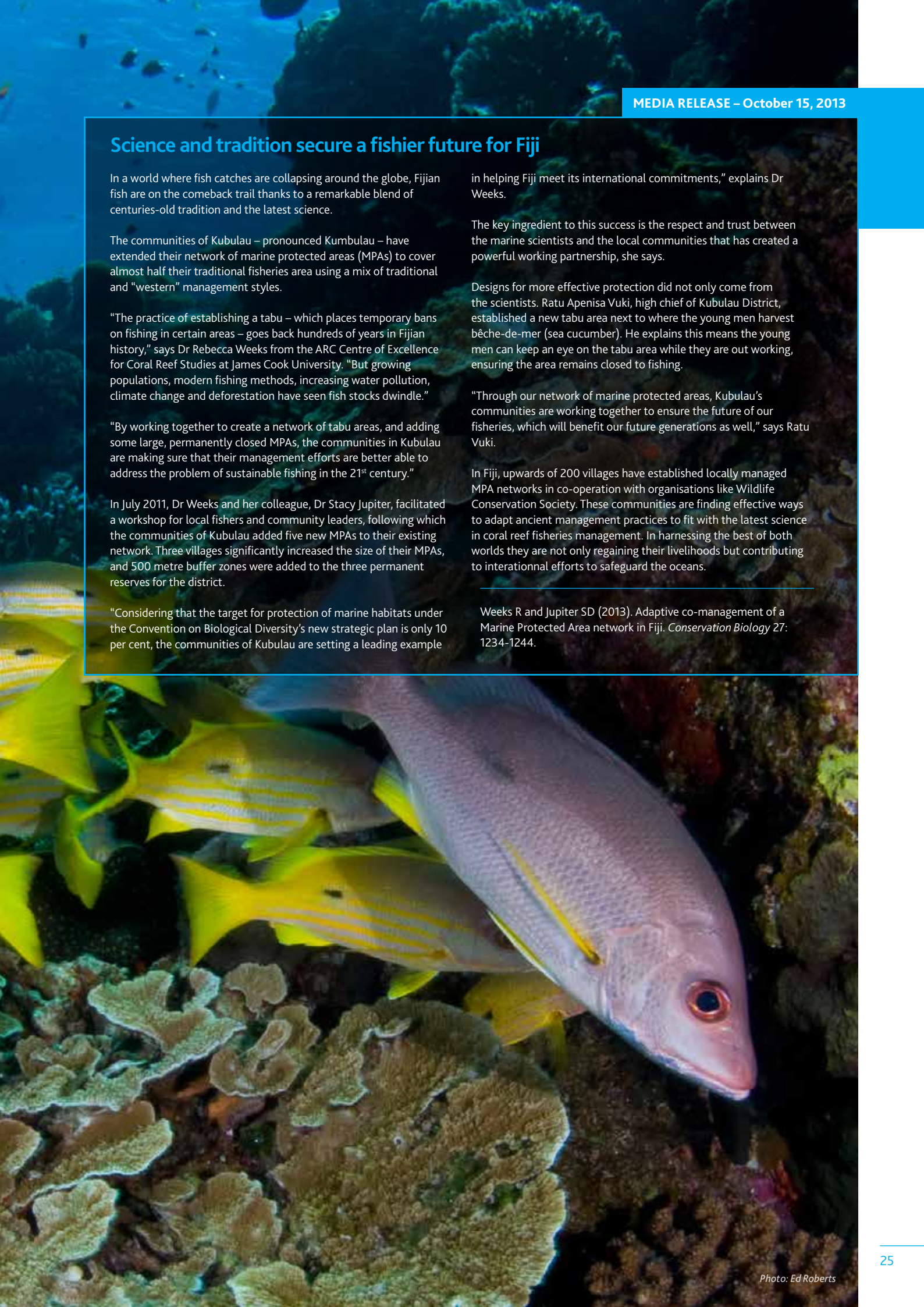
The key ingredient to this success is the respect and trust between the marine scientists and the local communities that has created a powerful working partnership, she says.

Designs for more effective protection did not only come from the scientists. Ratu Apenisa Vuki, high chief of Kubulau District, established a new tabu area next to where the young men harvest bêche-de-mer (sea cucumber). He explains this means the young men can keep an eye on the tabu area while they are out working, ensuring the area remains closed to fishing.

“Through our network of marine protected areas, Kubulau’s communities are working together to ensure the future of our fisheries, which will benefit our future generations as well,” says Ratu Vuki.

In Fiji, upwards of 200 villages have established locally managed MPA networks in co-operation with organisations like Wildlife Conservation Society. These communities are finding effective ways to adapt ancient management practices to fit with the latest science in coral reef fisheries management. In harnessing the best of both worlds they are not only regaining their livelihoods but contributing to international efforts to safeguard the oceans.

Weeks R and Jupiter SD (2013). Adaptive co-management of a Marine Protected Area network in Fiji. *Conservation Biology* 27: 1234-1244.





# Genomics and meta-genomics of coral reefs

## Researchers

**David Miller** (Program Leader)  
**Tracy Ainsworth** (Research Fellow)  
**Anthony Bertucci** (Research Fellow)  
**Simon Dunn** (Research Fellow)  
**Ove Hoegh-Guldberg** (Research Fellow)  
**Bruno Lapeyre** (Visiting Research Fellow)  
**Bill Leggat**  
**Benjamin Mason** (Research Fellow)  
**Aurélie Moya** (Research Fellow)  
**Susanne Sprungala** (Research Associate)  
**Madeleine van Oppen**  
**Bette Willis**  
**David Yellowlees**

Program 8 focuses on the genomics of the coral holobiome – the term given to the coral animal and its symbiotic dinoflagellate, bacterial and viral communities. The primary focus of this program is on characterising the genomes and transcriptomes of the various components of this complex association, in order to better understand how the holobiome functions under normal and stressed conditions. Program 8 works closely with the more biochemical and physiological approaches taken in Program 4: *Genetic, molecular and physiological processes*.

Innate immunity in corals is of special interest not only in the context of self-defense and disease but also in relation to the establishment and collapse (due to bleaching) of their obligate symbiosis with dinoflagellates of the genus *Symbiodinium*. In a study published this year in *Molecular Biology and Evolution*, David Miller and his collaborators in Japan surveyed the coral genome of *Acropora digitifera* to illustrate the extraordinary complexity of the innate immune repertoire of corals, which may in part reflect adaptive evolution to a symbiotic lifestyle in a uniquely complex and challenging environment. The significant and specific features of the immune repertoire shown in this study may indicate unique adaptations that

coral required for stress resistance, host-pathogen interactions, and possibly for symbiosis.

Other notable achievements by Centre researchers in 2013 include the first study to examine the response of the entire coral transcriptome to a defined immunogen. This work, carried out by PhD student Yvonne Weiss in collaboration with program members Tracy Ainsworth, Sylvain Forêt, Bill Leggat, David Miller and colleagues was published in *BMC Genomics*. As a step towards understanding coral immunity, the authors undertook the first whole transcriptome analysis of the acute responses of the coral *Acropora millepora* to bacteria. These experiments revealed similarities with the responses both of arthropods and mammals, as well as coral-specific effects. This study shows that a poorly characterised gene family implicated in vertebrate immunity also plays a role in the early response of the coral to immune challenge, suggestive of an ancient and conserved function. A phylogenomic survey of this gene family implies ancient origins, multiple independent losses and lineage-specific expansions during animal evolution.

Amongst the other 2013 publications from program members, a paper recently published in *Molecular Biology and Evolution* is of particular significance. This work, initiated by PhD student Lotte Huisman is the first comprehensive analysis of the proteins associated with the skeleton of *Acropora millepora*. The identification of the proteins will be particularly useful in future studies of the impact of stress on coral calcification, but what is most interesting – and completely unexpected – was the discovery that very few of the skeletal proteins are unique to corals, or are restricted to calcifying organisms.

Partner Investigator Madeleine van Oppen and collaborators co-authored a study presenting KEGG orthology-based annotation of the complete genome sequence of the scleractinian coral *Acropora digitifera*, which provides the first comprehensive view of the genome of a reef-building coral based on advanced bioinformatics. The annotated dataset is published in *ZoophyteBase*, an open access format with different options for searching the data. The study highlights the molecular basis of many of the key processes of coral physiology. Madeleine and postdoctoral fellows, Karen Weynberg and Elisha Wood-Charlson, also worked this year on the isolation of viral metagenomes from coral tissues. The metagenomes of six coral species (*Acropora millepora*, *A. tenuis*, *Pocillopora damicornis*, *Galaxea fascicularis*, *Fungia fungites* and *Goneastrea aspera*) are currently being analysed at the Australian Institute of Marine Science. Other novel viral research is being conducted on viromes isolated from experimentally heat-stressed corals, on a filamentous virus identified in monoclonal *Symbiodinium* cultures, and on the potential role of bacteriophages in the Black Band Disease affecting corals.

During the year, Program Leader David Miller and Sylvain Forêt were invited to participate in a workshop in Germany, funded by the Deutsche Forschungsgemeinschaft, aimed at achieving a better understanding of how changes in the environment affect the development of “lower” animals. David was also an invited participant in a workshop on the origins of multicellularity, organised by the US National Evolutionary Synthesis Center, at Duke University, and recipient of a short-term visiting fellowship from the Japan Society for the Promotion of Science to carry out collaborative research in Okinawa.

## How coral cures your ills

Next time you successfully fight off a nasty infection, give thanks to the Great Barrier Reef.

A dramatic discovery by an Australian team of scientists has revealed that the ability of humans to resist bacterial diseases may go as far back in our ancestry as corals.

Researchers at the ARC Centre of Excellence for Coral Reef Studies have found three genes in *Acropora* (staghorn) corals which show a very fast, strong immune response to the presence of bacteria – and the same genes also occur in mammals, including people.

"It's early days, but it certainly looks as if key aspects of our ability to resist bacteria are extremely ancient and may have been pioneered by the ancestor of corals – and then passed down to humans in our evolutionary lineage," explains team leader Professor David Miller.

"Corals are constantly attacked by bacteria in their natural environment, and so have perfected very efficient defences against them," he says. "These defences apparently work well enough to be preserved in mammals like us, and possibly in plants too. Certain animals in between us and coral, like roundworms and flies, seem to have lost these genes, but our line appears to have retained them."

The genes belong to a family known as the GIMAPs and have been associated with anti-bacterial immunity in mammals, including humans.

The team made its discovery by challenging living colonies of *Acropora* with certain chemicals commonly found in the coats of bacteria, and studying which genes reacted across virtually its entire genome of 20,000-plus genes.

"We were quite surprised at how rapidly and strongly these three genes in particular reacted to the presence of bacterial proteins," Prof. Miller says. "It was spectacular."

The main goal of the research is to better understand the mechanisms by which corals resist attack by bacteria and viruses – an urgent task in view of a massive upsurge in coral diseases around the world, which researchers attribute to the impact of human activity on the oceans and on coral reefs themselves.

"By better understanding the basis of coral immunity we may first be able to understand what is causing this pandemic of coral diseases and how human activity is connected to it."

"And secondly, this may lead us to better ways of managing our reefs that reduce the impact of disease, and give corals a better chance of survival during a period of major climatic and environmental change," he says.

Weiss Y, Forêt S, Hayward DC, Ainsworth T, King R, Ball EE and Miller DJ (2013). Acute transcriptional response of the coral *Acropora millepora* to immune challenge: expression of GiMAP/IAN genes links the innate immune responses of corals with those of mammals and plants. *BMC Genomics* 14: 400.



# Great Barrier Reef: World Heritage in Danger?

## Shrinking coral and failing government may land the reef on a “list of shame.”

By Brian Handwerk for National Geographic

**Australia's Great Barrier Reef is losing coral at an alarming rate—and may soon lose its prestigious status as one of the world's great natural treasures as well.**

The World Heritage Committee of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has warned that without the urgent implementation of sustainable management improvements, the reef could land on its list of World Heritage in Danger as early as 2014.

A government-funded Australian Institute of Marine Science report published last year in the journal *PNAS* echoed the shockingly bad news from earlier studies, concluding that the reef has lost half of its coral cover during the past 27 years—a period that roughly coincides with its listing as a World Heritage Site.

The reef, which stretches for some 1,250 miles (2,000 kilometers) off northeast Australia's Queensland coast, is the largest structure on Earth built by living organisms. It has been battered by storms and beset by an invasion of crown-of-thorns starfish that choke off the natural ecosystem. The reef faces global challenges like warming temperatures, as well as more localized problems including water-fouling runoff pollution, coastal port development, dredging, and increased shipping thanks to a booming local coal industry.

Concerned by the pace of reef deterioration, as well as government-approved port expansions and dredging operations that threaten to damage it, the World Heritage Centre and the International Union for the Conservation of Nature (IUCN) did a comprehensive report on the state of the reef's conservation last March. The group made a series of recommendations, and officially requested that Australia revamp plans to manage the reef.

### Reef Suffering “Death by a Thousand Cuts”

The Great Barrier Reef, actually a group of more than 2,800 separate entities along Australia's eastern coast, is home to a staggering diversity of marine life, from mollusks and fish to sea turtles and aquatic plants.

But Terry Hughes, who heads the Australian Research Council Centre of Excellence for Coral Reef Studies headquartered at James Cook University, describes it as currently “suffering death by a thousand cuts.”



*A diver measures carbon dioxide uptake in the Great Barrier Reef.*

Photograph by David Doubilet,  
National Geographic



"We have affected their survival, growth, and reproduction, which is the real reason why coral cover has been declining for many decades," he said. "Coastal reefs have been obliterated by runoff of sediment, dredging, and pollution. Once-thriving corals have been replaced by mud and seaweed."

Queensland farmers use seven times more nitrogen-based fertilizers than they did 50 years ago, Hughes said, and have far more land under cultivation. Coal mining has doubled each decade during the same time frame. "The expansion of mining has been accompanied by major rail and port development, near-shore dredging, and unprecedented growth in shipping," he explained.

Hughes says the crown-of-thorns starfish outbreaks that have decimated parts of the reef are merely a symptom of its problems, not the cause. Some scientists believe that dredging and nutrient runoff fuel phytoplankton blooms, which in turn feed starfish larvae so well that they explode in numbers. Others believe that systemic changes to the reef food chain mean that fewer young starfish are being eaten by predators.

"The well-documented decline in coral cover highlights UNESCO's concerns about the dwindling universal heritage values [a set of standards that qualifies a site for inclusion on the World Heritage List] of the Barrier Reef. The key question now is, what are we going to do about these losses?" Hughes said.

"To increase coral cover, we need to improve the conditions that help them reproduce, survive, and grow. The capacity for coral recovery is impaired on a reef that is muddy, polluted, or overfished. The ongoing decline of corals demonstrates that

the Great Barrier Reef is very poorly positioned to recover from future bouts of coral bleaching or to cope with accelerating coast development and new coal mines."

Hughes hopes to see both Queensland and Commonwealth governments control pollution, curb dredging, and ban new coal ports while reducing the use of carbon-emitting coal.

"We need a bold plan for transforming how the Great Barrier Reef catchment is used," he added. "The Commonwealth's Great Barrier Reef Marine Park Authority has almost no capacity to influence two major drivers of change that are increasingly affecting the reef—activities on land and in Queensland coastal waters that degrade water quality within the GBR World Heritage Area, and global climate change."

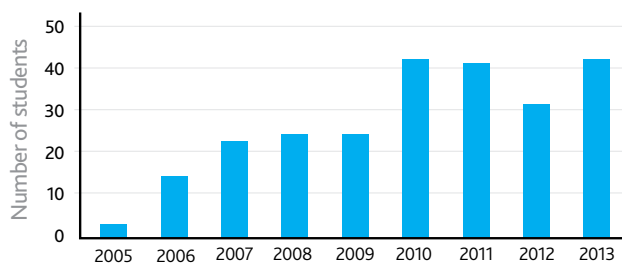
Australia's recent Energy White Paper, under then-Minister of Resources and Energy Martin Ferguson, would instead grow both coal and gas exports, and produce more than double the number of 2001 ship dockings by 2020.

WWF-Australia's Richard Leck says that environmentalists understand the concerns of those who favor economic development, but that time is running short to act on behalf of the reef. "WWF doesn't want to see industries shut down in Queensland, or farming and fishing. But we really do believe this year is a crucial period of time for the Great Barrier Reef. With the UNESCO meeting in June and a national election here in September, it's a rare opportunity to focus people's minds on the future of the reef. With the level of decline in coral cover, we've already seen that there isn't that big of a window to make commitments to turn this around."

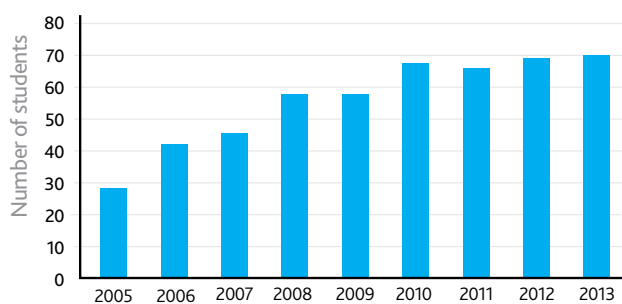
# Graduate Training

Since the ARC Centre's inception in 2005, our postgraduate enrolment has grown steadily from 66 to almost 200 students. All students are supervised by the Centre Chief Investigators and Research Fellows, and are based at the four nodes of the Centre. The postgraduate program in the ARC Centre continues to be recognised as the world's largest in coral reef research. From an initial focus on ecology and natural sciences our program now also has graduates in social sciences, conservation science and genomics. Centre funds support these students through their degree program covering the costs of their research and providing financial assistance to attend conferences and workshops. In all, the total investment in student activities is >25% of the Centre's annual budget. Over the eight years of its existence the number of students with supervisors at more than one institution has grown from 5 to 70, reflecting our commitment to multi-node integration and transdisciplinary training.

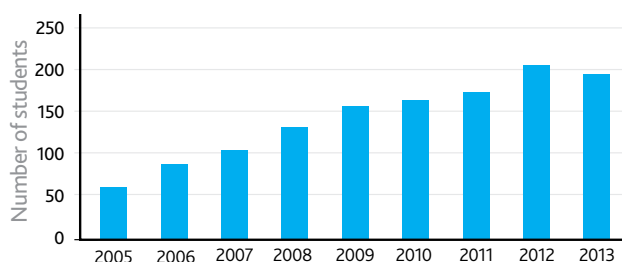
## Postgraduate completions



## Multi-institutional supervisions



## Postgraduate students enrolled



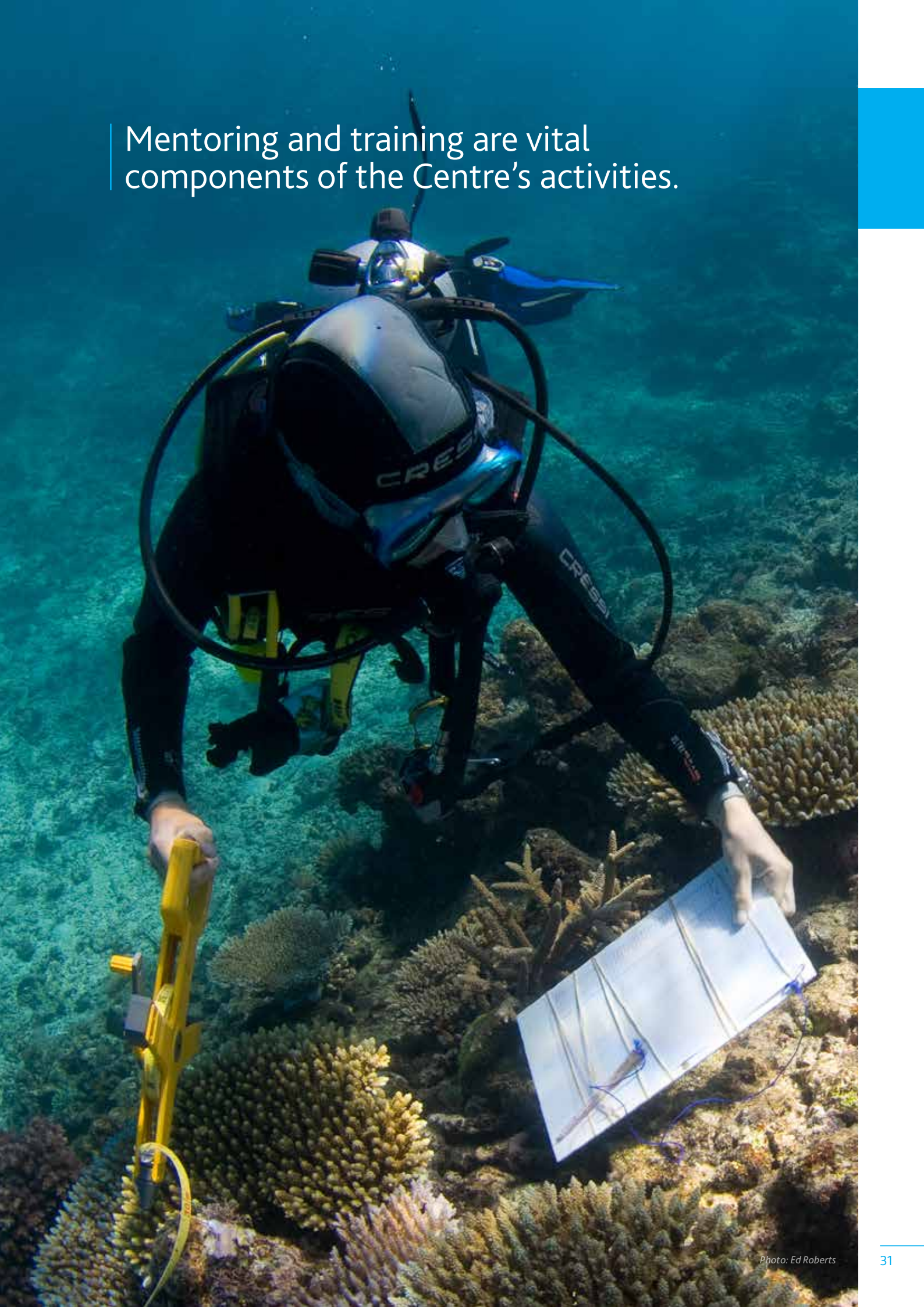
Mentoring and training is a vital component of the Centre's activities. Mentoring for graduate students includes a broad range of activities and multi-stranded training programs that go far beyond the standard interactions between a student and their supervisory committee. For example, in 2013, students attended graduate intensive training courses, and were heavily involved in weekly multi-nodal (video-conference) research seminars, and in quarterly review/planning meetings for each of the Centre's Programs. All students and their projects are highlighted individually on the ARC Centre's website at [www.coralcoe.org.au/people-students.html](http://www.coralcoe.org.au/people-students.html), emphasising their important contribution to the activities of the Centre. During the year, the Centre funded exchanges and travel between the nodes of the Centre and with collaborating partners, and we convened a National Mentoring Workshop for PhD and Masters students in conjunction with the annual symposium of the *Australian Coral Reef Society* in Sydney. This year the workshops, led by very senior as well as early-career researchers, focussed on enhancing students' research and publication skills, building networks, and fostering future collaborations.

The Centre's Student and Postdoctoral Committees managed annual funding allocations of \$50k, for mentoring activities, prizes and conference travel. The Centre's Student Committee organised two student retreats in 2013. The first, in February, was held on Magnetic Island in Townsville and provided an opportunity to invite outstanding speakers, including Nobel Prize Laureate Brian Schmidt, Centre of Excellence Research Fellow Tracy Ainsworth, media expert Liz Tynan, and marine ecology consultant Daniela Ceccarelli. The central theme was science communication, with special emphasis on presenting science to the public. Visiting speakers shared their experiences and ran workshops on effective use of language and working with media. In a special forum on "Science PR" Professor Schmidt and Dr Tynan discussed science in the media and the role of scientists in politics. Other aspects of the retreat promoted balance between a successful science career and a happy, healthy life. For instance Professor Schmidt, a renowned winemaker as well as astrophysicist, presented a winemaking seminar and Dr Ceccarelli, an Ashtanga teacher, led a yoga class for the students. Students from all four nodes of the ARC Centre attended.

The October student retreat was held in coordination with the Centre's Annual Symposium, which this year returned to Townsville. Students spent a day at the Australian Institute for Marine Science (AIMS) and heard speakers from AIMS and the Great Barrier Reef Marine Park Authority. The retreat included tours of the collections and facilities, including the new Sea Simulator (SeaSim) national facility.



Mentoring and training are vital components of the Centre's activities.



In 2013, the Centre continued to host networking events for women in science. Other activities included the student mentoring program, as well as designing a new ARC Centre student information booklet. As part of the annual Celebrating Research @JCU in September, the Centre held a training session for graduate students who were participating in the Centre's internal elimination round of the 3M competition (My Research in 3 Minutes). In the run up to the event, Liz Tynan, from the Graduate Research School, provided advice to the students on how to communicate their research to a lay audience. Melissa Bos was voted the representative for the Centre in the JCU competition.

Awards to Centre students in 2013 include:

- Robert Mason was awarded a Fulbright Queensland Scholar to conduct research at the University of Hawaii at Manoa.
- Kirsty Nash was the winner of the 2013 Bommies Award sponsored by the Great Barrier Reef Foundation. Her 3 minute video entitled 'BIG FISH, small fish: How will Climate Change affect Reef Fish?' attracted a prize of \$8,000. Simon Brandl was the first recipient of a Highly Commended entry, 'Who's mowing the lawn? Coral reef maintenance in a changing world'.
- Peter Waldie (along with supervisor Glenn Almany) was awarded \$25,000 from Sea World Research & Rescue Foundation to support his PhD project on grouper aggregations in Kavieng, PNG. Ashton Gainsford also received support from the Sea World Research & Rescue Foundation. Adrian Arias, Caroline Castro and Blanche D'Anastasi each received Paddy Palin Foundation grants towards the cost of their fieldwork. Jeroen van de Water (ACRS), Martina de Freitas Prazeres (Cushman Foundation for Foraminiferal Research) and Robert Mason (Joyce M. Vickery Scientific Research Fund Award) also received competitive grants to support their research.
- Travel grants were awarded to Erika Woolsey, Brett Taylor, Jeroen van de Water, Sandra Binning, Dominique Roche, Chiara Pisapia and Simon Brandl (Australian Coral Reef Society), Sandra Binning, Dominique Roche and Gabrielle Miller (Society for Experimental Biology), Sandra Binning (The Company of Biologists), Kirsty Nash (Fish Society of the British

Isles), Gabrielle Miller (Australian Society for Fish Biology) and Brigitte Sommer (Australian Biological Resources Study and British Ecological Society).

- Christopher Goatley received the Vicki Harriott Award at the annual meeting of the Australian Coral Reef Society (ACRS). Simon Brandl, Brett Taylor and Dominique Roche received bench fee awards and Sandra Binning won an award for her poster presentation.
- Melissa Bos was the lead author of two articles published in *The Conversation*.
- Blanche D'Anastasi and Simon Brandl received Young Science Ambassador Awards from the Australian Academy of Technological Sciences and Engineering. Martina de Freitas Prazeres received the Ian Potter Doctoral Fellowship at Lizard Island.
- Liza Roger was a finalist in the Western Australian Fresh Science 2013 competition.
- The Virginia Chadwick Awards are awarded each year to five ARC Centre of Excellence graduate students for the most outstanding publications in peer-reviewed international journals. The student must be the lead author on the paper which must be published in a high ranking journal. Each attracts a prize of \$1,000. The 2013 competition had a large number of competitive entries and the winners were Sandra Binning, Fraser Januchowski-Hartley, Jean-Baptiste Raina, Brigitte Sommer and Gergely Torda.

The ARC Centre would like to acknowledge the valuable and critical contribution of the Student Committee during 2013. Along with Olga Bazaka, our graduate student coordinator, they make an invaluable contribution to the success of the ARC Centre of Excellence for Coral Reef Studies. The year commenced with Erika Woolsey as Chair but she handed over to Tiffany Sih and April Boaden later in the year. Members of the committee during the year were Sandra Binning and Dominique Roche from ANU, Georgina Gurney, Tessa Hempson and Amelia Wenger from JCU, Renata Ferrari Legorreta, Chico Birrell and Alyssa Marshall from UQ and Lucy Georgiou and Jessie Short from UWA.

**The ARC Centre's international network of graduate students. In 2013, 152 students came to Australia from 40 countries.**





Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
<b>Novi Susetyo Adi</b>	UQ	Indonesia	Assessment of coral reef productivity using remote sensing data. (PhD)	A/Prof S Dove, Prof O Hoegh-Guldberg
<b>Catalina Aguilar Hurtado</b>	JCU, ANU	Colombia	The immune response of the coral <i>Acropora millepora</i> under CO <sub>2</sub> stress. (PhD)	Prof D Miller, Dr S Sprungala
<b>Bridie Allan</b>	JCU	New Zealand	The interactive effects of increased water temperatures and elevated dissolved CO <sub>2</sub> on the clutch quantity of two common reef fish: how does this impact on predator-prey interactions? (PhD)	Prof M McCormick, Prof P Munday
<b>Mariana Alvarez Noriega</b>	JCU, Macquarie	Mexico	Competition, growth form, and species coexistence in reef corals. (PhD)	Prof S Connolly, Dr A Baird
<b>Kristen Anderson</b>	JCU	Canada	Effects of changing environmental conditions on the growth rates of branching corals: consequences for habitat. (PhD)	Prof M Pratchett, Dr A Baird
<b>Natalia Andrade Rodriguez</b>	JCU	Ecuador	Immunity and secondary metabolite production in the soft coral <i>Lobophytum pauciflorum</i> and the effects of stress (temperature; CO <sub>2</sub> ) on these processes. (PhD)	Prof D Miller, Dr A Moya
<b>Adrian Arias</b>	JCU	Costa Rica	Marine spatial planning for developing countries: overcoming obstacles. (PhD)	Prof R Pressey, Dr J Cinner
<b>Jennifer Atherton</b>	JCU	United Kingdom	Effect of the threat of predation risk on offspring through maternal effects. (PhD)	Prof M McCormick, Dr A Frisch, Prof G Jones
<b>Maria Aurellado</b>	UQ	Philippines	Effect of predation risk on behaviour and microhabitat use of parrotfish. (PhD)	Prof P Mumby, Dr A Harborne
<b>Caroline Baille</b>	UQ, Agrocampus Ovest	France	A dynamic model of parrotfish (family: Scaridae) populations for the management of herbivory on Caribbean coral reefs. (MSc)	Prof P Mumby
<b>Stephen Ban</b>	JCU	Canada	Multiple stressor effects on coral reefs. (PhD)	Prof R Pressey, Dr N Graham, Prof S Connolly
<b>Giulio Barone</b>	JCU	Italy	Effects of reef isolation on colonization and community structure of reef fishes. (PhD)	Prof G Jones
<b>Lissa Barr</b>	UQ, JCU	Australia	Measuring the effectiveness of marine protected areas. (PhD awarded)	Prof R Pressey
<b>Anne Bauer</b>	JCU	USA	Effects of coral species and morphology on habitat use by coral reef fishes. (MSc)	Prof G Jones
<b>Andrew Bauman</b>	JCU, Nova South-Eastern	USA	The ecology and dynamics of coral reef communities in marginal reef environments. (PhD awarded)	Prof M Pratchett, Dr A Baird
<b>Roger Beeden</b>	JCU	New Zealand	How healthy is the Great Barrier Reef in a warming world? (PhD)	Prof B Willis
<b>Dorothea Bender</b>	UQ, Griffith	Australia	Effects of climate change and ocean acidification on coral reef turf algae. (PhD awarded)	A/Prof S Dove
<b>Sandra Binning</b>	ANU	Canada	Phenotypic plasticity in coral reef fish ecomorphology. (PhD)	Prof D Yellowlees
<b>Chico Birrell</b>	UQ, Griffith	Australia	Understanding the spatial and temporal variation in macroalgal growth and assemblage development on coral reefs. (PhD)	Prof P Mumby
<b>Shane Blowes</b>	JCU	Australia	Territoriality, competition, and coexistence of butterflyfishes. (PhD)	Prof S Connolly, Prof M Pratchett
<b>April Boaden</b>	JCU	Australia	Predator/prey interactions and the influence of predators on the abundance demography and growth of prey fishes on the GBR. (PhD)	Prof M Kingsford, Dr D Williamson
<b>Teresa Bobeszko</b>	JCU	Australia	The role of carbonic anhydrase in the coral-dinoflagellate symbiosis. (PhD)	Dr W Leggat, Prof D Yellowlees
<b>Lynda Boldt</b>	JCU	Australia	<i>Symbiodinium</i> photosynthetic genes and the effect of varying environmental conditions on photosynthetic processes. (PhD)	Dr W Leggat, Prof D Yellowlees
<b>Melissa Bos</b>	JCU	USA	Marine conservation finance. (PhD)	Prof R Pressey
<b>Lisa Bostrom Einarsson</b>	JCU	Sweden	Competitive interactions, habitat degradation and the structure of coral reef fish assemblages. (PhD)	Prof G Jones, Prof P Munday, Dr M Bonin
<b>Alyssa Bowden</b>	JCU	USA	Gill remodelling in fishes under climate change scenarios. (MSc awarded)	Dr J Rummer
<b>Dominique Bradbury</b>	JCU	USA	Bleaching susceptibility of corals: a hierarchy of causes and consequences. (PhD)	Prof M Pratchett, Dr A Baird, Prof T Hughes
<b>Simon Brandl</b>	JCU	Germany	Pair formation in herbivorous reef fishes: environmental and ecological implications. (PhD)	Prof D Bellwood

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Tom Brewer	JCU	Australia	Social and economic determinants of the exploitation and management of coral reef resources in Solomon Islands. (PhD awarded)	Dr J Cinner, Prof T Hughes, Prof R Pressey
Rohan Brooker	JCU	New Zealand	Habitat specialisation and its consequences for a corallivorous filefish. (PhD)	Prof G Jones, Prof P Munday
Sarah Buckley	UQ	Ireland	A reconstruction of historical baselines of Queensland fisheries since the Anthropocene. (PhD)	Prof J Pandolfi
Patrick Buerger	JCU, AIMS	Germany	Viruses in coral diseases: bacteriophages and phage therapy. (PhD)	Dr M van Oppen, Prof B Willis
Ian Butler	UQ	Australia	Ecological and geomorphological changes in the coral reefs of Hervey Bay from the Holocene to the present. (PhD)	Prof J Pandolfi
Ciemon Caballes	JCU	Philippines	Environmental constraints on reproduction and development of crown-of-thorns starfish. (PhD)	Prof M Pratchett, Dr J Rivera
Alexandra Carter	JCU	Australia	The effects of no-take zoning, region and year on reproductive output of the common coral trout, <i>Plectropomus leopardus</i> . (PhD)	Prof M McCormick, Prof G Russ
Jordan Casey	JCU	USA	The role of territorial grazer behaviour and community structure in coral reef trophic dynamics. (PhD)	Prof S Connolly, Dr T Ainsworth
Carolina Castro Sanguino	UQ	Colombia	Ecological drivers of <i>Halimeda</i> abundance and their implications for the carbonate production of coral reefs. (PhD)	Prof P Mumby
Napo Cayabyab	UWA, UQ	Philippines	Physiological, nutrient allocation, growth and survival responses of seagrasses to varying levels of pCO <sub>2</sub> along a latitudinal gradient in Western Australia. (PhD)	Dr J Falter
Paulina Cetina-Heredia	JCU, AIMS	Mexico	Modelling physical and biological processes driving larval transport and supply in reef systems. (PhD awarded)	Prof S Connolly
Adriana Chacón	JCU	Costa Rica	The contribution of the environment to wellbeing. (MSc)	Prof R Pressey
Neil Chan	JCU, UQ	Malaysia	Modeling the effects of pH, temperature and flow on calcification of reef corals. (PhD)	Prof S Connolly
Tory Chase	JCU	USA	Local environmental conditions determine whether coral-fish symbioses enhance coral growth. (MAppSc awarded)	Prof M Pratchett
Jessica Cheok	JCU	Singapore	Developing a theoretical matrix framework to evaluate current status and progress of co-management in Australia's marine protected areas. (MSc)	Prof R Pressey, Dr R Weeks
Kah Leng (Ling) Cherh	JCU	Singapore	Differential recovery of Cephalopholid groupers in Philippines' no-take marine reserves (MSc awarded)	Prof G Russ
Karen Chong-Seng	JCU	Seychelles	The mechanistics of regeneration in coral reef ecosystems. (PhD)	Dr N Graham, Prof D Bellwood, Prof M Pratchett
Pedro Cipresso Pereira	JCU	Brazil	Competition habitat selection and imprinting of coral-dwelling fishes. (PhD)	Prof P Munday, Prof G Jones
Michael Civiello	JCU, AIMS	USA	Towards a mechanistic understanding of black band disease. (MSc)	Prof B Willis
Christophe Cleguer	JCU	France	Distribution, relative abundance and habitat use of the dugong: a basis for marine conservation and management planning in New Caledonia. (PhD)	Dr A Grech, Dr M Fuentes
Philippa Cohen	JCU	Australia	The contribution of locally-managed marine areas to food security of Solomon Islands. (PhD awarded)	Prof T Hughes, Dr L Evans
Geoffrey Collins	JCU	Australia	Hypoxia tolerance in barramundi fish. (PhD)	Dr J Rummer
Amy Coppock	JCU	United Kingdom	Olfactory discrimination in juvenile coral reef fishes. (MSc)	Prof G Jones
Fanny Couture	JCU	France	Partitioning the effects of newly-implemented marine protected areas, benthic structure, depth, and recreational activities on the fish assemblages of Koh Tao, Thailand. (MAppSc awarded)	Prof G Russ, Dr D Williamson
Melissa Cowlshaw	JCU	Australia	Determinants of home range and territorial behaviour in coral fishes: roles of body size, habitat structure and population density. (PhD)	Prof G Jones, Prof M McCormick
Alicia Crawley	UTS, UQ	Australia	The synergistic effect of rising ocean temperature and acidification on coral reef ecosystems. (PhD)	A/Prof S Dove
Michael Cuttler	UWA	USA	Production, transport and fate of carbonate sediment in a fringing reef-system. (PhD)	Prof M McCulloch, Dr J Falter
Kathryn Danaher	JCU	Australia	Oceanography and the condition of plankton. (PhD awarded)	Prof M Kingsford



Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
<b>Blanche D'Anastasi</b>	JCU, UWA	Australia	Population genetics and genomic dietary analyses of Australian sea snakes. (PhD)	Dr V Lukoschek
<b>Sana Dandan</b>	UWA	Denmark	Resilience of coral reef communities and coral metabolism in extreme environmental conditions. (PhD)	Prof M McCulloch, Dr J Falter
<b>Benjamin Davis</b>	JCU	United Kingdom	Temporal nekton dynamics in tidal floodplain wetlands. (PhD)	Prof G Russ
<b>Jon Day</b>	JCU, CSIRO	Australia	Planning and managing the Great Barrier Reef – lessons learned for the future planning of the Reef and implications for marine protected areas elsewhere. (PhD)	Prof R Pressey
<b>Martina De Prezeres</b>	UQ, AIMS	Brazil	Foraminifera as tools for analysis of interactions between water quality and climate change effects on the Great Barrier Reef: historical reconstruction and biology at community, individual and cellular scales. (PhD)	Prof J Pandolfi
<b>Anderson de Sevilha</b>	JCU	Brazil	Systematic conservation planning for the Parana River Basin, Brazil. (PhD)	Prof R Pressey
<b>Juan Pablo D'Olivio Cordero</b>	ANU	Mexico	Cross-shelf variation of coral calcification in the central Great Barrier Reef and its relationship to ocean acidification, temperature and terrestrial run-off. (PhD awarded)	Prof M McCulloch
<b>Christopher Doropoulos</b>	UQ, Griffith	Australia	Climate change effects on the recruitment and succession of algae and corals from the Great Barrier Reef. (PhD awarded)	Prof P Mumby
<b>Britt Edelman</b>	JCU	USA	Trophodynamics of garfish (hemiramphidae) in the tropics. (MSc)	Prof G Russ
<b>Udo Engelhardt</b>	UQ	Australia	Community-level ecological responses of coral reef biota to mass coral bleaching events. (PhD awarded)	Prof O Hoegh-Guldberg
<b>Norbert Englebert</b>	UQ	Netherlands	Phenotypic and physiological responses of a widespread coral species to changing environmental conditions: functional variability in natural populations of <i>Stylophora pistillata</i> . (PhD)	Prof O Hoegh-Guldberg, A/Prof S Dove, Dr P Bongaerts
<b>Kar-Hei (James) Fang</b>	UQ, UWA, AIMS	China	Effects of climate change and eutrophication on the Indo-Pacific excavating sponge <i>Cliona orientalis</i> Thiele. (PhD awarded)	A/Prof S Dove, Prof O Hoegh-Guldberg
<b>Renata Ferrari Legorreta</b>	UQ	Mexico	Management implications of grazing spatial distribution, ecosystem structural complexity and macroalgal competition for coral reef dynamics. (PhD awarded)	Prof P Mumby, Dr A Harborne
<b>Rochelle Ferris</b>	JCU	Australia	Identification and assessment of available hawksbill turtle habitat in northern NSW and a review of existing tag return data. (MAppSc)	Dr M Fuentes
<b>Franz Martin Fingerlos</b>	JCU	Austria	Interannual variations in species composition in Cleveland Bay. (MSc)	Prof G Russ
<b>Eric Fisher</b>	JCU, AIMS	Australia	Spawning aggregation sites on tropical reefs. (MSc)	Prof M McCormick
<b>Taryn Foster</b>	UWA	Australia	Potential impacts of higher ocean acidity and warmer water temperatures on Abrolhos Island coral reefs. (PhD)	Prof M McCulloch, Dr J Falter
<b>Ashton Gainsford</b>	JCU	Australia	A multi-disciplinary evaluation of the hybrid anemonefish <i>Amphiprion leucokranos</i> : behaviour shaping evolutionary outcomes of hybridisation. (PhD)	Prof G Jones
<b>Anjani Ganase</b>	UQ	Trinidad and Tobago	The use of a standardised method for a broad-scale survey of coral reefs worldwide, to identify the level of environmental impact on coral reef communities. (PhD)	Prof O Hoegh-Guldberg, A/Prof S Dove, Prof P Mumby
<b>Lucy Georgiou</b>	UWA	United Kingdom	Constraining coral sensitivity to climate and environmental change: an integrated and experimental approach. (PhD)	Prof M McCulloch, Dr J Falter
<b>Sarah Gierz</b>	JCU	Australia	Acclimation of <i>Symbiodinium</i> to thermal stress. (PhD)	Dr W Leggat, Prof D Yellowlees
<b>Chris Goatley</b>	JCU	United Kingdom	The ecological role of sediments on coral reefs. (PhD)	Prof D Bellwood
<b>Benjamin Gordon</b>	JCU, AIMS	Australia	The metabolome of <i>Symbiodinium</i> phylotypes and their coral hosts. (PhD)	Dr W Leggat
<b>Alexandra Grand</b>	JCU	French Polynesia	The immune cell response of crown of thorns starfish to oxbile injections. (MSc awarded)	Dr J Rivera, Prof M Pratchett
<b>Christian Gredzens</b>	JCU	USA	The spatial ecology of marine megafauna. (MAppSc awarded)	Dr M Fuentes
<b>Renee Gruber</b>	UWA	USA	The importance of allochthonous nutrient inputs to fringing reef productivity: sources, transport and biogeochemical transformations in a macrotidal tropical ecosystem. (PhD)	Dr J Falter
<b>Georgina Gurney</b>	JCU, U. Victoria	Australia	Improving the success of marine protected areas: integration of social considerations into conservation planning. (PhD)	Prof R Pressey, Dr J Cinner

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Melanie Hamel	JCU, IRD Noumea	France	Costs, effectiveness, and cost-effectiveness of habitat-driven conservation planning for Solomon Islands lagoons and reefs. (PhD)	Prof R Pressey
David Harris	UQ	Australia	Ecology of high latitude populations of <i>Pomacentrus coelestis</i> . (PhD awarded)	Prof O Hoegh-Guldberg
Hugo Harrison	JCU, U. Perpignan	France	Larval recruitment dynamics and the genetic structure of coral reef fish populations in marine protected networks. (PhD awarded)	Prof G Jones, Prof G Russ
Margaux Hein	JCU	Monaco	The potential of marine protected areas to ameliorate coral health in one of the world's diving hotspots: Koh Tao, Thailand. (MSc)	Prof B Willis
Tessa Hempson	JCU, AIMS	South Africa	Coral reef mesopredator trophodynamics in response to reef condition. (PhD)	Dr N Graham, Prof G Jones
Sybille Hess	JCU	Switzerland	Do suspended sediments damage the gills of clownfish larvae? (MSc)	Dr J Rummer, Dr A Wenger
Christina Chemtai Hicks	JCU	United Kingdom	The interplay between economic values and societal settings in coral reef governance. (PhD awarded)	Dr J Cinner, Prof T Hughes, Prof R Pressey
Jennifer Hodge	JCU	USA	Evolution and speciation processes in coral reef fishes. (PhD awarded)	Prof D Bellwood
Jessica Hopf	JCU	Australia	Metapopulation analysis of the role of connectivity in marine protected areas design. (PhD)	Prof S Connolly, Prof G Jones, Dr D Williamson
Vera Horigue	JCU, U. Philippines	Philippines	Scaling-up to form marine protected area networks: the role of institutional collaborations and coordination of initiatives in the Philippines. (PhD)	Prof R Pressey
Alec Hughes	JCU	Solomon Islands	Population biology and demography of the squaretail coral trout in Solomon Islands. (PhD awarded)	Prof G Russ
Adriana Humanes Schumann	JCU, AIMS	Venezuela	Interactive effects of water quality and climate change on the early life history stages of hard corals. (PhD)	Prof B Willis
Andres Jacome Rodriguez	JCU	Colombia	Macroalgae as a reservoir of pathogens on coral reefs. (MSc)	Dr A Hoey
Matt Jankowski	JCU	United Kingdom	Effects of depth and aspect on distribution, habitat use and specialisation in coral reef fish. (PhD)	Prof G Jones, Dr N Graham
Fraser Januchowski-Hartley	JCU	United Kingdom	Biological mechanisms of customary management of Melanesian coral reefs and their consequences for the coral reef fish community. (PhD awarded)	Dr N Graham, Dr J Cinner, Prof G Russ
Young Koo Jin	JCU, AIMS	South Korea	Nature or nurture? Testing the correlation between stress tolerance and genotypes in <i>Acropora millepora</i> on the Great Barrier Reef. (PhD)	Prof B Willis, Dr M van Oppen
Charlotte Johansson	JCU, AIMS	Sweden	Managing coral reefs: the importance of working with functional groups to conserve ecosystem resilience. (PhD)	Prof D Bellwood
Jung Ok Kang	ANU	South Korea	Anthropogenic increase of atmospheric carbon dioxide and ocean acidifying and global warming: implications for long-term changes in the classification rate of coral reefs. (PhD)	Prof M McCulloch
James Kerry	JCU, AIMS	United Kingdom	Structural complexity and the ecology of large reef fish. (PhD)	Prof D Bellwood
Kimberly Kiskas	JCU	USA	Assessing marine turtle bycatch risk in Australian commercial fisheries: patterns, gaps and solutions. (MSc)	Dr M Fuentes
Judith Kok	JCU	Netherlands	The influence of changing coral compositions on reef fish competition. (MAppSc)	Dr N Graham
Michael Kramer	JCU	New Zealand	The functional importance of benthic carnivory on coral reefs. (PhD)	Prof D Bellwood, Prof S Connolly
Virginia Krone	JCU	USA	Baseline surveys of coral health to enable assessments of dredging impacts on coral populations. (MSc)	Prof B Willis
Chaoyang Kuo	JCU	Taiwan	Functional groups and functional diversity of corals. (PhD)	Dr A Baird, Prof T Hughes, Prof M Pratchett
Antony Kuret	UWA	Australia	Spatial and temporal variability of sea surface temperature in the Leeuwin Current system from coral paleoclimatology. (MSc)	Prof M McCulloch
Joleah Lamb	JCU, AIMS	USA	Influence of reef-based industries on coral health and disease. (PhD)	Prof B Willis, Prof G Russ
Susannah Leahy	JCU	Australia	The role of recruitment habitat in the effectiveness of a Philippine marine reserve network. (PhD)	Prof G Russ, Prof G Jones
Anne Leitch	JCU, CSIRO	Australia	Social resilience to climate change: the adaptive capacity of local government. (PhD)	Prof T Hughes



Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Anais Kimberley Lema	JCU, AIMS	Mexico	Diversity, stability and uptake of diazotrophic bacterial communities associated with corals of the Great Barrier Reef (PhD)	Prof B Willis
Mauro Lepore	UQ	Argentina	Tracing temporal coral community change in the southern Great Barrier Reef, and evaluating the relative role of global, regional and local stressors. (PhD)	Prof J Pandolfi
Govinda Liénart	JCU, University of Saskatchewan	Austria	Temperature effects of chemically mediated predator-prey interactions. (PhD)	Prof M McCormick
Mei-Fang Lin	JCU, ANU	Taiwan	Transcriptomics of Corallimorpharian <i>Rhodactis indosinensis</i> (Cnidaria: Anthozoa) and its usefulness to understanding coral bleaching. (PhD)	Prof D Miller
Oona Lonnstedt	JCU	Sweden	Ominous odour - the role of olfactory cues in predator-prey interactions. (PhD)	Prof M Kingsford, Prof M McCormick, Prof P Munday
Judi Lowe	JCU, CDU	Australia	Dive tourism, alternate livelihoods and the management of marine protected areas in the Coral Triangle. (PhD)	Prof R Pressey, Dr C Hicks
Adrian Lutz	JCU, AIMS	Switzerland	Coenzyme Q and plastoquinone redox balance as a physiological determinant of oxidative stress in coral algal symbiosis. (PhD awarded)	Prof D Miller, Dr M van Oppen
Rafael Magris	JCU, U. Victoria	Brazil	Applying biodiversity conservation planning tools into the design of a long-term conservation strategy for Abrolhos Bank, Brazil. (PhD)	Prof R Pressey, Dr A Baird, Dr R Weeks
Martino Malerba	JCU, AIMS	Italy	Optimizing microalgal production for future demand: insights from formulation and experimental evaluation of autoregressive dynamic models. (PhD)	Prof S Connolly
Rachel Manassa	JCU, U. Saskatchewan	Australia	Importance of social systems and information transfer in coral reef fish. (PhD awarded)	Prof M McCormick, Prof P Munday
Hannah Markham	UQ	United Kingdom	Long-term ecological dynamics along a gradient of anthropogenic activity on the inshore Great Barrier Reef. (PhD)	Prof J Pandolfi
Alyssa Marshall	UQ	Australia	The ecological role of herbivorous surgeonfish (Acanthuridae) on coral reefs. (PhD)	Prof P Mumby, Dr A Harborne
Robert Mason	UQ	Australia	Linking coral physiology to remote sensing of reefs. (PhD)	A/Prof S Dove, Prof O Hoegh-Guldberg
Ian McLeod	JCU	New Zealand	Influence of temperature on the early life history of coral reef fishes. (PhD)	Prof G Jones, Prof M McCormick, Prof P Munday
Morana Mihaljević	UQ	Croatia	Indo-Pacific coral evolution: Neogene reefs from the South China Sea. (PhD)	Prof J Pandolfi
Gabrielle Miller	JCU	Australia	Influence of climate change on early development in coral reef fishes. (PhD awarded)	Prof P Munday, Prof M McCormick
Amin Mohamed Esmail	JCU	Egypt	Distribution and characterisation of chromerids and apicomplexans associated with coral reefs. (PhD)	Prof D Miller, Prof B Willis
Stefano Montanari	JCU, AIMS	Italy	Hybridisation in reef fishes: ecological promoters and evolutionary consequences. (PhD)	Prof M Pratchett
Christopher Mooney	JCU	Australia	Statoliths of Cubozoan jellyfishes: their utility to discriminate taxa and elucidate population ecology. (PhD)	Prof M Kingsford
Katie Motson	JCU	United Kingdom	Developmental thermal acclimation in reef fishes. (MSc)	Prof P Munday
Lauren Nadler	JCU	USA	Influence on climate change on shoaling behaviour in coral reef fish. (PhD)	Prof M McCormick, Prof P Munday
Kirsty Nash	JCU	United Kingdom	Assessment of scale dependent function in reef fish, and its application to the evaluation of coral reef resilience. (PhD)	Dr N Graham, Prof D Bellwood
Katia Nicolet	JCU	Switzerland	Aetiology of Indo-Pacific coral diseases: disease dynamics and the role of vectors in disease outbreaks. (PhD)	Prof B Willis, Prof M Pratchett
Jessica Nowicki	JCU	USA	The roles of nonapeptides in modulating animal personality and reproductive behaviour in coral reef fish. (PhD)	Prof M Pratchett, Dr S Walker
Daisie Ogawa	JCU	USA	Synergistic effects of ocean acidification and elevated temperature on carbon-concentrating mechanisms and energy transfer in the coral holobiont. (PhD awarded)	Dr W Leggat, Prof D Yellowlees
Maria Palacios Otero	JCU	Colombia	Ecological selection in a complex marketplace. (PhD)	Prof M McCormick, Prof G Jones
Allison Paley	JCU, AIMS	USA	Colour polymorphism and thermal resilience in the coral <i>Acropora millepora</i> on the Great Barrier Reef. (PhD)	Prof B Willis, Dr M van Oppen
Pedro Pereira	JCU	Brazil	Competition, habitat selection and imprinting of coral dwelling gobies. (PhD)	Prof P Munday, Prof G Jones

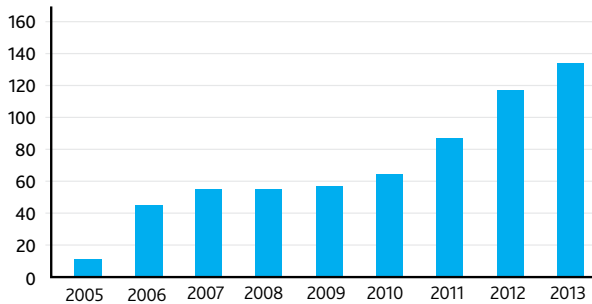
Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Srisakul Piroomvaragorn	JCU	Thailand	Spatial patterns in coral communities and recruitment in the Gulf of Thailand. (PhD)	Prof T Hughes, Dr A Baird, Prof S Connolly
Chiara Pisapia	JCU	Italy	Resilience of coral colonies to synergistic effects of bleaching and predation. (PhD)	Prof M Pratchett
F. Joseph Pollock	JCU, AIMS, College of Charleston	USA	Understanding the drivers of the coral disease white syndrome on the Great Barrier Reef. (PhD)	Prof B Willis
Davina Poulos	JCU	Australia	Prior residency effects and the dynamics of fish communities in a changing environment. (PhD)	Prof M McCormick, Prof G Jones
Kate Quigley	JCU, AIMS	USA	Genetic and environmental basis for <i>Symbiodinium</i> specificity in the coral-dinoflagellate association. (PhD)	Dr W Leggat, Prof B Willis
Paola G. Rachello-Dolmen	UQ, Australian Museum	Italy	Historical changes in marine molluscan assemblages from subtropical Moreton Bay Marine Park, Queensland (Australia). (PhD)	Prof J Pandolfi
Jean-Baptiste Raina	JCU, AIMS	France	Production and fate of dimethylsulfoniopropionate (DMSP) in reef-building corals and its integral role in coral health. (PhD <i>Cum Laude</i> awarded)	Prof B Willis
Ryan Ramasamy	JCU	Australia	The plasticity of escape responses: Does prior predator experience alter escape performance in a juvenile coral reef fish? (MSc)	Prof M McCormick
Tries Razak	UQ, AIMS	Indonesia	The effects of climate change on the growth rates of modern corals. (PhD)	Prof P Mumby
Maria Catalina Reyes-Nivia	UQ, Griffith	Colombia	The role of climate change on carbonate dissolution processes by microborers. (PhD awarded)	A/Prof S Dove, Prof O Hoegh-Guldberg
Justin Rizzari	JCU	USA	Reef sharks on the Great Barrier Reef: putting the bite on underwater visual census methods. (PhD)	Prof M McCormick, Prof G Jones, Dr A Frisch, Dr A Hoey
Jan Robinson	JCU	United Kingdom	Disentangling the causes of vulnerability to fishing in aggregating reef fishes. (PhD)	Dr N Graham, Dr J Cinner, Dr G Almany
Dominique Roche	ANU, JCU	Canada	Bio-physical interactions and predator-prey relationships in coral reef fishes. (PhD)	Prof D Yellowlees
Melissa Rocker	JCU, AIMS	USA	Effects of local and global stressors on the energy budgets and fitness of inshore reef-building corals. (PhD)	Prof B Willis
Alberto Rodriguez-Ramirez	UQ	Colombia	Inter-regional comparison of historical bleaching events in coral communities (Great Barrier Reef, South China Sea, and East Pacific): finding linkages to natural and anthropogenic factors. (PhD awarded)	Prof J Pandolfi
Liza Roger	UWA	United Kingdom	Boron isotopic systematics in pteropod shell and links to seawater pH. (PhD)	Prof M McCulloch
Giverny Rogers	JCU	Australia	Climate change in a stable thermal environment: effects on the performance and life history of a coral reef fish. (PhD)	Prof M McCormick, Prof P Munday, Dr J Rummer
David Rowen	JCU	Australia	Jellyfish as biomonitors of insecticides. (MSc)	Prof M Kingsford
Theresa Rueger	JCU	Germany	Reproduction and habitat use in reef fishes. (PhD)	Prof G Jones
Jimena Samper-Villarreal	UQ	Costa Rica	Carbon sequestration by seagrasses in Moreton Bay. (PhD)	Prof P Mumby
Jessie Short	UWA	Canada	The effects of ocean acidification on calcification rates of reef-building corals and crustose coralline algae in Western Australia. (PhD)	Prof M McCulloch, Dr J Falter
Tiffany Sih	JCU, AIMS	USA	Fisheries for deep sea snappers. (PhD)	Prof M Kingsford
Jennifer Smith	JCU	Canada	Influence of patch dynamics on coral reef fishes on the southern Great Barrier Reef. (PhD)	Prof G Jones, Prof M McCormick
Justin Smith	JCU	Australia	Movement and habitat assessment of <i>Natatory depressus</i> and <i>Lepidochelys olivacea</i> in the Gulf of Carpentaria, Australia. (PhD)	Dr M Fuentes
Brigitte Sommer	UQ, Southern Cross University	Australia	Ecological dynamics and conservation of subtropical coral communities of eastern Australia under climate change. (PhD)	Prof J Pandolfi
Blake Spady	JCU	USA	Elevated CO <sub>2</sub> alters behaviour in a tropical cephalopod ( <i>Idiosepius pygmaeus</i> ). (MAppSc awarded)	Prof P Munday
Leanne Sparrow	JCU	Australia	Trophic transfer of ciguatoxins in marine foodwebs. (PhD)	Prof G Russ
Jessica Stella	JCU, Australian Museum	USA	Climate impacts on coral-associated invertebrates. (PhD)	Prof G Jones, Prof M Pratchett, Prof P Munday
Richard Stevens	UQ, York	United Kingdom	Sharks: friend or foe? (MSc)	Dr R Thurstan



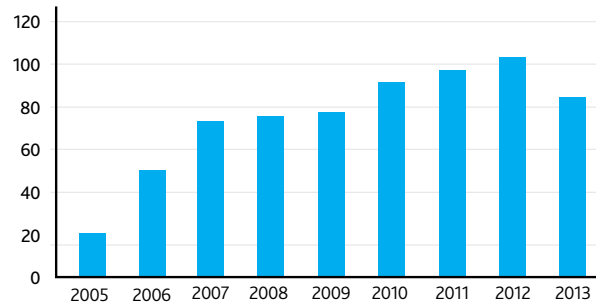
Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Robert Streit	JCU	Germany	The ecology of feeding behaviour of herbivorous coral reef fishes. (MSc)	Prof D Bellwood
Chun Hong Tan	JCU, AIMS	Malaysia	Environmental controls and evolutionary constraints on growth and reproduction in corals. (PhD)	Dr A Baird, Prof M Pratchett
Mele Tauati	JCU	Tonga	Effects of depth on habitat specialization in coral reef damselfishes. (MSc awarded)	Prof G Russ, Prof G Jones
Brett Taylor	JCU	USA	Parrotfish demography throughout Micronesia: effects of life histories on environmental and fishery-induced variability. (PhD)	Prof G Russ
Loic Thibaut	JCU, U. Pierre et Marie Curie	France	Resilience in coral reef and model ecosystems. (PhD)	Prof S Connolly, Prof T Hughes
Mélanie Trapon	JCU	France	Variation in population dynamics of reef-building corals along the Great Barrier Reef. (PhD awarded)	Prof M Pratchett, Dr A Baird, Dr A Hoey
Jeroen van de Water	JCU, AIMS	Netherlands	Molecular mechanisms of immunity in scleractinian corals and the influence of environmental factors on coral immunocompetence. (PhD)	Prof B Willis, Dr W Leggat, Dr M van Oppen
Annamieke Van Den Heuvel	UQ, JCU	Australia	The effects of exogenous nitrogen on the coral/dinoflagellate symbiosis: effect of nitrogen on staghorn coral. (PhD awarded)	A/Prof S Dove, Prof D Yellowlees, Dr W Leggat
Martin van der Meer	JCU, UWA	South Africa	Connectivity between populations of endemics or restricted species at risk of extinction in the marine protected areas in the coral reef outposts. (PhD awarded)	Prof G Jones
Heather Veilleux	JCU	Canada	Olfactory mechanisms at the genomic level by which dispersing coral reef fish larvae orient towards settlement sites. (PhD)	Prof P Munday, Dr W Leggat
Francisco Vidal Ramirez	UQ	Chile	Effect of possible future seawater environments on sea cucumbers and the sediments they process. (PhD)	A/Prof S Dove
Estefania Maldonado Villacis	JCU	Ecuador	Biological conservation planning for multiple species habitat restoration in Ecuador. (PhD)	Prof R Pressey
Peter Waldie	JCU, UQ	Australia	Toward the ecosystem-based co-management of exploited brown-marbled grouper spawning aggregations. (PhD)	Dr G Almany, Dr J Cinner
Patricia Warner	JCU, AIMS	USA	Evolutionary and ecological connectivity at hierarchical scales from sperm to species in the reef-building coral genus <i>Seriatopora</i> . (PhD awarded)	Prof B Willis, Dr M van Oppen
Donald Warren	JCU, UTS	USA	The impacts of CO <sub>2</sub> on competitive interactions and the potential for acclimation. (MSc)	Prof P Munday, Prof M McCormick
Heather Welch	JCU	USA	Regimes of chlorophyll-a in the Coral Sea and their implications for the adequacy of marine protected areas. (MSc)	Prof R Pressey
Megan Welch	JCU	USA	Transgeneration effects of CO <sub>2</sub> on fish behaviour. (PhD)	Prof P Munday, Prof M McCormick
Justin Welsh	JCU	Canada	Evaluating the spatial scale of ecosystem functions on coral reefs. (PhD)	Prof D Bellwood, Prof S Connolly
Amelia Wenger	JCU	USA	Suspended sediment and its effects on the behaviour and physiology of coral reef fishes. (PhD awarded)	Prof G Jones, Prof M McCormick
Wiebke Wessels	JCU, ANU	Germany	Genetic and molecular basis of coral embryonic development. (PhD)	Prof D Miller
James White	JCU, AIMS	USA	Personality and predation risk in fishes. (PhD)	Prof M McCormick, Dr M Meekan
Paul Whittock	JCU, Pendoley Environmental	United Kingdom	Understanding risk to marine turtles from expanding industrial development in northern Western Australia. (PhD)	Dr A Grech
Natalie Wildermann	JCU	Venezuela	Flatbacks at sea: understanding ecology in non-nesting populations. (PhD)	Dr M Fuentes
Jessica Williams	JCU	Australia	Searching for practical solutions to sea turtles poaching in Mozambique. (PhD)	Dr M Fuentes
Natalia Winkler	UQ	Chile	Can changes in symbiotic partnership facilitate shifts in thermal tolerance during the early onset of coral- <i>Symbiodinium</i> symbiosis? (MSc awarded)	Prof J Pandolfi, Dr E Sampayo
Erika Woolsey	JCU, U. Sydney	USA	Reefs on the edge: coral biogeography and larval ecology in a warming ocean. (PhD)	Dr A Baird, Dr S Keith
Matthew Young	JCU	Australia	Reef fishing: a social ecological perspective. (PhD)	Prof D Bellwood
Dan Zeh	JCU, AIMS	USA	The potential of using data-logging acoustic receivers to study the movements and residency patterns of dugongs in port environments: a comparison with satellite tracking. (PhD)	Dr A Grech

# National and International Linkages

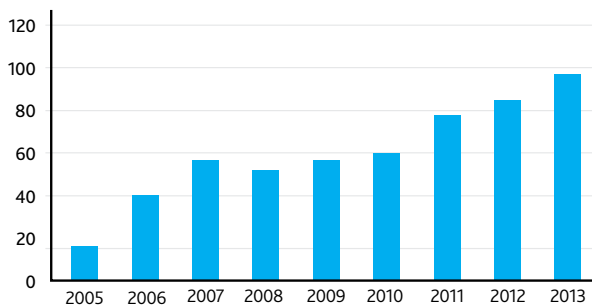
**Visits overseas**



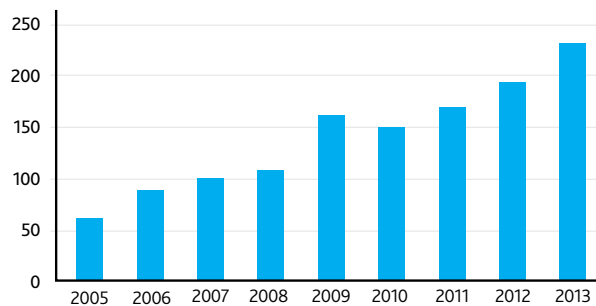
**International visitors**



**International engagements**



**Multi-institutional publications**



▲ **Metrics of the ARC Centre's international linkages 2005 to 2013.**

Since its establishment in 2005, the ARC Centre has become a global hub for coral reef science collaboration. The rapid growth in the engagement of Centre researchers with the international science community is exemplified by increases in the number of formal collaborations, multi-institutional publications, international working groups in which Centre researchers participate, visits to overseas institutions, and by the number of international scholars we host at the Centre. The research profile and reputation of the Centre has attracted close to 200 overseas postgraduate students to Australia since 2005, and in 2013 our graduate students come from 41 countries (p30).

In 2013, the ARC Centre personnel produced 229 cross-institutional publications involving researchers from 342 institutions in 49 countries. This year, Centre researchers were members of editorial boards for 41 international journals and many held other key roles on boards and committees around the World. For example, Peter Mumby is the President of the *Australian Coral Reef Society*, Morgan Pratchett is Secretary and Alistair Harborne and Nick Graham are elected Councillors of the *International Society for Reef Studies*, and Chris Fulton is the Vice-President of the *Australian Society for Fish Biology*. The Centre's researchers are major contributors to intergovernmental organisations such as the *International Union for the*

*Conservation of Nature (IUCN)*, the *World Bank*, *UNESCO*, the *Intergovernmental Panel on Climate Change (IPCC)*, *International Council for Science (ICSU)*, *United Nations Environment Programme*, *Global Ocean Biodiversity Initiative* and the *Society for Conservation Biology Ecological Economics and Sustainability Science*. In 2013, Ove Hoegh-Guldberg joined Terry Hughes, Malcolm McCulloch and Bob Pressey as an elected Fellow of the *Australian Academy of Science*. The ARC Centre participated in or convened 43 international working groups during 2013. We hosted 86 international visitors, and ARC Centre personnel made 134 visits to 43 countries. A few of the Centre's larger collaborations are outlined below.

## Wildlife Conservation Society

The Centre continues to have extensive international linkages with the New York-based conservation NGO, the Wildlife Conservation Society (WCS). Researchers in the Centre collaborate closely with several of the WCS marine programs. In Kenya and the wider western Indian Ocean Josh Cinner, Nick Graham and Christina Hicks have a number of ongoing projects with Tim McClanahan, including in 2013 an empirical assessment of social and ecological vulnerability of coral reef associated communities to climate change, and an evaluation



of the management options most preferred by fishers in the region. Andrew Baird, Andrew Hoey and Tom Bridge collaborate with Stuart Campbell, coordinator of the WCS Indonesia marine program, on issues such as coral depth refuges from temperature induced coral bleaching, and the impacts of crown-of-thorns starfish outbreaks on Indonesian coral reefs. Also in Indonesia, PhD student Georgina Gurney collaborates with WCS to assess the social impacts of marine protected areas in north Sulawesi. In Fiji, she has been examining how to better integrate socioeconomic considerations into spatial conservation planning; while Rebecca Weeks and Glenn Almany have been engaging with Stacy Jupiter of WCS (and a former Centre postdoctoral Fellow) to evaluate the utility of periodic marine closures in coral reef conservation, including through adaptive co-management arrangements.

### The Nature Conservancy

The Nature Conservancy (TNC), the world's largest non-profit conservation organisation, and the ARC Centre, work on a number of projects in several countries. TNC depends on sound scientific knowledge to accomplish its mission, and works closely with the Centre on many fronts. For example in 2013, Future Fellow Glenn Almany was seconded from the Centre's JCU node to TNC's Brisbane office, to work with researcher Alison Green, senior marine scientist for the TNC's Asia-Pacific Program. This collaboration centres on reef connectivity and the design of networks of coral reef marine protected areas in the Coral Triangle region. TNC and Program 6 Leader, Bob Pressey, also undertook ongoing collaborations in 2013, focusing on conservation planning and seascape approaches to coastal management in the Coral Triangle.

### WorldFish

WorldFish is an international, non-profit scientific agency working in Africa, Asia and the Pacific to '*reduce poverty and hunger through improving fisheries and aquaculture*'. WorldFish has a global staff of about 330, permanent offices in seven

countries and ongoing projects in 25 countries. In 2009, James Cook University and WorldFish established a Memorandum of Understanding to build new collaborative links. Recognising the collaboration, Neil Andrew, Principal Scientist and Pacific Regional Director for WorldFish joined the Centre's Advisory Board in 2011. In 2013, joint initiatives between the Centre and WorldFish were further strengthened. The Centre renewed an agreement with WorldFish to extend the secondment of researcher David Mills to the ARC Centre for a further three years. In addition, WorldFish post-doctoral researcher Pip Cohen was hosted in the Centre from 2013, while Jessica Blythe took up a three year co-funded postdoctoral position with the Centre in September. Substantial collaborative projects continue with WorldFish in the Solomon Islands, elsewhere in the Coral Triangle region, and in east Africa.

### King Abdullah University of Science and Technology

The King Abdullah University of Science and Technology (KAUST) opened in 2011 and is purpose-built as Saudi Arabia's premiere coral reef science institution. Its primary focus is developing a scientific basis for sustaining and conserving coral reef environments along the Red Sea coast of Saudi Arabia. Situated just north of Jeddah, it boasts world class facilities at its Red Sea Research Center. It has state of the art facilities for both field and laboratory based coral reef research. During its short life, multiple collaborations have been established with ARC Centre scientists on topics ranging from genomics to coral reef fish ecology and climate change. This has facilitated regular exchange visits of a dozen researchers in the past two years between the ARC Centre and KAUST, designed to build and extend collaborative research projects.

### Overseas visiting researchers

In 2013, 86 international visitors were hosted by one or more nodes of the ARC Centre, or participated in working group projects organised by the Centre.

## International visitors to the ARC Centre of Excellence for Coral Reef Studies in 2013

Visitor	Organisation	Country
Dr Kirsten Abernethy	University of Exeter	United Kingdom
Dr Rene Abesamis	Silliman University	Philippines
Dr Perry Alino	University of the Philippines	Philippines
Prof Chris Barrett	Cornell University	USA
Catherine Benson	University of Michigan	USA
Dr Michael Berumen	King Abdullah University of Science and Technology	Saudi Arabia
Dr Terry Bevan	Australian Government	Federated States of Micronesia
Dr Jessica Blythe	University of Victoria	Canada
Jessica Bouwmeester	King Abdullah University of Science and Technology	Saudi Arabia
Senator Barbara Boxer	United States Senate	USA
Prof Andrew Briereley	University of St Andrews	United Kingdom
Dr Andrew Brooks	University of California	USA
Dr Jana Brotankova	Czech University of Life Sciences	Czech Republic
Tory Chase	Elon University	USA
Prof Zichen Chen	Zhejiang University	China
Prof Ying Chen	Zhejiang University	China
Prof Kunsong Chen	Zhejiang University	China
Prof Douglas Chivers	University of Saskatchewan	Canada
Dr Pip Cohen	WorldFish	Malaysia
Prof Julia Cole	University of Arizona	USA
Cesar Cordeiro	Universidade Federal Fluminense	Brazil
Dr Katie Cramer	Smithsonian Institution	USA
Prof Catherine Curie	University of Montpellier	France
Dr Stephanie Dagata	University of Montpellier	France
Dr Danielle Dixson	Georgia Institute of Technology	USA
Dr Paolo Domenici	Istituto per l'Ambiente Marino Costiero	Italy
Dr Maria Dornelas	University of St Andrews	United Kingdom
Gal Eyal	Tel Aviv University	Israel
Dr Maud Ferrari	University of Saskatchewan	Canada
Prof Karl Flessa	University of Arizona	USA
Mara Freilich	Brown University	USA
Prof Gabi Gerlach	Oldenburg University	Germany
Dr Martin Glas	Max Planck Institute for Marine Microbiology	Germany
Adam Habery	University of Copenhagen	Denmark
Prof Lukman Hakim	Indonesian Institute of Science	Indonesia
Dr Mike Harfoot	United Nations Environment Programme-World Conservation Monitoring Centre	United Kingdom
Dr Christina Hicks	Stanford University	USA
Prof Sally Holbrook	University of California	USA
Prof Fuqiang Hu	Zhejiang University	China
Prof Simon Jennings	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom
Dr Ryan Kelly	Stanford University	USA
Carly Kenkel	University of Texas	USA
Dr Shaun Killen	University of Glasgow	United Kingdom



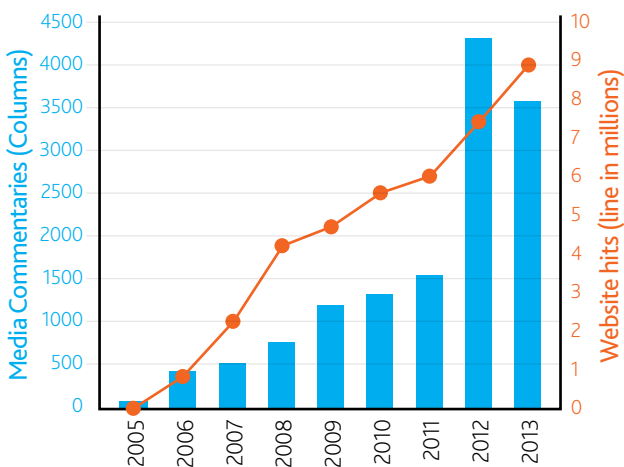
Visitor	Organisation	Country
Dr Stuart Kininmonth	Stockholm University	Sweden
Dr Jack Kittinger	Stanford University	USA
Prof Bruno Lapeyre	Centre de Recherche de Biochimie Macromoléculaire du CNRS	France
Dr Chanthly Lay	Royal University of Phnom Penh	Cambodia
Dr Sjannie Lefevre	University of Oslo	Norway
Dr Han Lindeboom	Wageningen University	The Netherlands
Dr Aaron Lobo	Deutsche Gesellschaft für Internationale Zusammenarbeit	India
Dr Yossi Loya	Tel Aviv University	Israel
Dr Aaron MacNeil	Dalhousie University	Canada
Prof Mikhail Matz	University of Texas	USA
Dr Tim McClanahan	Wildlife Conservation Society	Kenya
Joseph Mendelson	United States Senate	USA
Dr David Mills	WorldFish	Malaysia
Dr Antoni Moore	Otago University	New Zealand
Dr Camilo Mora	University of Hawaii	USA
Prof David Mouillot	University of Montpellier	France
Prof Henrik Mouritsen	Oldenburg University	Germany
Dr Naveem Namboothri	Indian Institute of Science	India
Dr Gerrit Nanninga	King Abdullah University of Science and Technology	Saudi Arabia
Prof Goran Nilsson	University of Oslo	Norway
Dr Valeriano Parravicini	Institut de Recherche pour le Développement	France
Dr Juarez Pezzuti	Federal University of Pará	Brazil
Prof Serge Planes	University of Perpignan	France
Bettina Poirier	United States Senate	USA
Mark Priest	King Abdullah University of Science and Technology	Saudi Arabia
Prof Timothy Ravasi	King Abdullah University of Science and Technology	Saudi Arabia
Prof Callum Roberts	University of York	United Kingdom
Dr Pablo Saenz-Agudelo	King Abdullah University of Science and Technology	Saudi Arabia
Prof Russell Schmitt	University of California	USA
Dr Kartik Shanker	Indian Institute of Science	India
Prof Kotaro Shirai	University of Tokyo	Japan
Veronica Silva	Chico Mendes Institute for Biodiversity Conservation	Brazil
Dr Steve Simpson	University of Exeter	United Kingdom
John Tanzer	WWF International	Switzerland
Tane Sinclair-Taylor	King Abdullah University of Science and Technology	Saudi Arabia
Kohki Sowa	Hokkaido University	Japan
Dr Jerker Tamelander	United Nations Environment Program	Thailand
Dr Kentaro Tanaka	Hokkaido University	Japan
Dr Simon Thorrold	Woods Hole Oceanographic Institution	USA
Dr James True	Okinawa Institute of Science and Technology	Japan
Dr Harry Wilson	Zhejiang University	China
Prof Jiaping Wu	Zhejiang University	China
Prof Fei Xue	Prince Songkal University	Thailand

# Media and Public Outreach

The ARC Centre plays a leading role in coral reef science communication and outreach, serving a global audience through the media, internet and a variety of other activities. Our aim is to promote understanding, awareness and cooperation in coral reef science and management.

The ARC Centre's communications strategy is multi-stranded and targeted at the local, national and international levels. We promote our research outcomes through media releases, and our website, in delivering public lectures and talks, visiting schools, convening annual symposia around Australia, presenting at international conferences and community workshops, providing government and industry briefings, and by generating reports and brochures on our activities.

The Centre's website caters for multiple audiences with continually updated access to the Centre's research programs, their activities and outputs, access to resources and research services, and allows downloads of research, teaching and educational materials and tools. The site received 8.9 million web hits in 2013, and has grown 15 fold since its establishment in 2006.



**Media commentaries and web hits of the ARC Centre of Excellence from 2005 to 2013 (excluding ICRS 2012)**

In 2013, researchers from the Centre participated in 64 public outreach events and programs, reaching audiences locally, nationally and internationally. Examples include:

- Working with indigenous leaders with the shared aim of increasing the number of formally trained marine scientists among Australia's Aboriginal and Torres Strait Islander population, Joe Pollock, a postgraduate student in the Centre, founded the *Aboriginals and Torres Strait Islanders in Marine Science's* (ATSIMS) Indigenous Scholars Initiative (p52).
- Activities aimed at school aged children are a continuing

and important focus of the Centre's outreach program. For example, as Science Ambassador, Blanche D'Anastasi, a postgraduate student in the Centre, made presentations on sea snakes to primary and secondary students at Tagai College in the Torres Strait as part of the *Get into Uni Camp* and *Wonders of Science Program*. Chief Investigator, Chris Fulton made several presentations to high school students throughout New South Wales as part of the Regional Schools Marine Science Program. In Townsville, Centre DECRA fellows, Nick Graham and Andy Hoey, are very active as Scientists in Schools at Hermit Park State School, as is Morgan Pratchett at Annandale State School.

- Glenn Almany, Future Fellow, made a series of presentations to local communities in the Solomon Islands and in Hawai'i on fisheries management and the importance of larval dispersal and recruitment habitat in the face of climate change.
- In October, the Centre's public forum *Coral Reefs in the 21<sup>st</sup> Century*, hosted by popular television entertainer Paul McDermott, attracted an audience of more than 300 from the Townsville general public. Topical presentations by Centre researchers David Bellwood, Sylvain Forêt, Aurélie Moya, John Pandolfi and Garry Russ focussed on the impacts of climate change on coral reefs and fish and the importance of marine protected areas. Videos of the presentations are available online from the Centre website [www.coralcoe.org.au/news-events/symposia/coral-reefs-in-the-21st-century-townsville/public-forum-coral-reefs-in-the-21st-century-townsville](http://www.coralcoe.org.au/news-events/symposia/coral-reefs-in-the-21st-century-townsville/public-forum-coral-reefs-in-the-21st-century-townsville).
- Centre researchers gave public talks in a diverse range of forums in Australia in 2013. For example, Malcolm McCulloch delivered the John de Laeter Memorial Lecture at Curtin University in Perth in March. Terry Hughes delivered the Alan Sefton Memorial Lecture *Securing the future of the Great Barrier Reef* in April 2013 at the University of Wollongong and also presented the Grand Challenge Lecture *Building the Resilience of the Earth's Ecosystems* at QUT in October 2013. Tom Bridge gave the annual Virginia Chadwick Reef Talk as part of the Australian Festival of Chamber Music in July. In September, Ove Hoegh-Guldberg gave a public lecture *Saving the planet one ocean at a time* in the Brisbane City Hall.
- Centre researchers also presented in many public forums internationally. Tom Bridge gave the lecture *The deeper we go the less we know* in the Maldivian Islands in March 2013, while Super Science fellow, Ashley Frisch, gave a public lecture on *The effects of climate change on reef fisheries* for the Hawai'i Conservation Alliance. Philip Munday delivered a talk on *Coral Reefs and Global Change* to the general public at the National Institution for Policy Studies in Tokyo in July. In September, DECRA fellow Andy Hoey presented *The role of fishes in reef ecosystems* in Abu Dhabi.

The Centre strives to build links between scientists, resource managers and policy makers. In 2013, Centre researchers gave more than 100 briefings, workshops and consultancies to governments, management agencies, non-government organisations and businesses. A few examples of briefings include:

- International agencies - Glenn Almany briefed The Nature Conservancy on using information on larval dispersal and population connectivity for conservation planning and fisheries management. In Ghana, David Mills briefed stakeholders from the Ministry for Fisheries and community representatives on institutional and legal reforms to support co-management of coastal fisheries. Ove Hoegh-Guldberg provided a series of briefings in the USA, Turks and Caicos Islands, Netherlands Antilles, Belize and Mexico on the future of the oceans and management of biodiversity. Josh Cinner discussed co-management of marine resources on the coast of Chile with the Chilean National Fisheries agency.
- Local, state and federal government in Australia – on topics such as the World Heritage Committee’s recommendations for the Great Barrier Reef, coastal development, costs of managing reserves, prioritisation of resource allocation for species protection, dynamics of seaweed habitats, monitoring coral bleaching and referral guidelines for dolphins and dugongs.
- Great Barrier Reef Marine Park Authority - on a range of topics such as coral disease, crown of thorns starfish control, the effects of cyclone Yasi on coral recruitment, the impact of predators, the value of “blue maps” for conservation, engagement with traditional owners, and impacts of port developments.
- Community groups - including Natural Resource Management Groups on catchment to coast integrated planning, conservation planning, and turtle management.
- A variety of other stakeholders and end-users in Australia - Morgan Pratchett was the scientific adviser in a series of workshops for more than 20 industry participants, to develop a stewardship action plan for improved management of the Marine Aquarium Fishery on the Great Barrier Reef. In May, the Centre led a workshop with end-users from NQ Dry Tropics, GBRMPA and Queensland National Parks and Recreation, on *Identifying conservation goals for the Great Barrier Reef coastal zone*. In October, Super Science fellow, Ashley Frisch participated in a Great Barrier Reef Outlook Report Consensus Workshop with a broad range of stakeholders including scientists, managers, fishers, and conservationists.
- International workshops – for example, In March, Rebecca Weeks consulted on marine protected areas with 20 national

government and non-government organisation representatives and technical advisors from six Coral Triangle countries. In Gizo, Solomon Islands, Pip Cohen contributed to a stakeholder consultation workshop for Aquatic Agricultural Systems. Mariana Fuentes participated in workshops with 20 Staff from *Projeto TAMAR*, Brazil on assessing the impacts of increased temperature on sea turtles. In September, Morgan Pratchett met with scientists and fisheries managers from Hawai’i Pacific Islands Climate Change Co-operative to workshop the effects of climate change on fisheries. Also in September in Abu Dhabi, Future Fellow Andrew Baird and DECRA fellow Andy Hoey held a capacity-building workshop on *Conserving Coral Reefs in the Gulf* attended by research scientists, government and non-government organisations.

## 2013 Media Releases

The ARC Centre produced 34 media releases during 2013 which generated 3,680 commentaries on the Centre’s activities in a wide variety of outlets around the world. A few examples are listed below.

- The China Post, *Mainland China’s boom savages coral reefs: study*, T Hughes, 20 February 2013
- Australian Geographic, *Coral eroded from within as oceans warm*, S Dove, 20 March 2013
- Nature magazine Research Highlights, *Bigger is better for protecting seas*, N Graham, 2 May 2013
- ABC Science, *Local action key to saving reefs*, P Mumby, 10 May 2013
- Guardian.co.uk Environment, *Great Barrier Reef is at risk even if it doesn’t make UNESCO’s danger list*, S Dove, 13 May 2013
- The Seoul Times, *Coral Reefs “Ruled by Quakes and Volcanoes”*, S Keith, 23 May 2013
- The Conversation, *How earthquakes and volcanoes shape coral diversity*, S Keith, S Connolly, 23 May 2013
- Scientific American, *Scientists urge preservation of deep ocean coral reefs*, Tom Bridge, 29 May 2013
- The Age, *Scientists rally for reef*, O Hoegh-Guldberg, M McCulloch, J Pandolfi, 5 June 2013
- National Geographic, *Great Barrier Reef: World Heritage in danger?* T Hughes, 8 June 2013
- National Geographic Italia, *La Grande Barriera Corallina sulla “lista nera” dell’UNESCO?* T Hughes, 13 June 2013
- Nature.com, *Making the most of muscle oxygen*, J Rummer, 14 June 2013



Australasian Science, *Dead coral spells trouble: fish 'don't smell danger'*, M McCormick P Munday, 1 July 2013

Australasian Science, *How coral cures your ills*, D Miller, 10 July 2013

Phys.Org, *Reef fish sink or swim in climate change waters*, C Fulton, 11 July 2013

News Ltd, *Great Barrier Reef faces 'awful perfect storm' in deadly crown of thorns starfish outbreak*, M Pratchett, O Hoegh-Guldberg, 13 July 2013

The Japan Times, *Caribbean nations making case for no-take fishing reserves*, P Mumby, 13 July 2013

Vancouver Sun, *Push for more no-fishing reserves in Caribbean regarded as best hope for restoring sea*, P Mumby 13 July 2013

Al Jazeera, *Reef Killers*, J Rivera-Posada, 22 July 2013

Time Magazine (Europe), *Great Barrier Reef under threat*, T Hughes, 22 July 2013

UPI.com, *Study: Reef fish grow 'eyes' on their tails to escape predators*, M McCormick, O Lonnstedt, 20 August 2013

Discovery News, *Google street view visits Caribbean coral reefs*, O Hoegh-Guldberg, 20 August 2013

NBCNEWS.com, *Dive on the Great Barrier Reef from the comfort of your recliner*, O Hoegh-Guldberg, 21 August 2013

Times of India, *Rising sea temperatures threaten the home of Nemo*, A Frisch, 21 August 2013

Scientific American, *How to love a Whale Shark*, M Meekan, 3 September 2013

Seattle Times, *Sea Change: The Pacific's perilous turn*, P Munday, J Rummer, 11 September 2013

The Guardian, *Coral reefs suffer as the relentless hunt for shark fins takes its toll*, M Meekan, 20 September 2013

Beijing News.net, *Reef fish future 'rests on China diners'*, M Fabinyi, 10 October 2013

SBS News, *Great Barrier Reef: Bar must be raised on development rules*, A Grech, B Pressey, 2 November 2013

ABC 7.30 Report, *Game of Thorns could wreak reef havoc*, M Pratchett, 6 November 2013

The Australian, Higher Education Supplement, *Crown of thorns plague moving south*, M Pratchett, 9 November 2013

ABC Science, *Dominant damsel distress over CO<sub>2</sub> rise*, P Munday, 22 November 2013

ABC [Radio National], *Runoff killing coral*, T Hughes, 27 November 2013

Nature World News, *Global warming could mean lazier, fewer fish: A Study*, J Jacobsen, M Pratchett, 28 November 2013

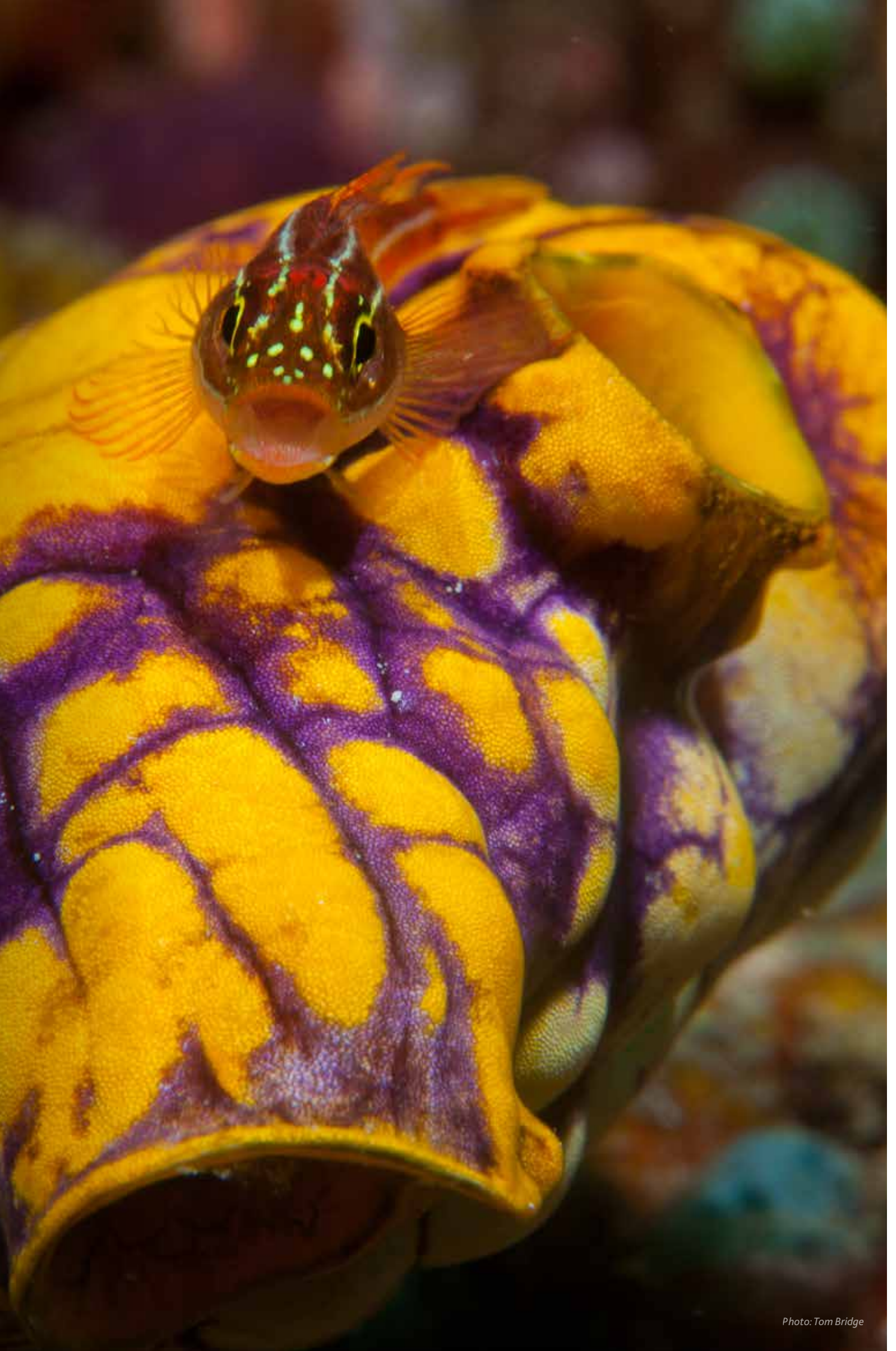
Honduras Weekly, *Caribbean coral reefs threatened by climate change*, G Roff, P Mumby 23 December 2013

“

*Most fish living in marine reserves are older, bigger and more fecund than those outside their borders... The potential for “spillover” of such fish into fisheries may boost support for reserves.*

”

Peter F Sale  
 “Older but less wise”  
*Nature* 10 January 2013, Vol 493





# Coral Reef Governance and Management

Sustaining coral reefs under rapidly changing socioeconomic and environmental conditions will require innovative governance solutions aimed at maintaining food security and preserving the livelihoods of the millions of people. The ARC Centre of Excellence for Coral Reef Studies is actively engaged in assessing, advising and improving governance and management of coral reefs around the world. In 2013, researchers at the Centre contributed to many policy initiatives and to establishing novel reef governance arrangements that are emerging around the world, including in Australia, the Coral Triangle, and the Western Indian Ocean:

- Centre researchers are also working closer to home informing management on the Great Barrier Reef. Centre Director, Terry Hughes, has been appointed by the Federal Environment Minister, Greg Hunt, to review the Great Barrier Reef Marine Park Authority's Outlook Report. This is arguably one of the most important policy documents on further research and management needs of the Great Barrier Reef, coming at a critical juncture in time when the World Heritage Listing of the reef is coming under question. Centre Fellow Louisa Evans led a large project to investigate different stakeholders' opinions on the potential futures facing the Great Barrier Reef and its industries. Importantly, the work, published in a number of reports and a journal article in *Human Ecology*, investigates the opportunities for, and limits to, adaptation to climate change in the region.
- In the Coral Triangle region neighbouring Australia, Centre researchers have evaluated the social and ecological benefits associated with the customary governance arrangements that are prolific in the region. In a paper in *Current Biology*, ARC Future Fellow Glenn Almany led a team of researchers who used recent breakthroughs in genetic parentage analysis to show that local protection of reef fish spawning aggregations was restocking the fisheries within the same village's fishing grounds (p23). By showing where the juvenile fish were recruiting, Glenn's research has inspired the community to not only protect the nursery area that the fish depend on, but also to successfully lobby for the closure of a mine that was polluting the important fishing grounds. In the Solomon Islands, Pip Cohen examined the local practice of periodically harvesting protected areas for ceremonial purposes. Her research, published in *Global Environmental Change* and *PLoS One* highlights how these strategies provide mixed benefits to local communities while potentially reducing overall fishing pressure.
- The Centre has also been engaged in building capacity, and informing and evaluating changing governance structures in the Western Indian Ocean (WIO) region. Transformations to the governance structures in places such as Kenya, Tanzania, and Madagascar have given much more ownership and control over managing coral reef resources to local fishing communities. Josh Cinner edited a special issue of *Global Environmental Change* that examined successful marine governance arrangements in the WIO, Coral Triangle, and Latin

America. Centre Research Fellow Christina Hicks is examining how different stakeholders benefit from the goods and services provided by coral reefs. In a study published in *Global Environmental Change*, Christina compared the priorities assigned to a suite of ecological services by four different stakeholder groups: fishers, managers and scientists across four countries in the WIO region. Interestingly, there were quite substantial differences between fishers and scientists, but managers' priorities reflected a middle ground suggesting they are well placed to provide brokering roles in governance decisions in the region. Another major recent governance change in the region was the establishment of the Chagos Archipelago as one of the world's largest no-take protected areas (~640,000 km<sup>2</sup>) (p50). Writing in the journal *BioScience*, Nick Graham compared the reef fish communities in this large wilderness area to smaller protected areas elsewhere in the Indian Ocean and found that it was protecting a much greater suite of the higher trophic level fish, enhancing biomass six times greater than the most successful smaller protected areas. Long-standing research and collaborations in the Seychelles are ongoing and the Centre is currently building capacity in the country in the form of training two PhD students, Karen Chong-Seng and Jan Robinson.

## Selected publications:

- Almany GR, Hamilton RJ, Bode M, Matawai M, Potuku T, Saenz-Agudelo P, Planes S, Berumen ML, Rhodes KL, Thorrold SR, Russ GR, and Jones GP (2013). Dispersal of grouper larvae drives local resource sharing in a coral reef fishery. *Current Biology* 23: 626-630.
- Cohen PJ and Alexander TJ (2013). Catch rates, composition and fish size from reefs managed with periodically-harvested closures. *PLoS ONE* 8(9): e73383.
- Cohen P, Cinner JE and Foale SJ (2013). Fishing dynamics associated with periodically harvested marine closures. *Global Environmental Change* 6: 1702-1713.
- Hicks CC, Graham NAJ and Cinner JE (2013). Synergies and tradeoffs in how managers, scientists, and fishers value coral reef ecosystem services. *Global Environmental Change* 23: 1444-1453.
- Graham NAJ and McClanahan TR (2013). The last call for marine wilderness? *BioScience* 63: 397-402.
- Cinner JE, MacNeil MA, Basutro X and Gelcich S (2013). Looking beyond the fisheries crisis: cumulative learning from small-scale fisheries through diagnostic approaches. *Global Environmental Change* 6: 1359-1365.
- Evans LS, Hicks CC, Fidelman P, Tobin R and Perry A (2013). Future scenarios as a research tool: investigating climate change impacts, adaptation options and outcomes for the Great Barrier Reef, Australia. *Human Ecology* 41: 841-857.





# The condition and stability of reef fish assemblages in the Chagos Archipelago

Dr Nicholas Graham  
James Cook University

Through various work across coral reefs of the western Indian Ocean, colleagues and I have shown that fish biomass on these coral reefs tends to peak at around 1,200 kg/ha. One of the best examples of this is from long-term time series of reef fish biomass build-up in Kenya's marine national park network.

After 20–25 years, the biomass within these parks stopped increasing and levelled off at 1,200 kg/ha. This value was therefore assumed to be the maximum that these reefs could support. However, it was noted that most marine parks in the region are quite small and are found along populated coastlines and are therefore embedded within large areas of heavy fishing pressure. My presentation at the Zoological Society of London (ZSL) put these findings in the western Indian Ocean into context, by comparing these other nation's fish biomass values to fish biomass values I recorded in Chagos. The fish biomass at Chagos was up to 6 times greater than that in the rest of the Indian Ocean, and included much more biomass from fish that were high up the food chain and of larger body size. These data form the basis of a forthcoming paper in the journal *BioScience* (Graham & McClanahan 2013).

I went on to compare reef fish biomass among atolls within Chagos, showing that the biomass of reef fish around Diego Garcia was generally lower than the biomass at the northern atolls. There is a recreational fishery around Diego Garcia, and even light fishing such as this has been shown to be detrimental to fish biomass in other locations. Although it is very hard to pinpoint that the recreational fishing is driving these differences, the fact that higher trophic level and larger fish are more scarce in Diego Garcia than the northern atolls is suggestive of fishing impacts. More details on these data can be found in a forthcoming book chapter (Graham et al. 2013). The



**A large school of paddletail snapper in the Chagos Archipelago.**

*Photo: Anne Sheppard*

chapter also updates a time series on the relative abundance of reef sharks in Chagos. These data, collected during scientific dives in the archipelago, extend from 1975 to 2012. Shark abundances had dropped by ~90% after the 1970s, most likely due to increased fishing for shark fin. The numbers have not recovered, but there are weak signs that a little recovery may be occurring. Importantly, this will be dependent on how well the Chagos marine protected area is enforced and complied with.

The final part of my talk assessed the impact of the 1998 coral mortality event on the reef fish communities in Chagos. This large disturbance event caused substantial reductions in the abundance and diversity of reef fish communities in some other parts of the Indian Ocean, such as the Seychelles. However, in





**A grey reef shark at Diego Garcia.**

Photo: Nick Graham



**Obligate coral feeding butterflyfishes in the Chagos Archipelago.**

Photo: Morgan Pratchett

Chagos the impacts were much smaller. Only obligate coral feeding fishes showed some reductions in abundance by 2006. The rapid recovery of corals in Chagos, combined with the lack of other human impacts (e.g. fishing), are the most likely reasons for the lack of impact.

Interestingly, by 2012 the fish communities, including the obligate coral feeding fishes, were abundant. A study of specialisation of these coral feeding fishes has shown that the more specialised a species is the more abundant they are, suggesting some sort of competitive advantage of this specialisation (Pratchett et al. in press). This is the first time this has been shown, again highlighting the novel scientific insights a largely untouched location such as Chagos can offer.

More details on these findings can be found in the following publications:

Graham NAJ, Pratchett MS, McClanahan TR, Wilson SK (2013) The status of coral reef fish assemblages in the Chagos Archipelago, with implications for protected area management and climate change. Pages 253-270 In: Sheppard CRC (ed) *Coral reefs of the UK Overseas Territories. Coral Reefs of the World Volume 4*, Springer

Graham, N. A., & McClanahan, T. R. (2013). The last call for marine wilderness?. *BioScience*, 63(5), 397-402.

Pratchett MS, Graham NAJ, Cole AJ (2013) Specialist corallivores dominate butterflyfish assemblages in coral-dominated reef habitats. *Journal of Fish Biology*. 82: 1177-1191.



# Indigenous High School Students Prepare for Careers in Marine Science

In 2013, the Centre's activities and research made a direct impact on the training and aspirations of young Indigenous Australians. Aboriginal and Torres Strait Islander peoples have been living adjacent to the Great Barrier Reef for tens of thousands of years. The reef is deeply engrained in their cultural, spiritual and economic fabric and they possess profound ecological knowledge of their Land and Sea Countries. One of the ARC Centre's postgraduate students, Joe Pollock, has this year founded the Aboriginals and Torres Strait Islanders in Marine Science's (ATSIMS) Indigenous Scholars Initiative, which is designed to help fill the gap between the potential of Indigenous Australians and the opportunities available to Australia's traditional custodians in marine science and management. By providing engaging, field-based science programs to predominantly Indigenous high school students the outcome has been to bolster the interest, experience, and hands-on skills that Aboriginals and Torres Strait Islanders need to initiate, and succeed in, tertiary studies in the field of marine science.

In the spring of 2013 Joe recruited 40 Townsville-based Indigenous students - the inaugural cohort of ATSIMS to experience a five week course in marine science. Under the guidance of marine researchers and Indigenous leaders, the young scholars engaged in interactive workshops at four participating high schools, and they came face-to-face with fish and coral during a weekend-long field experience at JCU's Orpheus Island Research Station. The students also toured the \$35 million National Sea Simulator at the Australian Institute of Marine Science (AIMS) and experienced life as an undergraduate student at James Cook University (JCU). The program, which is supported by the ARC Centre of Excellence for Coral Reef Studies, aims to inspire Indigenous high school students to pursue careers in marine science and management and prepares them to succeed in these critically important fields.

With more than 70 Aboriginal and Torres Strait Islander clan groups living adjacent to the Great Barrier Reef, effective conservation of Queensland's valuable marine resources is contingent upon the inclusion of Indigenous Australians in all aspects of marine management. "Indigenous Australians possess a wealth of both traditional and applied knowledge of Australia's marine systems that should strengthen existing research and management initiatives and spark new lines of inquiry," explains Joe. Although Indigenous Australians account for 2.4 percent of the nation's population, they constitute 1.3 percent of students entering universities and only 0.3 percent of staff at Australia's national science agency, CSIRO. ATSIMS hopes to kindle the passion, skills, and confidence needed to provide the national benefit and fill the critical gap between the potential of Indigenous Australians and the opportunities available in marine science and management.

The program plans to foster linkages between western marine science and traditional ecological knowledge. As an illustration of the power of this connection, the scholars learned from Mr Jim Gaston, a member of the Giru Dala Council of Elders. Mr Gaston founded an innovative sea turtle tracking program near Bowen with his wife Sheryl. Over the past 15 years, the husband-and-wife team have monitored the health of sea turtle populations in the region and – working closely with veterinarians and researchers at JCU – were the first to discover *fibropapillomatosis*, a potentially fatal viral disease, in local turtle populations.

"This has been an absolutely wonderful opportunity for our Indigenous kids," enthused Ms Natalie Howard, the Community Education Counsellor at William Ross High School. "For the students to learn about sustainability, the environment and how much the environment means to us as a culture and can continue to mean to us as a culture is just brilliant." Although it will be years before the first cohort of ATSIMS scholars enters the workforce, there are already compelling signs of the program's impact. "In the months since we completed the course the science marks of nearly all of our alumni have improved," affirms Pollock. "And nearly 100 percent of the scholars now believe they will attend university, up from less than fifty percent before the program." Although it is more difficult to quantify, the ATSIMS scholars' enthusiasm for the program is almost palpable. "This was one of the best experiences I have ever had," insists William Ross High student Daisha Johnson, 14. "I want to become a marine scientist now!"

"The ATSIMS program will run again in mid-2014, funded by a grant from the Higher Education Participation and Partnerships Program and with support from the ARC Centre, AIMS and James Cook University. A fresh batch of Indigenous high school students will take part in this unique learning experience. Joe is also keen to reach students beyond Townsville's borders. "I would love to see the ATSIMS program, and others like it, engaging with Traditional Owner groups along the length of the Great Barrier Reef," announced Joe. "I truly believe that students, communities and, ultimately, the Reef will benefit from the strengthened connections between western science and traditional knowledge that this program promotes."

<http://youtu.be/ckMDt7a3Bog>







## ***Too hot for sea turtles?***

Sea turtles are particularly susceptible to climate change because their behaviour, physiology and life history are affected by environmental changes.

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<http://conservationplanning.org/2013/11/current-conservation-special-issue-on-marine-turtles/>

Originally published in *Current Conservation* volume 6 issue 2.



All life stages of sea turtles (e.g. hatchlings, juvenile and adult) can be affected by climatic processes. The more detectable impacts of climate change on sea turtles will occur during their interlude on land (during the laying and incubation of eggs and hatching) because there are clear and relatively straightforward effects of increased temperature, sea level rise and cyclonic activity on their nesting sites and nesting success. For example, predicted increases in sand temperatures will skew sea turtle population sex ratios towards predominantly females, decrease hatching success and alter the size of the hatchlings. Sea-level rise and cyclonic activity will cause loss and/or alteration of nesting beaches and egg mortality. A reduction of available nesting area will decrease the area available for nesting, potentially increasing nest infection and destruction of nests by turtles. Other predicted impacts from climate change include shifts in latitudinal ranges, alteration of reproductive periodicity, changes in hatchling dispersal and migration and indirect effects on food availability. Indeed, research investigating the impacts of climate change on the largest green turtle population in the world, the northern Great Barrier Reef (nGBR) green turtle population, predicts a complete feminisation of annual hatchling output by 2070 and a potential loss of up to 38% of available nesting area across the most important nesting sites for this population.

Ultimately, the risk that climate change poses to sea turtle populations will depend on their ability to adapt. Sea turtles have existed for hundreds of millions of years and during this time, they have survived dramatic climate fluctuations and changes in sea level. It is speculated that sea turtles have historically adapted to environmental changes by redistributing their nesting sites and nesting season, by developing new migratory routes and by changing their behaviour. The extent to which sea turtles will (or can) adapt either behaviorally or physiologically and how these responses may counteract impacts of climate change, remains to be seen. Despite sea turtles' ability to cope with past climatic changes, their ability to do so again is uncertain. Current rates of climate change are much faster than historic rates and at present, they are being simultaneously affected by a variety of anthropogenic activities.

The uncertainty on whether and how sea turtles can adapt to climate change necessitates precautionary actions and adaptive management. A mix of different short-term and long-term approaches have been suggested including: 1) mitigating the threat by reducing global greenhouse emissions; 2) adaptively managing impacts from climate change to increase population persistence; and 3) employing actions that build biodiversity resilience, such as addressing current non-climate-related threats. Reducing emissions is perhaps the biggest challenge, but even immediate reductions will not stop the already apparent and unavoidable impacts of climate change but are still essential to ameliorate threats. Adaptive management is hindered by risks associated with implementing mitigation strategies (e.g. species relocations, manipulations or management actions that improve habitat) and a lack of understanding of how effective and feasible these strategies will be at reducing impacts at relevant temporal and spatial scales.

*The more detectable impacts of climate change on sea turtles will occur during their interlude on land (during the laying and incubation of eggs and hatching) because there are clear and relatively straightforward effects of increased temperature, sea level rise and cyclonic activity on their nesting sites and nesting success.*

The majority of the suggested strategies, to date, focus on the nesting environment, as this is where most research on sea turtles occurs and baseline knowledge is strongest as well as where implementation and monitoring is logistically easiest. However, even on nesting beaches, the implementation

of these strategies requires an understanding of the thermal profile at different nesting beaches, the current sex ratio of hatchlings entering the population and the proportion of males to females that are ready to mate at any one time for that population; information which is rarely available. Importantly, not many strategies have been suggested for mitigating in-water impacts from climate change or boosting resilience of foraging turtles, presumably because of a lack of data or an understanding of how these systems will be impacted.

Building biodiversity resilience, to date, has focused on reducing non-climatic threats under the rationale that large, healthy and stable populations will help maintain (1) genetic diversity, which can facilitate adaptation to variable conditions; (2) a wide geographic distribution, which can minimise the overall impacts of area-specific threats; and (3) a large breeding population, which can help absorb impacts through an increased ability to recover from population disturbance.

In this context, I conducted a survey with other sea turtle specialists, to explore factors that may influence the resilience of sea turtles to climate change, which indicated that persistence of nesting grounds themselves may also influence the resilience of sea turtle populations. This follows the rationale that optimal nesting areas are necessary for reproduction and therefore the entry of offspring into the population. It also provides buffer areas for sea turtles to redistribute the geographic locations of their current nesting grounds, if necessary, as an adaptive response to deal with environmental or land-use changes. This highlights the need to maintain and protect important nesting beaches and to identify and legally protect areas that will maintain suitable nesting environments in the future, even if they are not major nesting grounds today. This will be particularly difficult in areas where coastal development and beach alteration is widespread and continually expanding. Impacts from climate change are likely to interact with other anthropogenic threats, such as coastal development. Therefore, managers face the challenge of addressing the direct effects of climate change, as well as ongoing threats that sea turtles face throughout their geographic range. For

logistical, financial and political reasons, natural resource agencies cannot address all of these drivers or “threats” simultaneously; priorities must be established. For this, there is a need to understand the relative impacts of current and future threats to the overall population dynamics and the variation of those impacts. This is particularly important for sea turtles, since each of their life stages has a different reproductive value (potential for contributing offspring to future generations), and therefore reductions to each life stage will impact population growth rates differently.

*As iconic species, sea turtles could be used as flagships to promote understanding of the impacts of climate change on biodiversity, to build community support for conservation action and to provide incentives for effective management and support for research, conservation and changes in policy.*

Risk and vulnerability assessments are increasingly being used to help prioritise management of species in the face of climate change and also to investigate the risk of not addressing evident threats. For example, I used a vulnerability assessment to identify which climatic process will cause the most impact on the terrestrial reproductive phase of the nGBR green turtle population and to explore how the vulnerability of this population to climate change will alter if the impacts of different climatic processes are mitigated.

Even with innovative decision-support tools, the implementation of management will likely be compromised without the necessary laws and policy. Existing national and international laws might need to be revisited and adapted to ensure that





A green turtle, *Chelonia mydas*, at a foraging ground. Sea turtle can be affected at multiple life stages by climate change

management can address emerging climate change threats. Arguably, many laws are ill-suited to climate change because of their static nature. Many were written to address specific types of threats at a time when climate change was not at the forefront of concerns and are consequently limited in a changing world. Legislative flexibility will be essential, particularly for emergency responses. But changes in legislation require scientific, political, and community support. Public awareness of the links between climate change, the potential impacts to sea turtles, and the need to take action can provide the momentum to do something about it. As iconic species, sea turtles could be used as flagships to promote understanding of the impacts of climate change on biodiversity, to build community support for conservation action and to

provide incentives for effective management and support for research, conservation and changes in policy.

Ultimately, an integrated approach comprising several strategies will be needed. Most strategies will require community, government support and voluntary behavioural changes to minimise social and economic impacts and in many cases community consultation to improve the effectiveness and acceptance of new management arrangements. The best set of strategies will likely be site-specific and will depend on environmental, social, economic and cultural conditions at a particular location, yet also will be integrated at the appropriate regional scale. Importantly, targeted research to understand the adaptive capacity of marine turtles, the exposure and sensitivity of populations and key habitat to climatic processes, population-scale thresholds of concern, and synergistic impacts is necessary to help guide future efforts to manage sea turtles and enhance their adaptive capacity.

#### Suggested reading:

Fuentes MMPB, Pike DA, Dimatteo A & BP Wallace. 2013. Resilience of marine turtle regional management units to climate change. *Global Change Biology*, 19, 1399–1406.

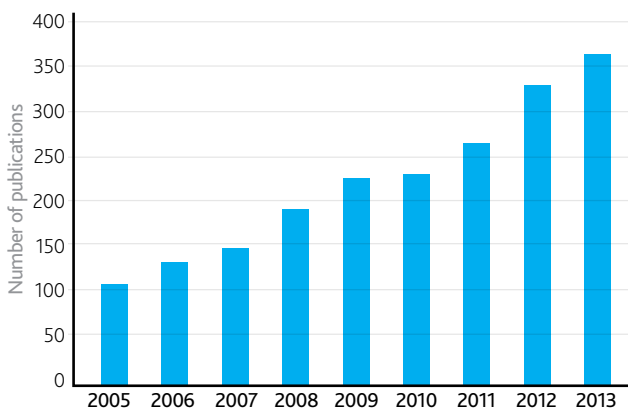
Fuentes MMPB, Limpus CJ & M Hamann. 2011. Vulnerability of sea turtle nesting grounds to climate change. *Global Change Biology*, 17, 140-153.

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# Publications

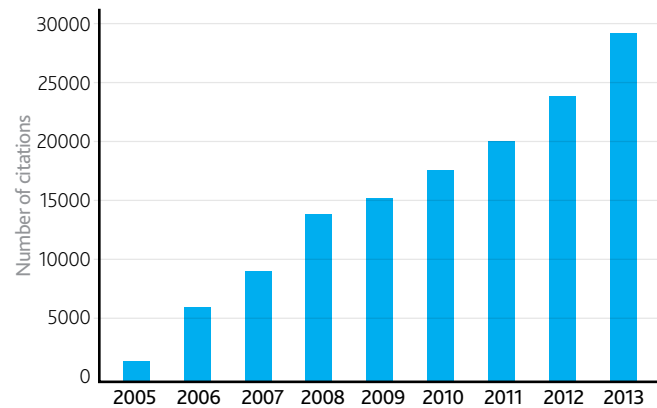
According to *Web of Science*, the ARC Centre of Excellence for Coral Reef Studies is the first-ranked institution globally for both the number of journal publications and citations in coral reef science. The ARC Centre produced 351 publications in 2013, more than 3-times the Centre's initial output in 2005. The total for this year includes 317 journal articles, 12 books and book chapters, 2 Symposium papers, and 20 reports and popular articles. This latest output brings the total number of publications by the Centre to 1,962 since 2005.

In 2013, Centre researchers published 86 articles in journals with Impact Factors greater than four, including 15 papers in top tier outlets - *Science*, the *Nature Journals*, *PNAS* and *Current Biology*. Over the 2005-2013 funding cycle, the Centre produced 114 articles in these prestige journals. The average Impact Factor for all 317 journal articles in 2013 was 4.35. The Centre's research outputs were published in a total of 115 journal titles, spanning many fields of research and reflecting the multidisciplinary breadth of the Centre, including a focus on biochemistry, biogeography, botany, conservation biology, ecology, evolution, fisheries, immunology, mathematical modelling, oceanography, paleobiology, photobiology, physiology, population biology, genomics, geochemistry, social science, and systematics.



**Growth in publication output by the ARC Centre of Excellence, 2005-2013**

The number of citations of the ARC Centre's publications has grown rapidly through the Centre's 2005-2013 funding cycle. According to *Web of Science*, in 2013, thirty researchers were each cited >200 times, 22 of the Centre members had >500 citations, and nine had >1000 citations during the past 12-month reporting period.



**Summed citations per year (2005-2013) to members of the ARC Centre of Excellence, according to Web of Science**

League table achievements in publications for 2013 include:

- *The Faculty of 1000 Biology* highlighted nine of the ARC Centre's publications for review in 2013:

Cinner JE, Graham NA, Huchery C and MacNeil MA (2013). Global effects of local human population density and distance to markets on the condition of coral reef fisheries. *Conservation Biology* 27(3):453-458.

Feary D, Pratchett M, Emslie M, Fowler A, Figueira W, Luiz O, Nakamura Y and Booth D (2013). Latitudinal shifts in coral reef fishes: why some species do and others do not shift. *Fish & Fisheries* doi: 10.1111/faf.12036.

Gilmour JP, Smith LD, Heyward AJ, Baird AH and Pratchett MS (2013). Recovery of an isolated coral reef system following severe disturbance. *Science* 340(6128):69-71.

Howells EJ, Berkelmans R, van Oppen MJ, Willis BL and Bay LK (2013). Historical thermal regimes define limits to coral acclimatization. *Ecology* 94(5):1078-1088.

Poloczanska, ES, Brown, CJ, Sydeman, WJ, Kiessling, W, Schoeman, DS, Moore, PJ, Brander, K, Bruno, JF, Buckley, LB, Burrows, MT, Duarte, CM, Halpern, BS, Holding, J, Kappel, CV, O'Connor, MI, Pandolfi, JM, Parmesan, C, Schwing, F, Thompson, SA and Richardson, AJ (2013). Global imprint of climate change on marine life. *Nature Climate Change* 3(10):919-925.

Keith SA, Baird AH, Hughes TP, Madin JS and Connolly SR (2013). Faunal breaks and species composition of Indo-Pacific corals: the role of plate tectonics, environment and habitat distribution. *Proceedings of the Royal Society B-Biological Sciences* 280(1763):20130818.

Lukoschek V, Cross P, Torda G, Zimmerman R and Willis BL (2013). The importance of coral larval recruitment for the recovery of reefs impacted by cyclone Yasi in the central Great Barrier Reef. *PLoS ONE* 8(6):e65363.

Perry CT, Murphy GN, Kench PS, Smithers SG, Edinger EN, Steneck RS and Mumby PJ (2013). Caribbean-wide decline in carbonate production threatens coral reef growth. *Nature Communications* 4:1402.

Rasher DB, Hoey AS and Hay ME (2013). Consumer diversity interacts with prey defenses to drive ecosystem function. *Ecology* 94(6):1347-1358.

- *ISI Essential Science Indicators* identified seven *Research Fronts* during 2013 that highlight the ARC Centre's research. A research front is a group of recent highly cited papers, referred to as *Core Papers*, in an emerging topic defined by a bibliometrical cluster analysis. The Research Fronts are:

- Marine protected areas and larval dispersal
- Coral reef resilience
- Ocean acidification
- Thermal tolerance and climate change
- Coral reef fish and fisheries
- Coral reef diseases
- Trophic cascades and herbivory

Twenty-four *Core Papers* in these *Research Fronts* were authored by Centre members Glenn Almany, David Bellwood, Joshua Cinner, Sean Connolly, Danielle Dixon, Nick Graham, Ove Hoegh-Guldberg, Andrew Hoey, Terry Hughes, Geoff Jones, Mike Kingsford, Janice Lough, Laurence McCook, Mark McCormick, Peter Mumby, Philip Munday, John Pandolfi, Serge Planes, Morgan Pratchett, Bob Pressey, Garry Russ, Bob Steneck, Madeleine van Oppen, David Williamson, and Bette Willis.

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*...it is plain that ecology and environmental sciences is a focus area for the nation (of Australia), ...and marine habitats and specifically coral reef studies are domains in which Australia plays a global leadership role. The Australian Research Council's Centre of Excellence for Coral Reef Studies, headquartered at James Cook University in Townsville, is one explanation of the nation's research impact in the field.*

April 2013 report on international Research Fronts by ISI Thomson Reuters

<http://sciencewatch.com/articles/research-fronts-2013-100-top-ranked-specialities-sciences-and-social-sciences>

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**Book (1)**

1. Pratchett, M, Berumen, M and Kapoor, B (2013). *Biology of Butterflyfishes*. CRC Press, Boca Raton, FL, 362 pp.

**Book Section (11)**

1. Ban, N, Januchowski-Hartley, S, Alvarez Romero, JG, Mills, M, Pressey, B, Linke, S and de Freitas, D (2013). Marine and freshwater conservation planning: from representation to persistence. In: Craighead, F and Convis, C. (eds). *Conservation Planning: Shaping the Future*, Esri Press, Redlands, 175-217 pp.

2. Cole, A and Pratchett, MS (2013). Diversity in diet and feeding behaviour of Butterflyfishes: reliance on reef corals versus reef habitats. In: Pratchett, MS, Berumen, ML and Kapoor, BG. (eds). *Biology of Butterflyfishes*, CRC Press, Boca Raton, 107-139 pp.

3. Connolly, SR and Kosnik, MA (2013). Fossil record. In: Levin, SA. (ed). *Encyclopedia of Biodiversity*, Academic Press, Waltham, MA, USA, 537-544 pp.

4. Gordon, BR, Leggat, W and Motti, CA (2013). Extraction protocol for nontargeted NMR and LC-MS metabolomics-based analysis of hard coral and their algal symbionts. In: Roessner, U and Dias, DA. (eds). *Metabolomics Tools for Natural Product Discovery: Methods and Protocols*, Humana Press, 129-147 pp.

5. Graham, N, Pratchett, MS, McClanahan, T and Wilson, SK (2013). The status of coral reef fish assemblages in the Chagos Archipelago, with implications for protected area management and climate change. In: Sheppard, C. (ed). *Coral Reefs of the United Kingdom Overseas Territories*, Springer Netherlands, 253-270 pp.

6. Hamann, M, Fuentes, M, Ban, N and Mocellin, V (2013). Climate change and marine turtles. In: Wyneken, J, Lohmann, KJ and Musick, JA. (eds). *The Biology of Sea Turtles*, CRC Press, Boca Raton, 353-370 pp.

7. Hobbs, J-P, van Herwerden, L, Pratchett, MS and Allen, GR (2013). Hybridisation among Butterflyfishes. In: Pratchett, M, Berumen, M and Kapoor, B. (eds). *Biology of Butterflyfishes*, CRC Press, Boca Raton, 48-69 pp.

8. Pratchett, MS, Chong Seng, K, Feary, DA, Hoey, A, Fulton, C, Nowicki, JP, Dewan, AK, Walker, S and Berumen, M (2013). Butterflyfishes as a model group for reef fish ecology: important and emerging research topics. In: Pratchett, M, Berumen, M and Kapoor, B. (eds). *Biology of Butterflyfishes*, CRC Press, Boca Raton, 310-334 pp.

9. Steneck, RS (2013). Sea urchins as drivers of shallow benthic marine community structure. In: Lawrence, JM. (ed). *Sea Urchins: Biology and Ecology, 3rd edition*, Academic Press, San Diego, 195-212 pp.

10. Wilson, SK, Graham, N and Pratchett, M (2013). Susceptibility of butterflyfish to habitat disturbance: Do 'chaets' ever prosper? In: Pratchett, M, Berumen, M and Kapoor, B. (eds). *Biology of Butterflyfishes*, CRC Press, Boca Raton, 226-245 pp.

11. Woolsey, E, Byrne, M, Webster, S, Williams, SA, Pizarro, O, Thornborough, P, Davies, R, Beaman, R and Bridge, T (2013). *Ophiopsila pantherina* beds on subaqueous dunes off the Great Barrier Reef. In: Johnson, C. (ed). *Echinoderms in a Changing World: Proceedings of the 13th International Echinoderm Conference*, CRC Press, Hobart, Tasmania, Australia, 175-179 pp.

**Conference Paper (2)**

1. Auge, AA, Maughan, M, Pressey, RL, Brodie, D and Yorkston, H (2013). Spatially explicit scenarios for conservation planning in the Great Barrier Reef coastal zone, Australia. In: Devillers, R, Lee, C, Canessa, R and Sherin, A. (eds). *Proceedings of the Coast GIS Conference 2013: Monitoring and adapting to change on the coast*, University of Victoria, British Columbia, Canada, 179-182 pp.

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**Dataset (1)**

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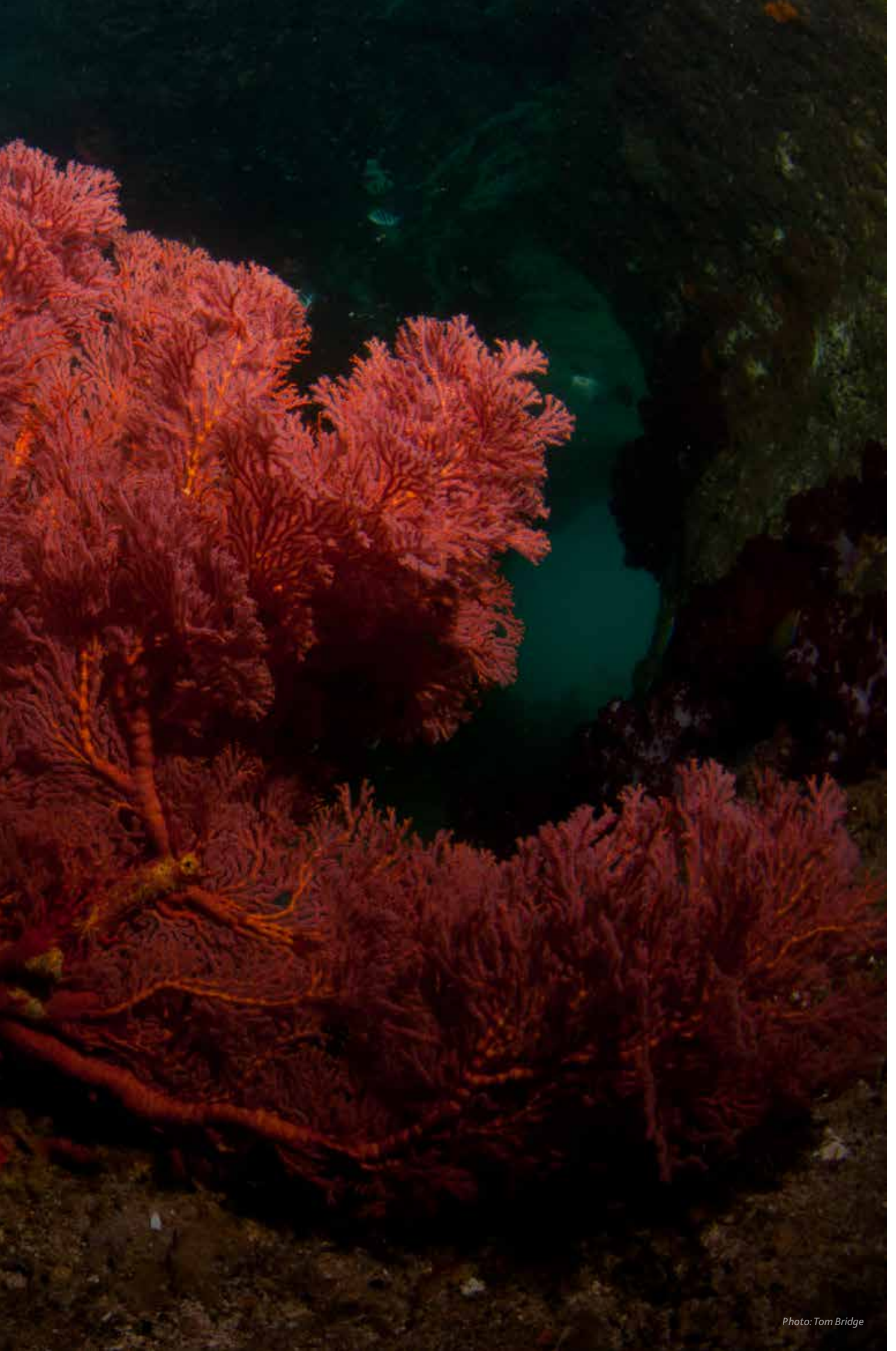
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An underwater photograph of a coral reef. The water is clear and blue-green. In the foreground, there are large, branching coral structures in shades of red and orange. The background shows more coral and the surface of the water with light reflections.

The ARC Centre of Excellence for Coral Reef Studies is actively engaged in assessing, advising and improving governance and management of coral reefs around the world.





# Performance Measures

## Research findings

Measure	Target 2013	Outcome 2013
Number of publications (p58)	190	351
Publications in journals with an impact factor > 4	42	86
Number of citations (p58)	12,000	28,222
Invitations to provide plenary addresses at international conferences	30	44
Invitations to provide review articles	36	39
Number and nature of commentaries about the Centre's achievements	1,350	3,680
Awards, prizes or recognition	23	42

## Research training and professional education

Measure	Target 2013	Outcome 2013
Number of postgraduates enrolled (p30)	150 over 5 years	196 enrolled in 2013 353 enrolled 2009-2013
Number of postgraduate completions	110 over 5 years	42 in 2013 181 completions 2009-2013
Number of Honours students	60 over 5 years	21 enrolled in 2013 73 enrolled 2009-2013
Number of professional workshops	20	42
Participation in professional workshops	26	64
Number and level of graduate student courses and workshops in the priority area(s)	16	39



## International, national and regional links and networks

Measure	Target 2013	Outcome 2013
Number of international visitors	80	86
Number of national and international Working Groups	16	80 researcher participations in 43 working groups
Number of visits to overseas laboratories and research facilities	55	134
Membership of national and international boards and advisory committees	45	98
Number of cross-institutional publications	110	229
Number of multi-institutional supervisory arrangements of graduate students	56	70
Number of internationally funded students	65 over 5 years	84 in 2013
Number of consultancies and contract research	20	29
Number of government, industry and business briefings	65	98
Number of Centre trained/ing personnel in knowledge / technology transfer and commercialisation	8	29
Public awareness programs		
Website hits	4.0 million	8.9 million
Public awareness presentations	26	64

## Organisational support

Measure	Target 2013	Outcome 2013
Annual cash contributions from Collaborating Organisations	\$1.8m	\$3.1m
Annual in-kind contributions from Collaborating Organisations	\$5.0m	\$8.5m
Number of new Organisations recruited to or involved in the Centre	6	6
Level and quality of infrastructure provided to the Centre	\$1.2m	\$1.4m
Annual cash contributions from other organisations	\$0.9m	\$3.6 m

## Governance

Measure	Target 2013	Outcome 2013
Breadth and experience of the members of the Advisory Board	Senior representation from all nodes. Representation of eminent international researchers. Members with commercial and business links	See page 6
Frequency and effectiveness of Advisory Board meetings	2 Centre Advisory Board meetings p.a.	2
	4 Scientific Management Committee meetings p.a.	5 See page 6
Quality of the Centre strategic plan	The Centre's progress against the plan will be formally reported to the Advisory Board and be renewed in light of outcomes	Strategic Plan reviewed and endorsed by the Centre Advisory Board. Ongoing performance against plan reviewed at Scientific Management Committee meetings
Effectiveness of arrangements to manage Centre nodes	Meetings of the Scientific Management Committee where each node and program is represented	All research programs represented at Scientific Management Committee meetings
	Monthly nodal leader phone or video conferences	Regular nodal and program leader meetings held
	Annual rotational visits to the nodes	There were 55 cross-nodal visits in 2013
	Annual research retreats for all Centre participants	Research planning meetings were held by each research program
	Annual research program planning meetings with cross-nodal attendance	Cross-nodal attendance at all research planning meetings
	Number of multi-institutional supervisory arrangements for students	70
	Number of multi-nodal seminar and discussion groups	62
	The adequacy of the Centre's Key Performance Measures	International benchmarking to research in top international marine research centres

## National Benefit

Measure	Target 2013	Outcome 2013
Measures of expansion of Australia's capability in the priority area(s)	150% increase on 2004 benchmark by 2013	<ul style="list-style-type: none"> <li>▪ 290% above the 2004 publications benchmark</li> <li>▪ 850% above the 2004 citations benchmark</li> </ul>
	65 briefings to government, business and industry groups	98 briefings
	30 cross-nodal publications	51 cross-nodal publications
	110 cross-institutional publications	229 cross-institutional publications
Case studies of economic, social, cultural or environmental benefits	2 to be highlighted in the annual report and distributed to media agencies	See pages 48, 52

Over the 2005–2013 funding cycle the Centre produced 114 articles in *Science*, the *Nature* journals, *PNAS* and *Current Biology*.



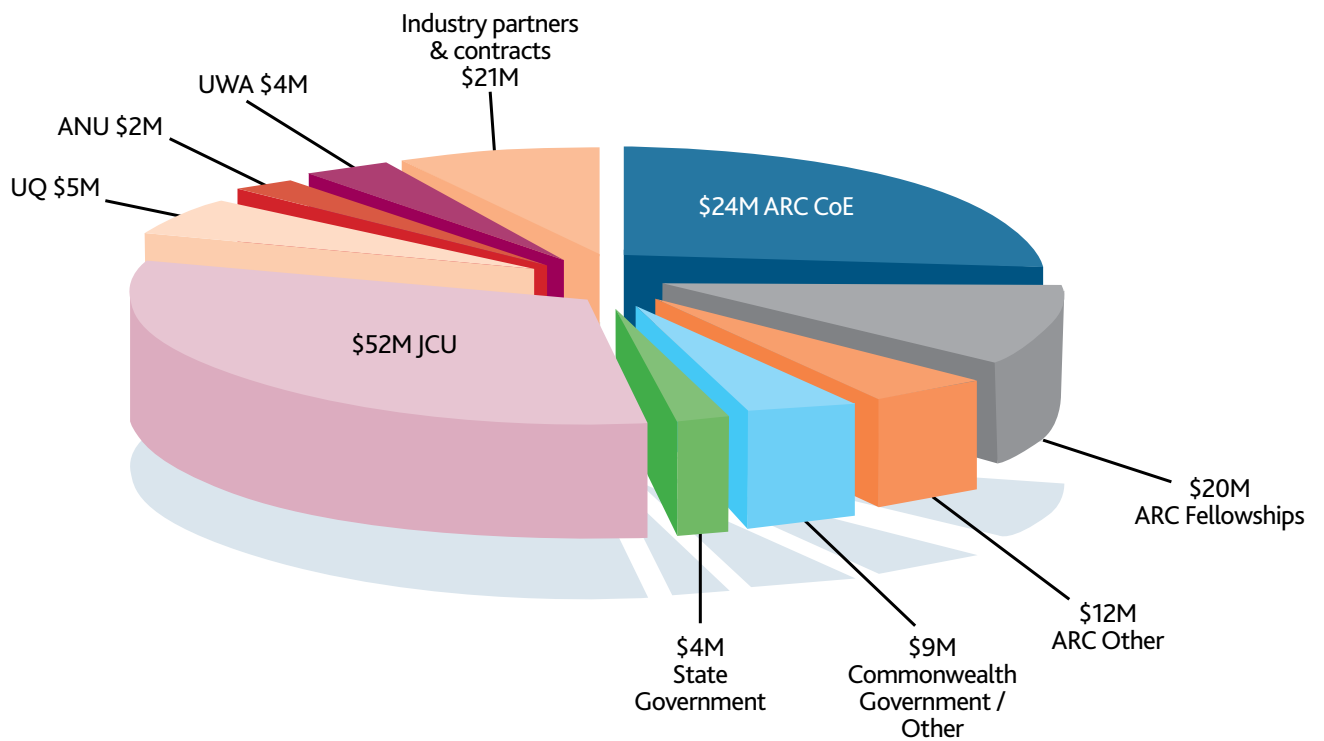
# Financial Statement

## ARC Centre of Excellence for Coral Reef Studies Statement of Operating Income and Expenditure for year ended 31 December 2013

Income	2012 \$	2013 \$
ARC Centre Grant	\$3,075,865	\$3,194,205
Host Institutions cash support	2,710,937	3,119,268
State Government	432,500	331,000
Commonwealth Government other grants	994,512	819,358
International and other contracts	970,172	716,780
ARC Fellowships	1,872,293	1,599,047
ARC Discovery	79,112	82,156
ARC Linkages	231,196	87,533
<b>Total Income</b>	<b>\$10,366,587</b>	<b>\$9,949,347</b>
Expenditure		
Salaries	\$6,659,259	\$5,853,865
Equipment	500,157	316,120
Travel	1,631,194	1,147,762
Research maintenance and consumables	1,455,466	938,325
Scholarships	95,478	130,979
Public outreach and administration	298,421	176,102
<b>Total Expenditure</b>	<b>\$10,639,974</b>	<b>\$8,563,153</b>
<b>Surplus (Deficit)</b>	<b>(\$273,386)</b>	<b>\$1,386,194</b>

# Financial Outlook

As at December 2013 the total cash and inkind budget for the ARC Centre of Excellence for Coral Reef Studies for 1 July 2005 to 31 December 2013 totals \$152M, 4.8 times the funding outlook when the Centre was established in 2005.



# Acknowledgements

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- Australian Academy of Science, Canberra
- Australian Centre for International Agricultural Research (ACIAR)
- Australian Coral Reef Society
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- Australian Government: Department of the Environment
- Australian Government: Department of Agriculture
- Australian Institute of Marine Science (AIMS)
- Beijer Institute for Ecological Economics, Sweden
- Bioplatforms Australia
- Boston University, USA
- Brazilian Government
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- Conservation International, Philippines
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- ETH Zurich, Switzerland
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- King Abdullah University of Science and Technology, Saudi Arabia
- Lizard Island Research Station, Queensland
- Malacological Society of Australasia
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- National Aeronautics and Space Administration (NASA), USA
- National Environment Research Program, Australia
- National Oceanic and Atmospheric Administration (NOAA), USA
- National Parks Association of Queensland
- National Science Foundation (NSF), USA
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- Northern Gulf Resource Management Group, Queensland
- NSF Research Coordination Network for Marine Disease, USA
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- Palawan State University, Philippines
- Palmyra Atoll Research Station, USA
- Queensland Department of Agriculture, Fisheries and Forestry
- Queensland Department of National Parks, Recreation, Sport and Racing
- Queensland Department of Science, Information Technology, Innovation and the Arts
- Queensland Department of the Premier and Cabinet
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- Reef Catchments Natural Resource Management, Mackay
- Reef and Rainforest Research Centre, Cairns
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- Royal Swedish Academy of Science, Sweden
- Save Our Seas Foundation, Switzerland
- Schmidt Ocean Institute, USA
- Sea World Research and Rescue Foundation, Australia
- Secretariat for the Pacific Community, New Caledonia
- Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Japan
- Seychelles Fishing Authority
- Silliman University, Philippines
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- Western Australian Department of Parks and Wildlife
- Western Australian Department of Premier and Cabinet
- Western Australian Marine Science Institution
- Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, New York
- Woods Hole Oceanographic Institution, USA
- World Commission on Protected Areas, Switzerland
- WorldFish, Malaysia
- World Wildlife Fund







“


I want to become a  
marine scientist now.

Diasha Johnson, 14  
*Aboriginals and Torres Strait Islanders in  
Marine Science participant*

”



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Coral Reef Studies



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