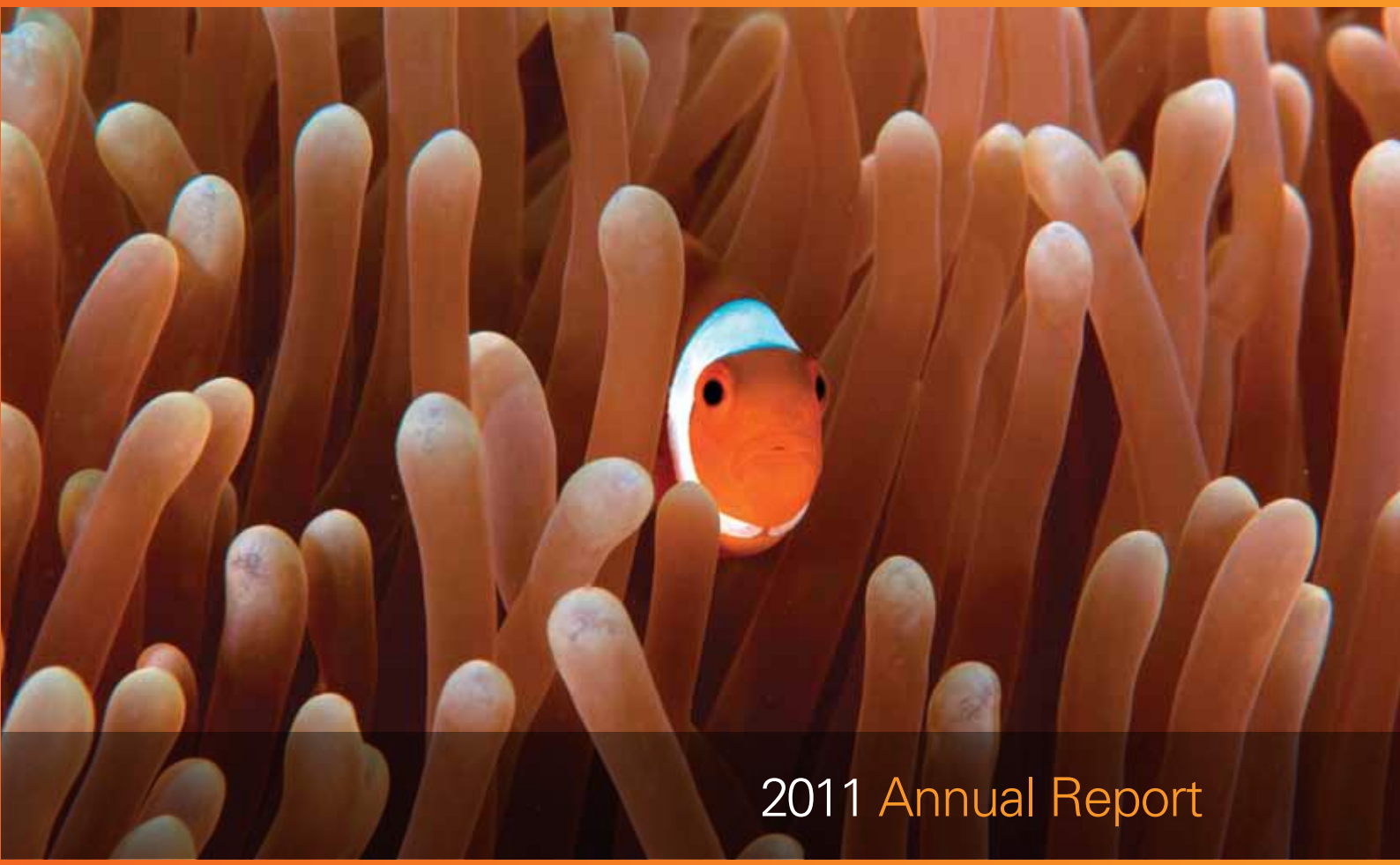
ARC Centre of Excellence
Coral Reef Studies



2011 Annual Report

ARC CENTRE OF EXCELLENCE

CORAL REEF STUDIES

2011 ANNUAL REPORT

CONTENTS

Cover Photos by Tom Bridge

Photo by Tom Bridge

Vision

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

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.

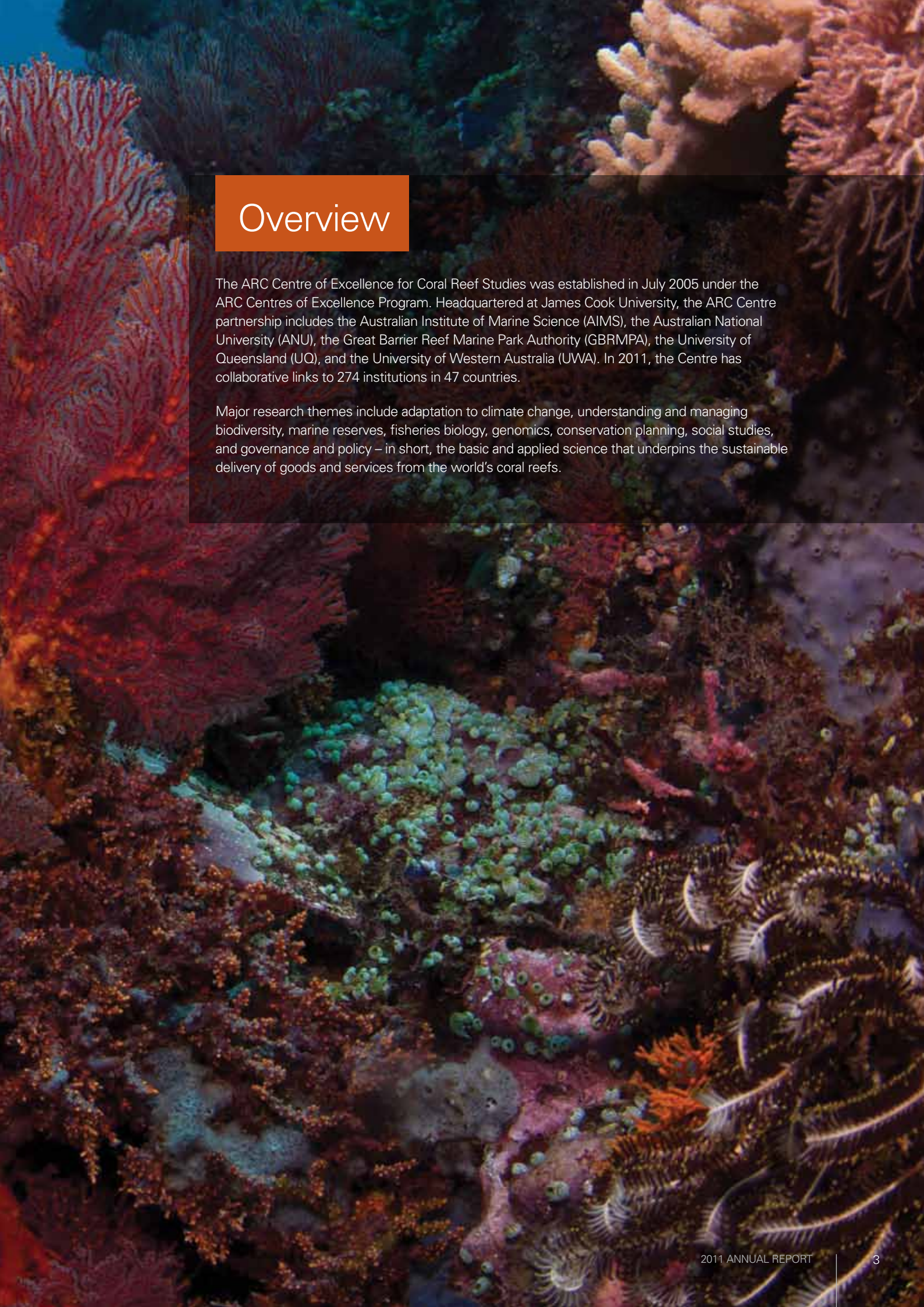
2. **Research Training and Professional Education**
   The Centre attracts and trains outstanding coral reef scientists at all stages of career, to build human capacity and expertise in coral reef science world-wide.

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.



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 2011, the Centre has collaborative links to 274 institutions in 47 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.

Photo by Tom Bridge

Director's Report

Welcome to our 2011 annual report. The *ARC Centre of Excellence for Coral Reef Studies* was established in 2005, making this our sixth annual report. Over the past few years we have achieved sustained growth in our research activities, publications, outreach and research training. This year, as the Centre continues to expand and mature, our fieldwork was undertaken in 25 tropical countries with a major focus on Australia, Fiji, French Polynesia, Kenya, the Philippines, Indonesia, Papua New Guinea and the Solomon Islands. Programs 3, 5, 6 and 7 were particularly active in the Coral Triangle region to the north of Australia, focusing on the ecology and design of marine parks, social science, and coral reef management and governance.

The Centre's publication output also continues to grow, with a record 263 publications in 2011. Our co-authors this year come from 274 institutions in 47 countries, reflecting our expanding collaborative network around the world. The Centre's research program summaries on pp.18–33 provide many examples of our activities throughout 2011.

2011 saw the retirement of Dr Ian Poiner from the Centre Advisory Board following the completion of his tenure as Chief Executive Officer of the Australian Institute of Marine Science. Dr Poiner has been a Board member since its establishment in 2005. The Centre of Excellence expresses its sincere thanks to Dr Poiner for the invaluable advice, support and friendship he has given the Centre and its members. We look forward to welcoming John Gunn, the new Chief Executive Officer of AIMS to the Centre's first Board meeting in 2012.

At the end of 2011, the Centre's membership stands at 21 Chief Investigators, 39 research fellows and 181 graduate students (from 43 countries). Membership of the Centre in 2011 has been further enhanced by the recruitment of 79 new graduate and Honours students, while 41 postgraduates completed, and the appointment of 14 new research fellows, including five round-2 ARC Super Science Fellows (for 2011-2013) and an Australian Research Fellow (2011-2015). In addition, in 2011, we hosted 98 international visitors to the Centre's nodes in Townsville, Brisbane, Perth and Canberra.

We provided more than 70 briefings, workshops and consultancies during the year to governments, management agencies, Non-Government Organisations and business organisations. Examples include Australian Commonwealth Departments, Deutsche Forschungsmeinschaft, Fisheries Research & Development Corporation, the Great Barrier Reef Marine Park Authority, International Union for Conservation of Nature, National Oceanic and Atmospheric Administration, Solomon Island Ministries, The Nature Conservancy, and USAid.

Outreach activities during 2011 included our annual symposium, held this year in Western Australia, at the Maritime Museum in Fremantle. The Centre's newest node at the University of Western Australia is led by Deputy Director Malcolm McCulloch, and many of the talks focused on new research programs underway on the west coast. Web recordings of 35 talks, including a very successful public forum, are posted at *www.coralcoe.org.au/events/symposium11/program.html*.

The Centre's website received 7.6 million hits and 287,000 visits in 2011, with 96% coming from outside Australia. The Centre's media coverage has also continued to grow rapidly during 2011, with more than 3,000 stories featuring the Centre's research activities published or broadcast around the world in the past year (p.50).

Looking forward to 2012, the ARC Centre will host in Australia more than 2,000 conference delegates from the global coral reef research community, when we have the honour of convening the *12th International Coral Reef Symposium* (ICRS2012) in Cairns. These four-yearly meetings are the world's largest and premier forum for the dissemination and discussion of coral reef science and management (see p.49). We have designed an exciting program of more than 1,500 talks and posters, which will make this 12th symposium the largest ever held to date.

Lastly, I'd like to express my gratitude to our many friends around the world for their contributions to a sixth outstanding year, and to the Centre's Advisory Board, and our partners from the *Australian Institute for Marine Science, The Nature Conservancy, WorldFish* and the *Great Barrier Reef Marine Park Authority*. I am especially grateful to the Centre's talented administrative team - Jenny Lappin, David Yellowlees, Olga Bazaka, Rose-Marie Vasiljuk, Janet Swanson, Louise Lennon, Eliza Glasson, Andrew Lo-A-Tong and Hayley Ware – for the key roles they play behind the scenes.

Terry Hughes
Director

Governance

James Cook University is the administering organisation of the ARC Centre of Excellence. The Centre Director, Terry Hughes, reports directly to Professor Chris Cocklin, the Senior Deputy Vice-Chancellor with responsibility for Research and Innovation. The Centre's Chief Investigators are located in three faculties at JCU, 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. 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 governance structures are designed to involve stakeholders in planning and management processes. The chart on page 8 illustrates the current governance structure and relationships.

Centre Advisory Board

The ARC Centre's Advisory Board provides vision and strategic advice to the Centre Director. It facilitates strengthened linkages between the Centre, industry and government to advocate and promote the Centre, and seeks to improve linkages nationally and internationally between the Centre and end-users to facilitate uptake 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 Centre Advisory Board matches the Centre's strong international linkages and multi-disciplinary research activities. We are privileged to have access to the expertise and experience of these leaders and extend our thanks to them for their advice. The Board met twice in 2011: on 1st March in Townsville and 19th October in Fremantle.

The Centre Advisory Board's membership comprises:

Dr Brian Walker (Chair), CSIRO
Sustainable Ecosystems

Dr Neil Andrew
Director, Natural Resources Management
The WorldFish Center, Malaysia

Professor Terry Hughes
ARC Centre Director and Federation Fellow

Dr Ian Poiner
Chief Executive Officer
Australian Institute of Marine Science

Andrew Skeat
General Manager
Great Barrier Reef Marine Park Authority

John Tanzer
Principal
Environmental Pathways and Solutions

Professor Mandy Thomas
Pro Vice-Chancellor (Research and Graduate Studies)
Australian National University

Scientific Management Committee

Ongoing operational management of the Centre and planning for its scientific research program is the responsibility of the Scientific Management Committee (SMC). The SMC is chaired by an eminent Israeli researcher, Professor Yossi Loya. Other members are the leaders of each of the Centre's eight Research Programs, and Dr David Wachenfeld, the Director of Ecosystem Conservation and Sustainable Use at the Great Barrier Reef Marine Park Authority, the Centre's principal end-user in Australia. Priorities for each meeting include reviewing and expanding the objectives and operations for the Centre's research programs, developing international collaborations and engagements, recruiting high-quality postdoctoral fellows, and effectively communicating the Centre's research to the broader community. The Committee met formally three times in 2011: on 7th April and 11th August in Townsville, and 18th October in Fremantle.

In 2011, the Scientific Management Committee focused on research program planning and development, strategic recruitment of research fellows, planning for the International Coral Reef Symposium in 2012 (see p.49) and longer term positioning of the Centre for its business continuity.

Scientific Management Committee Members are:

Professor Yossi Loya (Chair)
Professor of Marine Biology
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

Professor Malcolm McCulloch FAA FRS
Winthrop Professor and Premier's Fellow
School of Earth and Environment
University of Western Australia

Professor Sean Connolly
School of Marine and Tropical Biology
James Cook University

Professor Garry Russ
School of Marine and Tropical Biology
James Cook University

Professor Ove Hoegh-Guldberg
Premier's Fellow and Director
Global Change Institute
University of Queensland

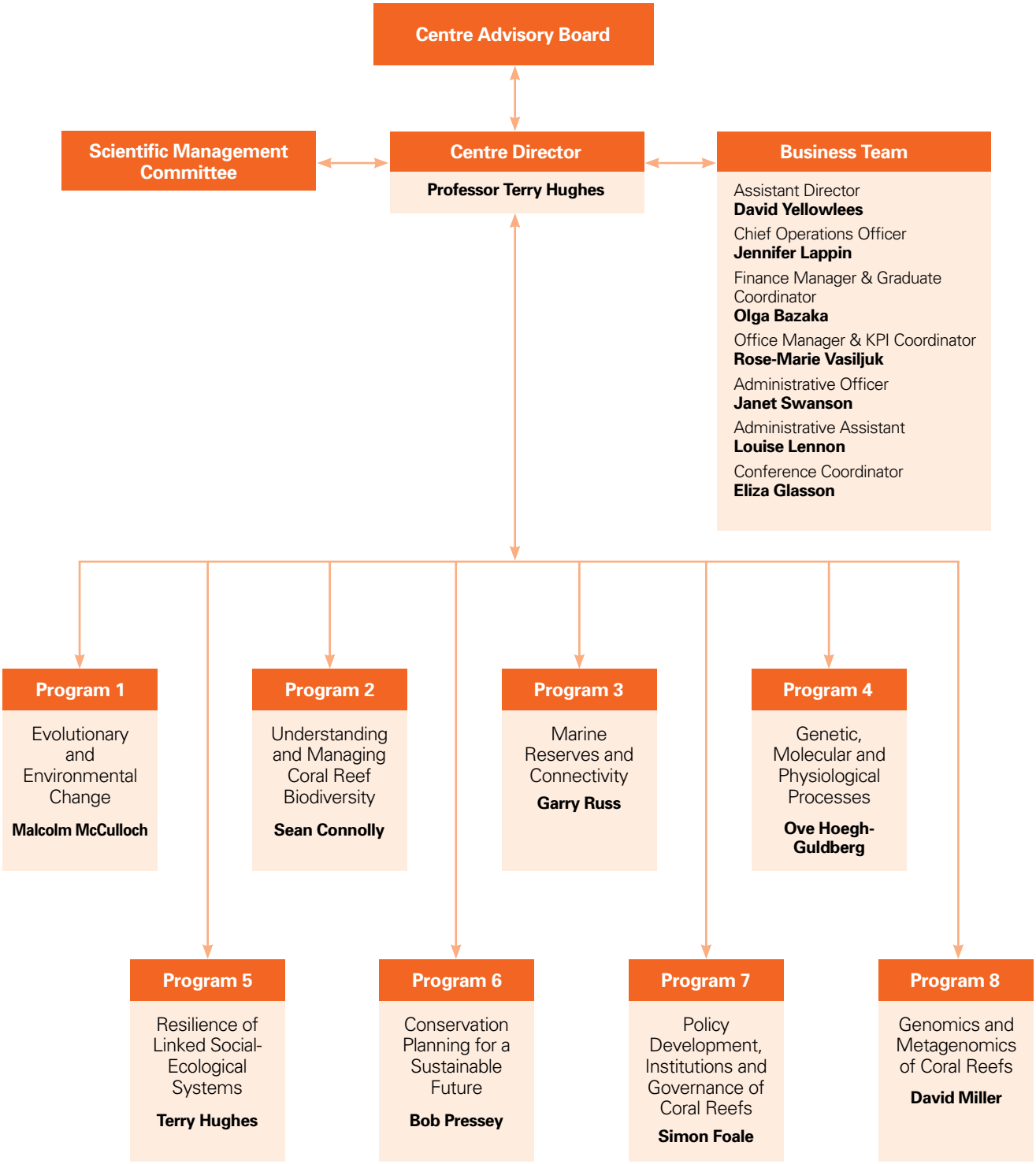
Professor Terry Hughes FAA
Federation Fellow and Director
ARC Centre of Excellence for Coral Reef Studies
James Cook University

Professor Bob Pressey FAA
ARC Centre of Excellence for Coral Reef Studies
James Cook University

Dr Simon Foale
ARC Centre of Excellence for Coral Reef Studies
James Cook University

Professor David Miller
School of Pharmacy and Molecular Sciences
James Cook University

Management Structure



Membership

Researchers

In 2011, the Centre's membership comprised 60 Chief Investigators and research fellows, 8 Partner Investigators, 7 resident international scholars and 18 adjunct researchers. Eighteen of the Centre's research fellows are funded by ARC schemes (Federation, Discovery grant fellowships, Laureate, Linkage, Future and Super Science), two are Queensland Smart Futures Fellows, one is a Queensland Premier's Fellow and one is a Western Australian Premier's Fellow.

Chief Investigators, Research Fellows and Partner Investigators

Professor Terry Hughes
Centre Director,
ARC Federation Fellow
James Cook University

Dr Tracy Ainsworth
ARC Australian Postdoctoral Fellow and Super Science Fellow
James Cook University

Dr Glenn Almany
ARC Future Fellow
James Cook University

Dr Kenneth Anthony
Chief Investigator
University of Queensland

Dr Andrew Baird
ARC Future Fellow
James Cook University

Dr Natalie Ban
ARC Australian Postdoctoral Fellow
James Cook University

Dr Line Bay
Research Fellow
James Cook University

Dr Maria Beger
Research Fellow
University of Queensland

Professor David Bellwood
Chief Investigator
James Cook University

Dr Anthony Bertucci
Super Science Fellow
James Cook University

Dr Severine Choukroun
Research Fellow
James Cook University

Dr Joshua Cinner
ARC Australian Research Fellow
James Cook University

Professor Sean Connolly
ARC Australian Professorial Fellow
James Cook University

Dr Ian Craigie
Research Fellow
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
Research Fellow
James Cook University

Dr James Falter
Research Fellow
University of Western Australia

Dr Pedro Fidelman
Research Fellow
James Cook University

Dr Joana Figueiredo
Research Associate
James Cook University

Dr Simon Foale
Research Fellow
James Cook University

Professor Carl Folke
Partner Investigator
Stockholm University

Dr Sylvain Forêt
Research Fellow
James Cook University and
Australian Institute of Marine Science

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
ARC Australian Postdoctoral Fellow and Queensland Smart Futures Fellow
James Cook University

Dr Alana Grech
Research Fellow
James Cook University

Professor Ove Hoegh-Guldberg
Deputy Director, Queensland Smart State Premier's Fellow
University of Queensland

Dr Michael Holcomb
Super Science Fellow
University of Western Australia

Dr Mia Hoogenboom
Research Fellow
James Cook University

Professor Geoffrey Jones
Chief Investigator
James Cook University

Dr Paulina Kaniewska
Research Fellow
University of Queensland

Professor Ronald Karlson
Partner Investigator
University of Delaware

Dr Sally Keith
Research Fellow
James Cook University

Professor Michael Kingsford
Chief Investigator
James Cook University

Dr Johnathan Kool
Research Fellow
James Cook University and
Australian Institute of Marine Science

Dr Bill Leggat
Chief Investigator
James Cook University

Professor Janice Lough
Partner Investigator
Australian Institute of Marine Science

Dr Vimoksalehi Lukoschek
Queensland Smart Futures Fellow
James Cook University

Dr Laurence McCook
Partner Investigator
Great Barrier Reef Marine Park
Authority

Dr Mark McCormick
Chief Investigator
James Cook University

Professor Malcolm McCulloch
Deputy Director, Western Australia
Premier's Fellow
University of Western Australia

Dr Mark Meekan
Partner Investigator
Australian Institute of Marine Science

Dr Vanessa Messmer
Research Fellow
James Cook University

Professor David Miller
Chief Investigator
James Cook University

Professor Peter Mumby
Australian Laureate Fellow
University of Queensland

Professor Philip Munday
ARC Queen Elizabeth II Fellow
James Cook University

Professor John Pandolfi
Chief Investigator
University of Queensland

Dr Serge Planes
Partner Investigator
University of Perpignan

Dr Morgan Pratchett
ARC Australian Research Fellow
James Cook University

Professor Bob Pressey
Research Fellow
James Cook University

Dr Nela Rosic
Research Fellow
University of Queensland

Dr Jodie Rummer
Super Science Fellow
James Cook University

Professor Garry Russ
Chief Investigator
James Cook University

Dr Susanne Sprungala
Research Associate
James Cook University

Professor Robert Steneck
Partner Investigator
University of Maine

Dr Ruth Thurstan
Research Fellow
University of Queensland

Dr Linda Tonk
Research Fellow
University of Queensland

Professor Madeleine van Oppen
Partner Investigator
Australian Institute of Marine Science

Dr Stefan Walker
Research Fellow
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 Zhenlin Zhang
Super Science Fellow
University of Western Australia

Resident International Scholars

Dr Rodolphe Devillers
Associate Professor, Department of Geography
Memorial University of Newfoundland, Canada

Dr Andrew Hoey
Research Fellow
King Abdullah University of Science and Technology, Saudi Arabia

Dr Stephanie Manel
Lecturer
Université de Provence, France

Dr David Mills
Research Fellow
WorldFish Center, Malaysia

Professor David Mouillot
Marie Curie Fellow
Montpellier University, France

Dr Aurélie Moya
Marie Curie Fellow
University of Nice, France

Dr Mathieu Pernice
Marie Curie Fellow
University of Pierre and Marie Curie, France

Adjunct Researchers

Dr Vanessa Adams
Charles Darwin University

Professor Serge Andréfouet
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

Dr Alison Green
The Nature Conservancy

Dr Richard Hamilton
The Nature Conservancy

Dr Alexander Kerr
University of Guam, USA

Maurice Knight
World Wildlife Fund, USA

Professor Janice Lough
Australian Institute of Marine Science

Professor Yossi Loya
Tel Aviv University, Israel

Dr Laurence McCook
Great Barrier Reef Marine Park Authority

Dr Shunichi Takahashi
Australian National University

Professor John Tanzer
Environmental Pathways and Solutions Consultants

Professor Madeleine van Oppen
Australian Institute of Marine Science

Dr David Wachenfeld
Great Barrier Reef Marine Park Authority

Graduate Students

(see page 36)

Research Support Staff

Lewis Anderson
James Cook University

Giovanni Bernal Carrillo
University of Queensland

Andrea Biondo
University of Western Australia

Mary Bonin
James Cook University

Maya Carmi
University of Queensland

Aaron Chai
University of Queensland

Maria Gomez-Cabrera
University of Queensland

Mizue Hisano
James Cook University

Cindy Huchery
James Cook University

Alex Piekutowski
University of Western Australia

Kai Rankenburg
University of Western Australia

Dr Maya Srinivasan
James Cook University

Jenn Tanner
James Cook University

Anna Van Den Heuvel
University of Queensland

Dr Sue-Ann Watson
James Cook University

Matthew Young
James Cook University

Business Team

Jennifer Lappin
Chief Operations Officer
James Cook University

David Yellowlees
Assistant Director
James Cook University

Olga Bazaka
Finance Manager and Graduate Coordinator
James Cook University

Eliza Glasson
ICRS Conference Coordinator
James Cook University

Louise Lennon
Administrative Assistant
James Cook University

Andrew Lo-A-Tjong
Administrative Officer
University of Western Australia

Janet Swanson
Administrative Assistant
James Cook University

Rose-Marie Vasiljuk
Office Manager and KPI Officer
James Cook University

Hayley Ware
Administrative Officer
University of Queensland

Research Program Leaders

Professor Sean Connolly

ARC Professorial Fellow Sean Connolly, from James Cook University, 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 50 publications in leading international journals, including 5 papers in *Science* or *Nature*, and he has supervised 25 Postgraduate and Honours students since 2001. He currently holds an Australian Professorial Fellowship from the Australian Research Council, and was awarded the *Fenner Medal* of the Australian Academy of Science in 2009, which honours outstanding research in the biological sciences by a scientist under 40.

Dr Simon Foale

Senior Research Fellow Simon Foale leads the ARC Centre's Program 7: *Policy development, institutions and governance of coral reefs*. He joined the Centre in late 2006, after a postdoctoral fellowship at the Australian National University's Resource Management in Asia Pacific Program. Simon is a marine biologist who, since his PhD was awarded in 1998 at the University of Melbourne, has been increasingly engaging with the social sciences to address pressing fishery management issues in the Pacific, particularly in the Solomon Islands and Papua New Guinea. Simon has very broad applied experience in the Pacific, having worked for non-government conservation organisations, mining companies, regional agencies, governments and aid agencies. He publishes in a wide range of journals spanning the natural and social sciences. Simon's current research examines political, social and economic aspects of fishery use and management in Melanesia, with a particular emphasis on developing locally relevant and culturally appropriate educational resources for improving coral reef fishery management.

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 has published over 200 papers, including 16 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 fate in the face of rapid climate change, and maintains an active blog, which regularly features the ARC Centre's research. In 2008, Ove was awarded the prestigious Queensland Premier's Smart State Fellowship (2008-2013).

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". He has been awarded two Federation Fellowships by the Australian Research Council, from 2002-2012, and is a Fellow of the *Beijer Institute for Ecological Economics*, in Stockholm. In 2007 he was awarded the *Sherman Eureka Prize for Environmental Research*. From 2008-2010, he was a member of the *ARC Advisory Council* and is a Board Member of the *Resilience Alliance* and the *Beijer Institute*. 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* and ranked first in Australia for citations in Ecology & Evolution. In 2008, he was awarded the prestigious quadrennial *Darwin Medal* by the International Society for Reef Studies.

Professor Malcolm McCulloch

Professor Malcolm McCulloch is one of the Centre's two Deputy Directors and Leader of Program 1: *Evolutionary and environmental change*. He is a Winthrop Professor in the School of Earth and Environment at the University of Western Australia, Perth, and a Western Australian Premier's Fellow (2009-2013). In 2010, Malcolm was elected Fellow of the Royal Society in recognition of his work in developing innovative new indicators of climate change preserved in coral skeletons. Malcolm's research interests focus on the recent geologic 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 has received a number of prestigious awards, including Fellowships of the Australian Academy of Science (2004), the Geological Society of Australia (2007), the Geochemical Society (2008) and the American Geophysical Union (2002) and the *Jaeger Medal in Earth Sciences* by the Australian Academy of Science (2009). Malcolm holds an Honorary Doctorate from Curtin University, and he is an *ISI Highly Cited Researcher*. His >250 scientific papers have been published in leading international journals including 23 articles in *Science* or *Nature*.

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 in 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 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 James Cook University Distinguished Professor. His most recent recognition is his election in 2010 as a Fellow of the Australian Academy of Science, for his contributions to the field of systematic conservation planning. Bob is leading research projects in the Asia-Pacific region, from the Philippines to Fiji, and further afield in Mexico and Brazil.

Professor Garry Russ

Professor Garry Russ, from the School of Marine and Tropical Biology at James Cook University, is Leader of Program 3: *Marine reserves and reef connectivity*. Garry studies the biology of reef fish of commercial and recreational fishing significance (mostly serranids, lutjanids and lethrinids). A major area of his applied research involves population and community dynamics of reef fish of commercial significance. In the Coral Triangle region and Australia, he is undertaking long-term (>25 year) studies of reef fish populations inside and outside marine reserves. Russ received his PhD from the University of Melbourne in 1981. Subsequently he was awarded an ARC Queen's Fellowship at the Australian Institute of Marine Science. Garry moved from the University of Sydney to JCU in 1988 where he is currently a Professor in Marine Biology. Garry has published over 75 papers in international journals. In 1999, he received a prestigious Pew Fellowship in Marine Conservation jointly with his long-time colleague Dr Angel Alcala. In 2007, he was awarded recognition for his contributions to management of the Great Barrier Reef, by the Great Barrier Reef Marine Park Authority.

Business Leaders

Jennifer Lappin

Jennifer Lappin is the Chief Operations Officer of the ARC Centre of Excellence. Jennifer has a Bachelor of Commerce degree from the University of Queensland and is a Certified Practicing Accountant. She has over 20 years of senior management experience with responsibilities for strategic planning, financial management, facilities planning and management, human resources, communications, 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 started 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 Centre of Excellence to oversee, with the Centre Director, its 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 since the mid 1980s. 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 the transfer of this 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 in a part time capacity 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 award nominations, 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.

Researcher Profile

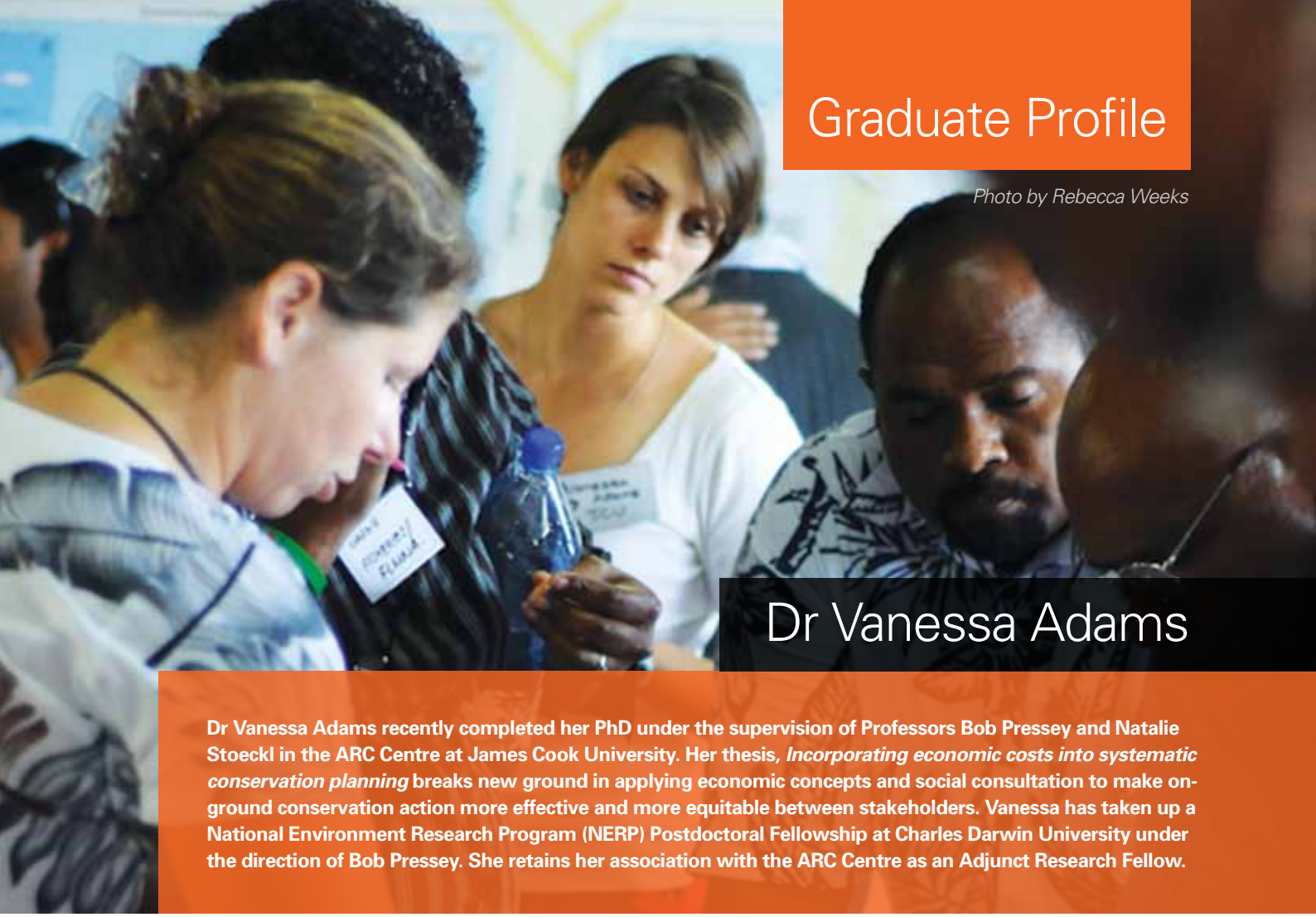
Professor John Pandolfi

John was awarded his PhD by the University of California-Davis in 1987 before he embarked on postdoctoral fellowships at the Australian Institute of Marine Science and the Smithsonian Tropical Research Institute in Panamá. In 1997, he took up a position as a Research Palaeobiologist at the National Museum of Natural History in Washington D.C. In 2003, he was awarded the Smithsonian Institution's Scientific Achievement Award. In 2004, he returned to Australia, where he is now a Professor and Chief Investigator at the ARC Centre's University of Queensland node in Brisbane.

John's novel research integrates palaeoecological, ecological, historical and climate data to provide critical insights into how natural communities are assembled and structured in the face of environmental variability over extended periods of time. His most significant contributions to ecology and palaeoecology have been in four main areas: the evolution and biogeography of colonial organisms; coral reefs and climate change; the long-term ecological dynamics of coral reef communities; and the historical ecology and management of coral reefs. John's main contributions to the ARC Centre are in Programs 1 and 2 (*Evolutionary and environmental change,* and *Understanding and managing coral reef biodiversity*).

"One of the most important questions in ecology is: how are species, and hence biodiversity, maintained in ecological communities?" says John. He has pioneered a rapidly evolving field of marine palaeoecology that uses the recent past history (hundreds of thousands of years) of living species to investigate ecological dynamics over meaningful time periods. For example, his work in Western Australia documents poleward migration by extant (still living) species during past periods of global warming, showing that corals and other reef species can respond to climate change by extending their geographic range. John's chief collaborators in the ARC Centre are David Bellwood, Sean Connolly and Terry Hughes, all of whom are based at James Cook University, exemplifying the cross-nodal integration that the Centre has achieved over the past five years.

According to John, "Perhaps the most pressing issue for conservation science is: What was natural in the world before humans impacted it?" Together with an international team of leading ecologists, oceanographers, archaeologists and social scientists, John's work documents in broad terms the history of human alterations in the sea, identifying overfishing as the first and farthest reaching cause of decline in coastal marine ecosystems. In a seminal paper published in *Science* in 2003, John and his colleagues investigated the history of ecosystem changes among 14 different tropical reef sites worldwide. This work informed the Australian government's decision to set aside 33% of the Great Barrier Reef as no-take areas in 2004. This novel approach was later expanded to include US sites (*Science 2005 - Policy Forum*) and to convince the US government to enact legislation to protect more of its coral reefs which it did in Hawaii the following year. In 2011, John and colleagues published a major review in *Science*, entitled *Projecting coral reef futures under global warming and acidification* (see p.19), which lays out a critical research agenda for coming years.



Graduate Profile

Photo by Rebecca Weeks

Dr Vanessa Adams

Dr Vanessa Adams recently completed her PhD under the supervision of Professors Bob Pressey and Natalie Stoeckl in the ARC Centre at James Cook University. Her thesis, *Incorporating economic costs into systematic conservation planning* breaks new ground in applying economic concepts and social consultation to make on-ground conservation action more effective and more equitable between stakeholders. Vanessa has taken up a National Environment Research Program (NERP) Postdoctoral Fellowship at Charles Darwin University under the direction of Bob Pressey. She retains her association with the ARC Centre as an Adjunct Research Fellow.

Vanessa graduated in Biology and Mathematics from Washington and Lee University in the USA and joined the Centre following a period as a Fulbright Fellow in Professor Hugh Possingham's group at the University of Queensland. However, Vanessa's skills go well beyond conservation planning. For nearly four years she worked as an actuarial analyst for the international human resources and finance company Mercer HR. Prior to that she had worked as a laboratory manager and mathematics tutor.

Her thesis investigated how to include social preferences and economic costs as a selection criteria for new protected areas. This led to the discovery that including social and economic factors shifted priority conservation areas to more financially and socially feasible areas, and avoided imposing inequitable costs on different groups of stakeholders in her study regions. She said that her over-riding philosophy was that "for a marine protected area to work, the people living around it have to trust it to deliver both conservation goals and the needs of the community. They have to be comfortable with it – otherwise they won't comply with it."

Vanessa's PhD research used a number of different case studies to investigate different aspects of her research question. These were in diverse geographical and ecological contexts including the expansion of the Queensland protected area system to 12 million ha, reconfiguring of the marine protected area network in the Kubulau district of Fiji (see p.27), the Mbaracayu Forest Biosphere Reserve in Paraguay and the stewardship program in the Daly River catchment of the Northern Territory of Australia. To date, she has published nine papers in international peer-reviewed journals. Seven of these stem from her PhD, one of which won a *Virginia Chadwick Award* from the ARC Centre of Excellence in 2010.

Uptake of research by end-users is a major motivation for Vanessa. She can claim some success in this with her research influencing government conservation policies in both Queensland and the Northern Territory. In particular, she explains, her research has influenced the promised expansion of the Queensland protected area system and has fostered a continued collaboration with the Queensland Department of Environment and Resource Management.

Looking forward, Vanessa said she would like to utilise her skills by moving to a position within a funding organisation such as the Global Environment Facility or The World Bank. This, she indicated, will enable her to develop, within organisations, a stronger understanding of the costs of conservation and the consequent implications of undertaking conservation actions in regions of high poverty.

Vanessa has received a number of awards during her studies. Apart from the Fulbright Fellowship which brought her to Australia from the USA, she has also received an Australian-American Association Sir Keith Murdoch Fellowship.

Research

Program 1
Evolutionary and Environmental Change

Researchers

- **Malcolm McCulloch** (Program Leader)
- **Sean Connolly** (Research Fellow)
- **Delphine Dissard** (Research Fellow)
- **James Falter** (Research Fellow)
- **Ove Hoegh-Guldberg** (Research Fellow)
- **Michael Holcomb** (Research Fellow)
- **Terry Hughes** (Research Fellow)
- **Michael Kingsford**
- **Janice Lough**
- **John Pandolfi**
- **Robert Steneck**
- **Ruth Thurstan** (Research Fellow)
- **Zhenlin Zhang** (Research Fellow)

Understanding how coral reefs are responding to the ongoing effects of both climate and environmental changes is the major objective being addressed by Program 1. Global warming and ocean acidification are already changing the physiology, ecology and geology of coral reefs in ways that are still poorly understood. In order to meet these growing challenges, researchers in Program 1 have combined resources to develop and apply novel geochemical methods, historical records and ecological studies to identify and understand changes in biodiversity and ecosystem function, over a range of timeframes. With the establishment of the new node of the ARC Centre at UWA, a series of new studies have now been initiated across the wide range of coral reef ecosystems that occur along the Western Australian coastline. This region is unique in that coral reefs occur over a wide latitudinal gradient ranging from ~12°S to 32°S, encompassing an unusually diverse range of environments.

A broad range of studies have been launched this year at Ningaloo Reef, the Abrolhos Islands, and at Marmion and Rottnest Island, offshore from Perth. Led by Program Leader Malcolm McCulloch, these projects focus on locations that are subject to relatively benign conditions, with seasonal temperatures generally in the range from 20°C to 26°C, that are strongly moderated by the southward flowing Leeuwin Current. These systems are of special interest because terrestrial inputs from river systems are minimal because of low rainfall. Hence the reefs are mainly responsive to the natural variability in marine conditions and, importantly, are influenced by the combined forces of climate change and ocean acidification. In the Kimberley region to the north, maximum temperatures in exposed tidal pools can exceed 35°C with daily fluctuations from ~25°C to ~35°C. The resilience of coral to such an extreme range of conditions is being investigated by PhD student Sana Dandan under Malcolm's supervision, with the assistance of the Cygnet Bay Pearling Station. The extent of coral calcification is being determined over this width of usually high temperatures as well as the wide range of seasonal conditions associated with the wet and dry seasons. Ongoing measurements that will continue into next year show that corals are able to sustain relatively high levels of calcification, demonstrating the importance of local adaptation to such extreme and widely varying environmental conditions.

A major milestone in 2011 has been the commissioning and opening of the new *Advanced Geochemical Facility for Indian Ocean Research* at UWA. Using these facilities, Program 1 researchers achieved an important breakthrough in our understanding of how the physiological controls on calcification are being affected by decreasing seawater pH from ocean acidification. Boron isotope systematics indicate systematic pH up-regulation at the site of calcification which acts as a buffer to emolliate external changes in seawater pH during calcification. This process effectively enhances the resilience of corals to ocean acidification.

John Pandolfi and colleagues published two major papers in *Science* in 2011. The first, co-authored with ARC Professorial Fellow Sean Connolly and others, is a comprehensive review of the predicted influence of global climate change on the future of coral reefs. The analysis integrates findings from palaeontology, evolution, ecology, and physiology, to identify likely causes and consequences of variability in reef responses to climate change, and it assesses implications for management. The second paper examines the shifting climate and seasonal patterns on land and in the oceans, by integrating historical data on sea surface temperatures over the past 50 years. The pace of climate change has been higher in the ocean than on land at some latitudes, despite slower ocean warming. A particular challenge for conservation and management is that areas of high marine biodiversity often have greater velocities of climate change and seasonal shifts. Program 1 students supervised by John published numerous papers this year, including studies on the ecological dynamics of reef foraminifera from Papua New Guinea, the relationship between past environmental change (both anthropogenic and natural climatic), reef development and composition from reefs in Moreton Bay, Queensland, and the historical reconstruction of reef decline and recovery in Hawaii.

Photo by K-le Gomez

Climate will damage reef "at different rates"

Climate change and acidifying ocean water are likely to have a highly variable impact on the world's coral reefs, in space, time and diversity, international coral scientists caution.

The picture emerging from studies of past coral extinctions and present impacts on today's reef systems is complex and subtle and will demand much more sophisticated management to preserve reefs intact, the team of scientists said in a paper in the international journal *Science*.

"New research confirms that coral reefs…. are indeed threatened by climate change, but that some current projections of global-scale collapse of reefs within the next few decades probably overestimate the rapidity and uniformity of the decline," the researchers say.

"A considered view of all the most recent evidence suggests that some coral reef systems will decline more rapidly – especially those subject to other human pressures such as overfishing – while others may change in composition, but manage to persist for longer," says lead author John Pandolfi of the ARC Centre of Excellence for Coral Reef Studies.

"Coral reefs occupy a small part of the world's oceans, yet harbour a hugely disproportionate amount of its biodiversity," the researchers say. "More than 450 million people from 109 countries live close to coral reefs, which provide important sources of ecosystem goods and services for these communities."

"But reefs have suffered degradation from human over-exploitation and pollution over centuries to millennia, degradation that has accelerated in the last 50 years. Global warming and ocean acidification are now compounding these threats."

However, reefs are naturally highly diverse and resilient, and are likely to respond to the changed conditions in different ways and at varying rates.

Past extinction crises in coral reef ecosystems appear to coincide with episodes of rapid global warming and ocean acidification, they say. This has led some to predict rapid, dramatic, global-scale losses of coral reefs.

"Widespread degradation of reefs is already underway. However, rates of future decline will be highly variable, because coral reefs are naturally highly diverse with some species able to cope with change more than others. Moreover, changes in ocean and climate conditions will be different in different regions, and the partnership between corals and their symbiotic algae has variable capacity to adapt to changing conditions," says Sean Connolly.

Evolution and genetic change in both creatures may make them more tolerant of major changes in ocean temperature and chemistry – but, paradoxically, it may also accelerate the decline of reef species. However, human management is necessary to improve the corals' chances. Actions that improve coral diversity will tend to make reefs more resilient. The researchers also note that large populations of reef species, not already stressed by overfishing or coastal runoff, are likely to be better able to adapt to the challenges of climate change.

"This makes the overall picture extraordinarily complex. We do not yet have a model that explains the full spectrum of reef responses everywhere," Professor Pandolfi says.

The team concludes: "The best and most achievable thing we can do for coral reefs currently to deal with climate change is to seek to manage them well".

Pandolfi, JM, Connolly, SR, Marshall, DJ and Cohen, AL (2011). Projecting coral reef futures under global warming and ocean acidification. *Science* 333(6041): 418-422.

Program 2
Understanding and Managing Coral Reef Biodiversity

Researchers

- **Sean Connolly** (Program Leader)
- **Andrew Baird** (Research Fellow)
- **Maria Beger** (Research Fellow)
- **David Bellwood**
- **Joana Figueiredo** (Research Associate)
- **Chris Fulton**
- **Nick Graham** (Research Fellow)
- **Andrew Hoey** (Visiting Research Fellow)
- **Mia Hoogenboom** (Research Fellow)
- **Terry Hughes** (Research Fellow)
- **Geoffrey Jones**
- **Sally Keith** (Research Fellow)
- **Laurence McCook**
- **Vanessa Messmer** (Research Fellow)
- **David Mouillot** (Visiting Research Fellow)
- **Peter Mumby** (Research Fellow)
- **Philip Munday** (Research Fellow)
- **John Pandolfi**
- **Morgan Pratchett** (Research Fellow)
- **Jodie Rummer** (Research Fellow)
- **Robert Steneck**
- **Ruth Thurstan** (Research Fellow)
- **Stefan Walker** (Research Fellow)

Program 2 aims to understand the mechanisms and processes that maintain coral reef biodiversity, using a combination of mathematical modelling and field studies. This multi-disciplinary approach 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.

Program 2 grew significantly in 2011, with the addition of seven new post-doctoral fellows, who have initiated projects on global warming and ocean acidification (Jodie Rummer and Vanessa Messmer), macroecology (Sally Keith), herbivory and resilience (Andrew Hoey), macrophysiology (Mia Hoogenboom), marine historical ecology (Ruth Thurstan) and evolution and sociobiology (Stefan Walker).

Program 2 research in 2011 provided several key breakthroughs in understanding how biodiversity is maintained on coral reefs, on how reefs are likely to respond to ongoing human impacts, and importantly how management can mediate those responses.

Climate change research is a major focus of Program 2. For example, in a study published in the *Proceedings of the National Academy of Sciences,* Peter Mumby questioned the assumption that climate change is linked to the observed increase in prevalence of coral disease. In *Nature Climate Change*, PhD student Jennifer Donelson, Philip Munday and Mark McCormick demonstrated that some coral reef fishes have more capacity to adjust to rising ocean temperatures than previously thought possible, because subsequent generations of fish perform better in warmer waters when their parents have also experienced the same conditions. Nick Graham and colleagues published a paper in *Ecology Letters* which developed a novel method for predicting species extinction risk, and went on to compare the combined threats of climate change and fishing on coral reef fishes, finding that the key functional groups of fish are more vulnerable to local impacts of fishing, than global effect of climate change – providing support for local policy actions for promoting reef resilience.

Other research during 2011 focused on ecosystem dynamics and evolution. Andrew Hoey and David Bellwood, in a paper published in *Ecology Letters*, uncovered unexpected vulnerabilities of reefs to outbreaks of seaweed, highlighting the need to anticipate and prevent regime shifts to seaweed-dominated states on coral reefs. In a related study, Morgan Pratchett, Joshua Cinner, Nick Graham and others showed, in a paper in the journal *PLoS Biology*, that high biodiversity does not necessarily ensure healthy ecosystem functioning of reef fish assemblages. Sean Connolly and research associate Mizue Hisano used novel statistical methods to estimate rates of reef shark population decline on the Great Barrier Reef. Their findings, published in the journal *PLoS ONE*, lend strong support to recent steps to substantially reduce fishing pressure on these species, and highlight the need for protecting the functional roles of apex predators. In a landmark study in the *Journal of Evolutionary Biology*, PhD student Peter Cowman and David Bellwood revealed that coral reefs have played a critical role in both the origins of global coral reef biodiversity, and in sustaining diversity during episodes of extinction in the world's oceans.

Researchers in Program 2 also made numerous important contributions in 2011 to coral reef policy issues at State, Commonwealth, and international levels. For example, Philip Munday was invited to participate in the IPCC Workshop on Ocean Acidification, which was convened to provide expert input into the upcoming report of the UN's International Panel on Climate Change. Morgan Pratchett, Andrew Baird, and Andrew Hoey were part of a team of Australian researchers commissioned by the Australian Government to assess the status of Australia's offshore subtropical reef systems on Elizabeth and Middleton Reefs. Morgan also made a significant contribution to the Commonwealth's 2011 *State of the Environment Report*, proposing a new framework for assessing the vulnerability and population status of Australian marine fishes. Centre Director Terry Hughes and Nick Graham advised the President of the Seychelles and his associated delegation, including the Minister for Environment, Minister for Foreign Affairs and President of the University of Seychelles, in a round table discussion on reef conservation, management and international collaboration.

Photo by J P Krajewski

The constant gardeners of the world's reefs

Australian scientists have urged greater consideration for the brilliantly-hued parrot fishes that tend and renew the world's imperilled coral reefs.

"Parrot fishes are the constant gardeners of the reef. They play a crucial role in keeping it healthy, suppressing weed, removing sediment and helping the corals to regrow after a setback," explains David Bellwood of the ARC Centre of Excellence for Coral Reef Studies.

In a major new study published in the *Proceedings of the Royal Society,* Prof. Bellwood, Andrew Hoey and Terry Hughes have investigated parrot fish populations on 18 coral island reefs extending from Mauritius in the western Indian Ocean to Tahiti in the central Pacific.

"There are two sorts of parrot fish - the large ones which perform the main garbage removal task for the reef, and the much smaller ones which scrape away at the reef and keep it clean, healthy and free of weed. Both are being targeted by fishers, but the smaller parrotfish appear better able to withstand the pressure."

Prof. Bellwood says the activities of these small parrot fishes (and other reef cleaners) are possibly the main explanation why many coral reefs around the world subject to heavy human pressures have not yet collapsed.

"These smaller fish are incredibly tough and this is good news, because it means they are in a sense buying us time to get the management of coral reefs right."

While the smaller parrotfish are indeed resilient, it is nevertheless vital not to overfish them because of the role they perform in helping reefs regenerate, he cautions. Larger parrotfish have already suffered extensively from heavy targetting by spear fishers.

"Our analyses found that the most heavily-fished reefs have lost virtually all of their large parrot fishes, with individuals larger than 25cm accounting for just 3–6% of the remaining stocks on the five most heavily fished reefs," the team say.

In marked contrast, reefs which were protected, as in Australia, had healthy populations of large and small parrotfish, which in turn kept the corals in peak condition.

The team found a strong connection between human population densities, exposure to fishing and the depletion of parrot fishes. In many areas of the world important groups of fishes were effectively missing. It was particularly striking how few people it required to fundamentally change the ecology of a coral reef.

In many areas studied, large parrot fish had been virtually eliminated, and with the loss of the fishes their ecological roles are no longer delivered, only the smaller species remained to keep the reef healthy. "However on reefs in the GBR which are fully protected, parrot fish populations are completely intact and performing their essential roles in looking after the reef," Prof. Bellwood says.

The team adds "The most positive aspect of our findings is that even in the face of moderately high human population densities and intensive fishing, the Indo-Pacific reefs we examined still retain enough grazing activity to prevent the phase shifts to macroalgae (seaweed) that are occurring elsewhere, particularly in the Caribbean."

"The significance of this work lies in the greater understanding it gives us about how coral reefs work as a system," says Prof. Bellwood. "

Bellwood, DR, Hoey, AS and Hughes TP (2012). Human activity selectively impacts the ecosystem roles of parrotfishes on coral reefs published online *Proceedings of the Royal Society (Biological Sciences)* 10.1098/rspb.2011.1906.

Program 3
Marine Reserves and Reef Connectivity

- **Garry Russ** (Program Leader)
- **Glenn Almany** (Research Fellow)
- **Andrew Baird** (Research Fellow)
- **David Bellwood**
- **Severine Choukroun** (Research Fellow)
- **Sean Connolly** (Research Fellow)
- **Ashley Frisch** (Research Fellow)
- **Nick Graham** (Research Fellow)
- **Terry Hughes** (Research Fellow)
- **Geoffrey Jones**
- **Michael Kingsford**
- **Vimoksalehi Lukoschek** (Research Fellow)
- **Laurence McCook**
- **Mark McCormick**
- **Mark Meekan**
- **Philip Munday** (Research Fellow)
- **John Pandolfi**
- **Serge Planes**
- **Morgan Pratchett** (Research Fellow)
- **David Williamson** (Research Fellow)
- **Bette Willis**

Program 3 focuses on how marine reserves enhance biodiversity and fisheries management. Networks of marine reserves (no-take areas) are increasingly used to manage biodiversity and fisheries. Zoning for multiple levels of use and protection, including no-take areas, has become one of the principal mechanisms for management of marine resources in Australia and around the world. A major research issue is the level of larval dispersal and connectivity within and between marine reserve networks. Program 3 focuses on the optimal design of reserve networks for coral reef conservation and fisheries management; and on the consequences of shifts in connectivity, due to climate change and other processes that affect stock-recruitment relationships. Program 3 continues to lead the world in development and application of techniques to tag and track marine larvae. In recent years Program 3 researchers have applied these technologies and computer modeling to assess larval connectivity among no-take marine reserves established in networks in three separate countries.

Groundbreaking research in 2011 by Geoff Jones, David Williamson and colleagues has used genetic techniques on commercially-important fish to demonstrate the extent of substantial larval connections between the no-take marine reserves ("Green Zones") and the fished ("Blue") zones on the Great Barrier Reef, Australia. The research demonstrates that the green zones are "punching above their weight", that is they are delivering substantially more recruits to support fisheries than the area of Green Zones would suggest. The major finding is that Green Zones not only produce more fish and bigger fish, but they also export substantial amounts of recruit fish to fished areas. The management implications of this finding for the Great Barrier Reef Marine Park are substantial. The practical application of these results will be that reef managers in the future will be able to place, size and space Green Zones to meet objectives such as maximizing larval connections and larval export to fished zones.

Future Fellow Glenn Almany and colleagues completed analysis and interpretation of the Manus Island, Papua New Guinea (PNG), connectivity project in 2011, measuring larval dispersal and connectivity from a grouper spawning aggregation. The team demonstrated significant self-recruitment within a few kilometres of the aggregation (proving that community-based management of the fishery yields benefits to the local community) as well as larval connectivity within 35km of the aggregation. These important findings were delivered to Manus community partners, PNG fisheries agencies, the Manus provincial government and The Nature Conservancy in November 2011 and are being used in March 2012 to inform a "Ridges-to-Reefs" conservation plan for Manus Province. Geoff Jones, Glenn Almany and colleagues also completed extensive genetic surveys of butterfly fish and anemone fish in Kimbe Bay (PNG) to demonstrate remarkable consistency in local (1–10km) recruitment of larvae over a four year period.

Program Leader Garry Russ in collaboration with Rene Abesamis, investigated recruitment subsidy (export of larvae from reserves to fished areas) and connectivity of 39 small (<1 km^2) community-based reserves situated on heavily fished coral reefs in the central Philippines. To predict long-term trends they used an exponential model of population recovery and larval production inside reserves, coupled with an individual-based larval dispersal model. Garry and his colleague, Angel Alcala, in a related study spanning 26 years showed that as species richness and community complexity of large predatory reef fish increased over time inside a reserve, some of this enhanced richness and complexity also spilled over into local fished areas. This is the first study to demonstrate the important benefit of biodiversity and ecosystem export from reserves.

One of the new members of Program 3, Super Science Fellow Ashley Frisch, has begun investigations of the abundance and role of sharks on coral reefs. In particular, Ashley is looking at the role of the highly protected no-entry "Pink Zones" of the Great Barrier Reef, in maintaining natural abundances of reef sharks, and thus maintaining the natural role of sharks on coral reefs as top-level predators.

Program 3 researchers were also highly successful in 2011 in attracting major funding from the Australian *National Environmental Research Program* (NERP) to continue, over the next three years, long-term monitoring studies of the reef fish and corals of inshore reefs of the GBR. Program 3's research on marine reserve networks in Australia, Papua New Guinea, the Solomon Islands and the Philippines is making a major contribution to the Coral Triangle Initiative (CTI), a multi-national initiative in marine governance. A key component of the CTI requires the design and implementation of marine reserve networks.

Photo by Philip Munday

World-first discovery 'can help save coral reefs'

An international team of scientists has achieved a major breakthrough in fishing sustainability on coral reefs which could play a vital role in preventing their collapse.

"Fishermen and scientists have long wondered how many fish can be taken off a reef before it collapses," says Nick Graham of the ARC Centre of Excellence for Coral Reef Studies.

"The consequences of overfishing can be severe to the ecosystem and may take decades to recover, but hundreds of millions of people depend on reefs for food and livelihoods, so banning fishing altogether isn't a reality in many nations."

In a report in the *Proceedings of the National Academy of Sciences* the researchers demonstrate how overfishing can generate a predictable sequence of events that lead to the collapse of reef ecosystems.

Their research offers a vital new tool for managing corals reefs and tropical fisheries worldwide, providing clear targets for sustainability that can help reef fisheries support the very resource they depend on.

"Our work shows that as fish biomass – the number and weight of fish living on a reef – declines due to fishing pressure, you cross a succession of thresholds, or tipping points, from which it is increasingly hard to get back," Dr Graham explains.

"For example, you see patches of weeds replacing coral, you see more sea urchins devouring the coral, you see a general decline in the species richness on the reef, and you see less coral cover."

The study shows that in well-protected areas, there are typically 1000-1500 kilos of reef fish of various species per hectare of coral reef.

As the volume is fished down below 1000 kilos, the early warning signs – like increased seaweed growth and urchin activity, begin to show up. Between 300-600 kilos/ha there appeared to be a window of what is known as maximum sustainable yield, but when the fish stock drops below 300 kilos/ha the reef is in real trouble, they say.

Aaron MacNeil from the Australian Institute of Marine Science adds: "This information is critical to policy makers and reef managers: if fish stocks can be maintained at a certain level, the chances of retaining a sustainable fishery and a healthy reef system are greatly improved."

"Of course, having a target is one thing, but achieving it is, well, another kettle of fish" adds Joshua Cinner. "So we also assessed how well different reef management schemes did at maintaining reefs within or above this sustainability window.

"Reef fisheries with no regulations tended to perform poorly, with some completely collapsed. No-take marine reserves, where fishing was prohibited were the best performers and tended to maintain key ecosystem processes, such as predation."

"But people depend on reefs for their livelihoods, so we can't prohibit fishing everywhere." notes Dr. Cinner. "A key finding from our study was that even easily enforceable regulations that restrict gear or the types of species that can be caught helped maintain biomass. These regulations are often more palatable to fishermen than no-take closures and consequently receive higher levels of support and compliance."

McClanahan, TR, Graham, NAJ, MacNeil, MA, Muthiga, NA, Cinner, JE, Bruggemann, JH and Wilson, SK (2011). Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences* 108(41): 17230-17233.

Program 4
Genetic, Molecular and Physiological Processes

Researchers

- **Ove Hoegh-Guldberg** (Program Leader)
- **Tracy Ainsworth** (Research Fellow)
- **Ken Anthony**
- **Line Bay** (Research Fellow)
- **Anthony Bertucci** (Research Fellow)
- **Sophie Dove**
- **Simon Dunn** (Research Fellow)
- **Paulina Kaniewska** (Research Fellow)
- **Bill Leggat**
- **David Miller**
- **Mathieu Pernice** (Visiting Research Fellow)
- **Nela Rosic** (Research Fellow)
- **Jodie Rummer** (Research Fellow)
- **Linda Tonk** (Research Fellow)
- **Madeleine van Oppen**
- **Bette Willis**
- **David Yellowlees**

Reef-building corals and their symbionts, sponges and algae are fundamental elements of tropical coastal ecosystems. Researchers from Program 4 continued to investigate the responses of these key reef organisms to environmental stressors. These issues are important in light of the rapid rates of environmental change occurring at both local and global scales. Research results generated by Program 4 scientists have important implications for the future and management of coral reefs. The physiological tolerances and the genetic response of organisms such as corals to rapid changes in the environment has been a major focus in Program 4. This, when combined with the ecological approaches of other programs within the Centre, provides a powerful integrated understanding of the changes that are occurring on coral reefs in Australia and elsewhere.

Madeleine van Oppen received an ARC Future Fellowship which she took up in May 2011. This year has seen the departure of Ken Anthony, Line Bay and Paulina Kaniewska. All three have taken up positions at the Australian Institute of Marine Science. We welcomed Jodie Rummer and Anthony Bertucci as Super Science Fellows in July and November respectively.

Ove Hoegh-Guldberg has been leading Program 4's approach to investigating how the oceans are changing in response to elevating atmospheric CO_2. This provides a valuable insight into the types of synergistic impacts that coral reef organisms are likely to be faced with in the coming decades, and hence establishes the necessary and regionally specific parameters for future experimental studies on hard coral and other key reef organisms. In collaboration with Israeli scientists, the team has investigated variation in gene expression in both corals and algal symbiosis as a function of the time of day. This work, undertaken in 2011 on the Great Barrier Reef, has revealed complex gene expression patterns that are associated with this highly integrated symbiosis.

Sophie Dove and others are studying the impact of past, present and projected atmospheric carbon dioxide levels on calcification and mortality. Experiments in 2011 that include natural diurnal and seasonal fluctuations showed high rates of mortality in hard corals, algae, and sponges under A1F1 (IPCC Report) scenarios, combined with reduced rates of calcification and increased rates of bioerosion.

Simon Dunn and Mathieu Pernice have made major contributions this year to our understanding of the symbiosis metabolism. Their studies, using state of the art technologies (HPLC-MS and Nanosim) provide insight into how corals may rapidly assimilate the pulses of nitrogen excreted by visiting organisms, as well as information on the distinct pathways through which host and symbiont obtain and synthesise fatty acids. Studies by Nela Rosic and Paulina Kaniewska on hard corals and *Symbiodinium* cultures have shown downturns in host metabolism with acidification, suggesting that acidification impacts on host biology in addition to skeletal formation.

Madeleine van Oppen and co-workers have shown in 2011 that local adaptation in *Symbiodinium* shapes the thermal tolerance of coral holobionts. In addition, they have continued to work on the allorecognition, chimera formation and the immune response in corals. *Symbiodinium* has also been the focus of Linda Tonk's research. She is developing a database of *Symbiodinium* diversity on the Great Barrier Reef, with the final goal to overlay this information with environmental parameters such as sea surface temperature, phytoplankton availability and turbidity.

Bill Leggat, David Yellowlees and Tracy Ainsworth have continued their investigation into the effect of sub-bleaching temperatures on the expression of basic metabolic genes in both the coral host and *Symbiodinium* and how these sub-lethal temperatures modify the expression of genes involved in apoptosis. These results show that at temperatures 2-3 degrees below the bleaching threshold there are significant changes in gene expression in the coral host. This has important implications for how corals will respond to future increases in temperature. In related studies, and based on the observation that host mitochondria could be independent of symbiont cellular degradation during thermal stress, Simon Dunn has suggested an alternative to the current hypothesis that ROS (reactive oxygen species) generated by the symbiont drives the bleaching response.

Bette Willis and colleagues have been investigating the diverse microbial symbioses that, in combination, underpin the health of corals. Willis and her team have also measured coral immune responses and correlations between coral diseases, human activities and environmental factors, particularly seawater temperature and water quality. These critical studies are adding important information to our understanding of how coral reefs are likely to vary under a changing climate.

Corals can sense what's coming

Australian scientists have thrown new light on the mechanism behind the mass death of corals worldwide as the Earth's climate warms.

Coral bleaching, one of the most devastating events affecting coral reefs around the planet, is triggered by rising water temperatures. It occurs when the corals and their symbiotic algae become heat-stressed, and the algae which feed the corals either die or are expelled by the coral.

There have been seven major bleaching events globally in the past 30 years, the most recent being in 2010 across the Indian Ocean and Coral Triangle. Australia's Great Barrier Reef has suffered eight events since 1980, the worst being in 2002 when 55% of the total reef area was affected. The frequency of these events appears to be increasing.

Now a team of scientists from the ARC Centre of Excellence for Coral Reef Studies has shown that a complex cascade of molecular signals leading up to the self-inflicted death of corals and their symbiotic algae is triggered as sea water begins to warm.

Working with *Acropora* corals from the reef at Heron Island, the researchers found the cascade begins at ocean temperatures as much as 3 degrees lower than those normally associated with coral bleaching.

And the process culminates in 'apoptosis' or programmed cell-death – a situation in which living organisms deliberately destroy their weakened or infected body cells, effectively a form of 'cell suicide' or amputation designed to protect the organism as a whole.

"Our results suggest that the control of apoptosis is highly complex in the coral-algae symbiosis and that apoptotic cell death cascades potentially play key roles in tipping the cellular life or death balance during environmental stress prior to the onset of coral bleaching," explains lead author Tracy Ainsworth.

"It is also clear that this chain reaction responds significantly to subtle, daily changes in the environment and to sea temperatures which were generally thought till now to have little impact on the function of coral and its symbiotic algae."

Paradoxically, the team's research identified molecular signals both promoting and discouraging programmed cell-death in the corals.

This has led them to a theory that corals respond to the stresses caused by warming sea water by killing off some of the cells, while strengthening others in order to stage a possible recovery after the hot water has moved off the reef and conditions have returned to normal.

"This would explain why some corals are able to recover quite quickly from a bleaching event, if it has not gone too far."

"The next step in our research will be to see how we can use this new insight into the processes of coral bleaching to understand their recovery mechanisms. We also need to know more about how this process works at lower temperatures, or under varying temperatures."

Ainsworth, TD, Wasmund, K, Ukani, L, Seneca, F, Yellowlees, D, Miller, D and Leggat, W (2011). Defining the tipping point. A complex cellular life/death balance in corals in response to stress. *Nature Scientific Reports* 1: 160.

Program 5
Resilience of Linked Social-Ecological Systems

Researchers

- **Terry Hughes** (Program Leader)
- **Andrew Baird** (Research Fellow)
- **Natalie Ban** (Research Fellow)
- **David Bellwood**
- **Joshua Cinner** (Research Fellow)
- **Louisa Evans** (Research Fellow)
- **Pedro Fidelman** (Research Fellow)
- **Simon Foale** (Research Fellow)
- **Carl Folke**
- **Nick Graham** (Research Fellow)
- **Laurence McCook**
- **John Pandolfi**
- **Bob Pressey** (Research Fellow)
- **Robert Steneck**

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. Program Leader and Centre Director Terry Hughes is a founding member of the *Scientific Steering Committee* for the *Program on Ecosystem Change and Society* (PECS), a new global initiative which aims to integrate research on the stewardship of ecosystems. PECS will provide scientific knowledge to the new *Intergovernmental Platform on Biodiversity and Ecosystem Services* (IPBES), established by the UN in 2010, and will play a role similar to that of the IPCC, with a focus on biodiversity and human well-being. The goal of PECS is to generate the scientific and policy-relevant knowledge of social and-ecological dynamics needed to improve governance, including mitigation of poverty. The key question that PECS will address is: "*how do policies and practices affect resilience of the portfolio of ecosystem services that support human well-being and allow for adaptation to a changing environment?*" The goals of PECS align perfectly with the research goals pursued by our ARC Centre, especially Programs 5, 6 and 7.

In January 2011, Josh Cinner began a prestigious 5-year Australian Research Fellowship, based at James Cook University, which will enable him to continue and expand his work on climate change adaptation, in collaboration with Centre Director Terry Hughes and Tim McClanahan who is based in Kenya. Their project, *Linking social science and ecology to understand the vulnerability of coastal societies to changes in coral reef resources*, will be based mostly in east Africa and the Indian Ocean. In February, Josh Cinner and Nick Graham presented invited talks at the AAAS meeting in Washington DC. Another research highlight in 2011 was the publication of a co-authored book by Josh and Tim McClanahan, entitled *Adapting to a Changing Climate – Confronting the Consequences of Climate Change*, published by Oxford University Press. One of Program 5's recent publications in *Trends in Ecology & Evolution*, was designated as a Hot Paper in 2011. This study, entitled *Rising to the challenge of sustaining coral reef resilience* was undertaken by Terry Hughes, Nick Graham, Jeremy Jackson, Peter Mumby and Partner Investigator Bob Steneck.

In March, Natalie Ban, Josh Cinner, Terry Hughes, Simon Foale, Louisa Evans along with several ARC Centre students presented a dozen talks at the Resilience Conference in Arizona, USA, including a Panel Session on *Opportunities and Challenges for Transformation in Marine Social-Ecological Systems*, chaired by Hughes. In April, Terry joined an international selection panel convened in Berlin by *Deutsche Forschungsgemeinschaft*, charged with establishing a new German Research Centre for Integrative Biodiversity. Terry was also a guest of the new Red Sea Research Center (RSRC), King Abdullah University of Science & Technology in Saudi Arabia, where he presented a plenary talk during the launching of RSRC.

In May, the ARC Centre hosted a visit to Townsville and Brisbane by Professor Jeremy Jackson and Vivian Lam, to plan a series of workshops designed to develop the *Global Coral Reef Monitoring Network*, with support from the International Union for Conservation of Nature (IUCN). The next workshop will be hosted by Jeremy at the Smithsonian Tropical Research Institute, where Sean Connolly, Terry Hughes, Peter Mumby, and John Pandolfi will comprise the ARC Centre participants.

In December, Ove Hoegh-Guldberg, Terry Hughes and John Pandolfi contributed to a working group at the *Center for Ocean Solutions* in Monterey, California, chaired by Stephen Palumbi from Stanford University, The purpose of this ongoing working group is to define the state of knowledge on climate change and coral reef resilience, particularly new advances in our understanding of coral adaptation, biogeochemistry, coral growth and population dynamics, in the face of multiple human-caused stressors such as runoff from land, overfishing and climate change.

Photo by Wayne Moy

Finding new ways to protect both fish and fishers

Researchers at Australia's leading coral reef research centre have developed a way to protect both coral reef fish - and the interests of fishers.

In pioneering research carried out in Fiji in collaboration with the Wildlife Conservation Society (WCS), the team has reported a new approach that enables communities to balance the need to protect the environment with the need to maintain local food supplies and incomes.

Concern over the worldwide decline of coral reefs has prompted many countries and local communities to impose marine reserves to protect dwindling fish stocks. However these can adversely affect the incomes and welfare of fishers and their communities, says lead author Vanessa Adams of the ARC Centre of Excellence for Coral Reef Studies.

"For a marine protected area to work, the people living around it have to trust it to deliver both the conservation goals and the needs of the community. They have to be comfortable with it - otherwise they won't comply with it," she says.

"Designing a protected area so that it meets both conservation and community goals is a complicated affair. It requires strong community involvement and a lot of dialogue," she explains.

Working with community leaders and managers, WCS designed a protected area network for Fiji's Kubulau District in 2005 to help conserve natural resources for the future. Following local conflict over the location of some of the closures, the Centre of Excellence team agreed to help WCS to re-design the protected areas to better reflect local needs. To achieve this, the team collected fish catch data from local fishermen and underwater fish census data from WCS staff. This was used to create models to design alternative protected areas.

"Essentially we modeled the highest value fishing grounds, both now, and into the future assuming the introduction of new kinds of fishing gear," explains Ms. Adams. "We then investigated how we could reposition the fishing closures to reduce conflict and ensure that fishermen would not lose too much income."

In coming months, WCS will present a range of options to the Kubulau communities who will then have ultimate say over the preferred management scheme.

The success of the project was founded on two elements - the first being that many coral-dependent communities across the Pacific and Coral Triangle want to establish marine protected areas to protect their sea areas from incursions by large industrial fishing vessels.

In Fiji, they have long had areas which are tabu, where fishing is forbidden on traditional grounds, so the concept of a protected area is part of their culture.

"But we also noticed that fishermen are well aware that protected areas help to restock the surrounding waters with fish, and can see the benefits from practical experience," says Ms Adams.

"The bottom line is that you need to engage with the community, and make sure they own the idea of having a protected area on their doorstep. That way you can protect the reefs, the fish and the fishers livelihoods at a time when they are all under rising pressure from both climate and human activity."

Adams, VM, Mills, M, Jupiter, SD and Pressey, RL (2011). Improving social acceptability of marine protected area networks: a method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. *Biological Conservation* 144(1): 350-361.

Program 6
Conservation Planning for a Sustainable Future

Researchers

- **Bob Pressey** (Program Leader)
- **Glenn Almany** (Research Fellow)
- **Natalie Ban** (Research Fellow)
- **Maria Beger** (Research Fellow)
- **Ian Craigie** (Research Fellow)
- **Rodolphe Devillers** (Visiting Research Fellow)
- **Mariana Fuentes** (Research Fellow)
- **Alana Grech** (Research Fellow)
- **Johnathan Kool** (Research Fellow)
- **Laurence McCook**
- **Rebecca Weeks** (Research Fellow)

Program 6 focuses on spatial solutions to resource management problems, involving the design of conservation areas that are managed to promote the persistence and sustainable use of natural resources, and implemented with local communities and other stakeholders. Topics of particular interest include conservation planning under a changing climate, land-sea linkages, reconciling conservation values and economics, and engagement with managers and policy makers.

Systematic conservation planning provides a rigorous approach, increasingly synthesising advances in biology, geography, economics, computing and the social sciences, to minimising the loss of biodiversity and ecosystem services. As well as shaping the field's science, Program 6 leads a world-wide shift towards translating concepts and techniques into actual conservation planning decisions on the ground. In 2011, the Great Barrier Reef, the Coral Sea and the Coral Triangle remain major geographical focal regions of Program 6. In the Great Barrier Reef region, Bob Pressey and colleagues are engaging with the *Great Barrier Reef Marine Park Authority, Queensland Parks and Wildlife Service, the Great Barrier Reef Foundation,* and with *Natural Resource Management Boards* in northern Queensland. In 2011, Program 6 received $1.4 million in funding from the *National Environmental Research Program* for three projects in tropical Australia: 1. Alternative development and conservation scenarios for the Great Barrier Reef coastal zone; 2. Prioritising management actions on Great Barrier Reef islands; and 3. Integrated management of three large catchments from the Gulf of Carpentaria to the Kimberley. All three projects will proceed in close collaboration with managers in government agencies, Non Government Organisations and Natural Resource Management Boards.

Across the Coral Triangle, Program 6 researchers have established new collaborations with government agencies and non-profit organisations in several countries, including the Philippines, Indonesia and the Solomon Islands. In February 2011, Pressey gave the year's inaugural presentation at the Australian Ambassador's Visiting Speaker Series in Washington DC, introduced by Ambassador Kim Beazley. The title of the presentation, to a large audience of diplomatic, agency and university representatives, was "Coral reef planning – biodiversity and fisheries in the Coral Triangle". Pressey used his time in the USA to work with colleagues in National Oceanic and Atmospheric Administration and World Wildlife Fund and to establish links with the Centre for Ocean Solutions at Stanford University.

Further afield, new Program 6 projects have been established in Fiji, the Solomon Islands, and the Abrolhos reefs off the northern coast of Brazil. Topics to be investigated in these areas will include the effects of marine protected areas on local communities, the biological information contained in different classifications of coral reef ecosystems, and ways of incorporating both reef connectivity and adaptation to climate change into marine conservation planning.

Ian Craigie, who completed his PhD on protected area management at the University of Cambridge was recruited to Program 6 in 2011. He has begun work on a research project funded by the Queensland Parks and Wildlife Service. The project will involve working closely with park managers to record the costs of management activities with the aim of modeling them spatially. The results will enable management costs to be explained and predicted in terms of the relative importance of cost drivers.

Program 6 was well represented at two important international meetings in 2011. The first was the *Second International Marine Conservation Congress*, in Victoria, British Columbia (May 2011). Program 6 organised a symposium on "Scaling down and scaling up – bridging the gap between regional-scale conservation design and local-scale conservation actions in marine spatial planning". There were seven invited presentations and four contributed presentations from Program 6 scientists. The second large meeting for the year was the *25th International Congress for Conservation Biology* held in Auckland, New Zealand (December 2011). Program 6 was involved in organising three symposia: 1. Adaptive conservation planning – rationale and requirements for adjustment of conservation designs to fit the real world; 2. Conservation and development – exploring the evidence for how conservation strategies are impacting both the social and ecological communities; and 3. Systematic management of marine mega-fauna in a changing climate. Program 6 researchers also led a workshop on operational principles for the planning and implementation of conservation actions in Indigenous and Traditional communities, and contributed to an extended workshop on improving the effectiveness of community-managed marine protected areas. As well, our scientists were involved in eight oral presentations and a poster display.

Photo by Mary Bonin

Big marine parks 'save money and oceans'

Big marine protected areas (MPAs) are cheaper to manage per hectare than small ones, and no-fishing zones are cheaper to manage than multiple-use zones, a new study has found.

"Management costs are rarely taken into account in MPA design," say Natalie Ban and colleagues, in an article in the latest edition of the journal *Conservation Letters*. "However it is important to budget for them effectively, so we can be sure the long term goals of the park are achieved."

The world has an estimated 5000 marine protected areas covering 2.85 million square kilometres of ocean – but due to lack of adequate management and enforcement, many are protected in name only. Effective management, and budgeting for the cost of management, is therefore very important. So far only 12 of 190 countries have met their full commitments under the UN Convention on Biological Diversity.

"MPAs are an investment by society in something we all want to protect – our oceans, the life they contain, and the fishing communities that depend on them," says Dr Ban, from the ARC Centre of Excellence for Coral Reef Studies. "There is a strong call for even more MPAs globally, because so far they only cover about 2% of the world's oceans."

However, she adds, it is important to factor in the management costs of a marine park at the outset – not just the cost of initial implementation.

Drawing on the experiences of Australia's Commonwealth MPAs, researchers in the ARC Centre of Excellence for Coral Reef Studies examined what contributes to the cost of management.

"In our work we took two scenarios to ask how much it might cost to manage a large area such as the Coral Sea – one a simple no-take marine park, where all fishing was banned, and the other a multiple-use marine park where various activities including fishing are allowed but controlled."

"The bottom line is that it costs almost 50% more to manage a large multiple-use park than it does to manage a simple no-take area", says co-author Bob Pressey.

"With spotter aircraft, mandatory fishing vessel transponders and satellites it is becoming much easier to monitor and control fishing activity especially in coastal waters – but the open oceans still pose major difficulties in enforcing MPA rules," says Dr Ban.

"In a multiple-use MPA you have to be able to see who is doing what and where – and that may include fishing, both commercial and recreational, tourism, trade, resources exploration and so on. That's where many of the extra costs lie."

International legal mechanisms are in place to monitor and manage the high seas, but in practical terms the resources for doing so are still drastically inadequate and the incidence of 'pirate fishing' and plunder of marine stocks is still high.

"Personally, I believe we can involve a strong network of volunteer rangers who keep an eye on what is going on while they go about their business within a marine park," Dr Ban suggests.

"But at the end of the day you still need scientists, fisheries patrol officers, education and outreach programs, and some administrators to back them up. Also, a volunteer system is only really practical in frequented coastal waters."

Ban, NC, Adams, V, Pressey, RL and Hicks, J (2011). Promise and problems for estimating management costs of marine protected areas. *Conservation Letters* 4(3): 241-252.

Program 7
Policy Development, Institutions and Governance of Coral Reefs

Researchers

- **Simon Foale** (Program Leader)
- **Joshua Cinner** (Research Fellow)
- **Louisa Evans** (Research Fellow)
- **Michael Fabinyi** (Research Fellow)
- **Pedro Fidelman** (Research Fellow)
- **Terry Hughes** (Research Fellow)
- **David Mills** (Visiting Research Fellow)
- **John Pandolfi**

Program 7, led by Simon Foale, addresses the multi-faceted challenges of improving coral reef governance. This broad research program covers the human dimension of coral reefs, including cultural, political, historical, and economic aspects. Like all of our Programs, Program 7 is global in scope, with an emphasis on research into governance challenges throughout the Indo-Pacific region, especially in the Coral Triangle. Program 7 is also involved in capacity-building activities in many countries, working closely with NGOs and national governments.

In 2011, Simon and his students continued work on local attitudes and responses to overfishing and on various management interventions in Papua New Guinea and the Solomon Islands. This project includes an exciting collaborative venture with the multi-award winning media production company, Digital Dimensions, and with Telekom Television in the Solomon Islands. This social science project will develop and test a DVD-based fishery biology learning tool for Pacific secondary school students.

Research Fellow Louisa Evans completed a 12 month project in 2011 on climate change adaptation by people within the Great Barrier Reef region (see *National Benefit Case Study* 1, p.54), co-funded by the *National Climate Change Adaptation Research Facility*. This study developed a set of scenarios in collaboration with end-users, focusing on how reef-related industries could adapt to anticipated climate change.

Louisa also commenced a new program of research in the Solomon Islands to examine societal resilience to climate change over the next three years. She was awarded a JCU Competitive Research Incentive Grant this year, and is also a major player in a new €1.2 million project on subsistence fishing in Tanzania, funded by *EuropeAid*. Louisa is also a leading collaborator on a project to code 'design principles' for sustainability of large social-ecological systems with the *Resilience Alliance Young Scholars*.

Research Fellow Mike Fabinyi focused his research this year on the live reef fish trade across the Philippines-Malaysian border, and on the cultural, political and economic contexts of luxury seafood consumption in China. These two projects involve new collaborations with Palawan State University and Beijing University, respectively. Pedro Fidelman completed and published his stakeholder analysis of the *Coral Triangle Initiative* as well as his studies on climate change adaptation and governance in the Great Barrier Reef region. Pedro has recently taken up another research position at the University of the Sunshine Coast, following the completion of his ARC Centre Fellowship.

In 2011, Program 7 established a new network of over 20 social and interdisciplinary scholars from across the nodes of the ARC Centre, as well as researchers from two faculties at James Cook University, the WorldFish Center in Penang, and CSIRO. The broad aim of the network is to provide support to early- and mid-career social science researchers, by sharing ideas, skills and expertise in theories and concepts, research methodologies, and analysis techniques, as well as providing practical support through pre-submission review of papers and grant proposals. The network, which is organised by graduate students Pip Cohen and Christina Hicks, also ran two popular courses in 2011, on mixed methods approaches and on new frameworks for social network analysis. Future topics will include sense-making tools, different disciplinary perspectives on human values, attitudinal and behavioural change, resilience and functionalism, and institutional norms and rules. This network of scholars provides a valuable forum in which to bounce ideas around or to help address particular challenges faced in early research careers. The meetings are open to anyone who wishes to participate.

Photo by Michael Fabinyi

Give fishers a break, says researcher

Demonising fishermen does not help protect fisheries, a leading scientist will tell the *Coral Reefs: Coast to Coast* symposium in Fremantle on Friday.

"The fishing trade is of huge importance to the livelihoods of many communities in the coastal parts of Southeast Asia, including the Philippines, Malaysia and Indonesia," Dr Mike Fabinyi of the ARC Centre of Excellence for Coral Reef Studies says.

"The world may be threatened by a possible collapse of fisheries and destruction of coral reefs, but fishing communities are under constant, daily pressure to feed their families and send their kids to school," he says.

"Many local fishers in Southeast Asia survive at a subsistence level and are battling poverty," he says. "Although they are well aware that heavy fishing pressure can lead to lower catches, in many locations they have few other ways to earn an income - so fishing is their only viable livelihood."

"Their urgent need to achieve decent living conditions often outweighs their concerns for ocean life."

Dr Fabinyi's research in Palawan, the Philippines, has revealed an increase in the importance of the live reef fish trade for local fishers over the last decade. The increasing demand from affluent consumers in China for live reef fish such as coral trout and other types of groupers has driven up the price of these species dramatically.

"The global trade in live reef fish is worth around $2 billion. A good-sized coral trout can bring a fisherman over $50 a kilogram. As demand increases it is natural that more people will turn to the live fish trade for their income."

"Some groups blame fishers for lacking far-sightedness and for not regulating their fisheries effectively, but these communities are concerned chiefly with putting daily food on the table, improving their living standards, obtaining healthcare and paying for their children's education."

Government policymakers, environmental groups and society generally need to be aware of the different priorities of local fishing communities - because reforms aimed at controlling fishing activities will be hard to implement without local support, he says.

"Current attempts at local regulation of the live fish trade are failing because local people are often opposed to measures that would heavily restrict their incomes."

"Poor people will find a way to obtain income from live reef fishing regardless of what the laws say."

"There is likely to be ongoing market demand for live reef fish products and, while an intensive trade can damage the marine environment, the solutions will most likely involve making hard choices about livelihoods and coral reefs. Instead of assuming that we can find win-win solutions, we should be focusing instead on identifying potential trade-offs that might need to take place between promoting better livelihoods for fishers, and better protection of fish stocks and coral reefs."

Fabinyi, M and Dalabajan, D (2011). Policy and practice in the live reef fish for food trade: a case study from Palawan, Philippines. *Marine Policy* 35(3): 371-378.

Program 8
Genomics and Metagenomics of Coral Reefs

Researchers

- **David Miller** (Program Leader)
- **Tracy Ainsworth** (Research Fellow)
- **Line Bay** (Research Fellow)
- **Anthony Bertucci** (Research Fellow)
- **Simon Dunn** (Research Fellow)
- **Sylvain Forêt** (Research Fellow)
- **Ove Hoegh-Guldberg** (Research Fellow)
- **Paulina Kaniewska** (Research Fellow)
- **Bill Leggat**
- **Aurélie Moya** (Visiting Research Fellow)
- **Susanne Sprungala** (Research Fellow)
- **Madeleine van Oppen**
- **Bette Willis**
- **David Yellowlees**

Program 8 is based around the structure and function of the genomes of corals, their dinoflagellate symbionts and associated bacterial and viral communities, known as the "holobiome". The long-term aim of Program 8, in association with Program 4, is to understand how the "holobiome" functions under normal and stressed conditions.

The major research achievements of program participants in 2011 were the release of the draft whole genome sequence of the coral *Acropora millepora* (see p.56) and, in collaboration with Professor Nori Satoh's research group in Okinawa, the publication of the first coral genome sequence, in *Nature*. The whole genome sequence of *Acropora millepora* is particularly significant because this is the first animal to undergo whole genome sequencing and assembly by an all-Australian team. This ground-breaking project was based exclusively on short-read "next-gen" sequencing methods, and was a partnership between the ARC Centre, The Australian Genome Research Facility and Illumina Inc. The nature of the data necessitated the development of novel methods for genome assembly by ARC Centre Fellow Sylvain Forêt, and the assembly was a heroic effort by a team led by Sylvain. In combination with the genome sequence, the availability of the large volumes of transcriptome data accumulated by the combined efforts of David Miller's group at JCU and ARC Centre adjunct Eldon Ball's group at the Australian National University, have led to *A. millepora* becoming the coral of choice for molecular and cell biology research by most scientists in the coral research community worldwide.

This year saw major international engagement by Program 8 members. In March, the Centre hosted a Boden Conference on "Genome biology of corals and their relatives", which was held on Magnetic Island co-sponsored by the Australian Academy of Science. The meeting featured many international participants including a strong representation from the Okinawa Institute of Science and Technology (OIST, Japan) and Academia Sinica (Taiwan). Amongst the overseas speakers were Thomas Bosch (Kiel), Angela Douglas (Cornell), Nori Satoh (OIST), Oren Levy (Bar-Ilan), Rebecca Vega-Thurber (Oregon), Allen Chen (Academia Sinica) and Konstantin Khalturin (Kiel). Also in March, David Miller, Sylvain Forêt and PhD student Marcelo Kitahara were invited speakers at an international symposium on biodiversity held at Academia Sinica (Taipei). In September, Sylvain Forêt was an invited participant and organiser of a workshop on the state of the art in genomics and metagenomics of basal metazoans held in Aidling, southern Germany; these biennial workshops are small, invitation-only meetings of the key players in the field. In December, David Miller was a plenary speaker and Sylvain Forêt an invited speaker at the Marine Environmental and Evolutionary Genomics conference held in Taiwan. Program 8 also hosted a number of international visitors during 2011. Amongst the visiting postgraduates, Lotte Huisman (Amsterdam) was with us for much of the year, and Wiebke Wessels (Bremen) and Juila Purtov (Kiel) for shorter periods. Rebecca Vega-Thurber (Oregon) and two members of her group visited for more than a month around coral spawning time. Paul Fischer from Simon Davies' group visited to conduct experimental work with the Leggat group.

Publication highlights in 2011 included major advances in understanding normal daily cycles in gene expression in corals, described in a short *Science* piece co-corresponded by Ove Hoegh-Guldberg and David Miller. One major difference between corals and most other animals is that the presence of the symbionts imposes massive changes in physiological conditions within the coral in response to changes in the light environment. In the *Science* piece, we showed that the coral responds to changing oxygen tensions within the tissue using a classic animal-specific mechanism based on the hypoxia-inducible transcription factor HIF1, and that the cycles of gene expression linked to oxygen tension are superimposed on top of other cycles that are directly light-coupled through the cryptochrome system.

Bill Leggat became part of a Marie-Curie European Union exchange program "SYnergies through Merging BIOlogical and biogeochemical expertise in COral Research (SYMBIOCoRe)". In October, research fellow Aurélie Moya departed to take up the domestic component of her Marie-Curie fellowship, hosted by Jean-Pierre Gattuso at INSU-CNRS in Villefranche, France. In November, Anthony Bertucci joined us from Monaco to take up a Super Science Fellowship with David Miller's group to work on the impact of climate change on coral calcification. In December, the Centre farewelled Sylvain Forêt who has taken up a tenure-track academic position at the Australian National University.

Photo by Carlos Sanchez

De coral has de rhythm to beat de night-time blues

The world's corals not only display stunning beauty and diversity – they also have rhythm. And that helps to keep them going through the lonely low-point of the night, when their partner robs them blind.

That corals, among the simplest of Earth's creatures, have some curiously human-like attributes is emerging in a fresh set of revelations from a team of Australian and Israeli coral geneticists which highlight some of the things we and corals have in common, thanks to our shared genes.

Both corals and people have circadian rhythms which govern our body functions according to changes in day and night or season, explains David Miller of the ARC Centre of Excellence for Coral Reef Studies. Corals use these rhythms to dictate their feeding and breeding and to manage their symbiotic relationship with algae.

But the corals appear to have taken rhythm to an intense pitch, to the point where they have developed an internal 'clock' that ticks reliably even if the corals are no longer stimulated by external signals like the change from day to night or full moon to total dark.

"This ability to tell the time appears hard-wired into corals," Prof. Miller says. "What they do is automatically make a whole swag of "emergency response" proteins known as chaperones – molecules that mop up the damage that corals sustain every day when their symbiotic algae carry out photosynthesis. It is something they have learned to do automatically – probably because it was a matter of life or death."

Independently of the internal clock, another typically vertebrate-like response saves the corals from 'suffocating' during the hours of darkness, when their symbiotic algae (zooxanthellae) reverse their usual supportive role in the partnership – and begin to rob the corals of precious oxygen, which they (the algae) need for survival until daylight.

During this deep, dark period, the coral responds by making more of the same enzymes that help a sprinter's muscles deal with a lack of oxygen, enabling it to struggle through this period of oxygen-stressed depression and live to see another day – when the algae will be powered up again by the sun and return to their duties of nourishing the coral.

Close study of the sets of genes involved in this subtle interaction has persuaded the team that coral's rhythms in response to light/dark cycles operate in two distinctly different ways at the same time – there are those that are primed directly by the coral's own molecular timekeeper, but also other coral genes that respond indirectly to light/dark cycles, by sensing changes in oxygen levels in the coral tissue that result from algal activity. Both systems are necessary to the survival of the symbiotic 'marriage' of the coral animal with a completely different lifeform, a plant.

"Like any marriage, symbiosis is demanding – and one partner often has to make big changes to accommodate the other," observes Ove Hoegh-Guldberg. "The zooxanthellae appear to have forced these enormous changes on the corals – but then corals have had at least 240 million years to adapt to symbiosis, as many kinds of fossil corals are known from the period immediately after the mass extinctions that occurred at the end of the Permian."

"It's a fresh example of the marvelous complexity and interplay that takes place in the partnership, where both have evolved sets of genes that enable them to survive with the other's quirks."

Levy, O, Kaniewska, P, Alon, S, Eisenberg, E, Karako-Lampert, S, Bay, LK, Reef, R, Rodriguez-Lanetty, M, Miller, DJ and Hoegh-Guldberg, O (2011). Complex diel cycles of gene expression in coral-algal symbiosis. *Science* 331(6014): 175.

Reproduced with thanks:
Adaptation Research Network Marine Biodiversity & Resources (a.k.a Marine Adaptation Network) from Marine Adaptation Bulletin (MAB), Volume 3, Issue 4, Summer 2011/12; pp 2 *http://arnmbr.org/content/images/uploads/MAB_v3_i4_Summer_2011-12.pdf*, *www.nccarf.edu.au/marine*

Photo by Wayne Moy

Adaptive Marine Protected Area Planning and Management: Research progress and gaps

Professor Robert L Pressey FAA and Dr Vanessa M Adams; ARC Centre of Excellence for Coral Reef Studies, James Cook University

The establishment of marine protected areas (MPAs) is a widespread and acknowledged tool for conserving biodiversity and providing ecosystem services; however, the potential benefits of MPAs will only be realised through effective protected area design as well as compliance and enforcement. Emerging trends in MPA design, implementation and management demonstrate that, in the face of climate change and increasing human pressures on marine resources, MPAs must be adaptively planned and managed. In addition there should be a particular focus on the social-ecological context during the planning phase to ensure that plans are implementable[1].

Fishers in Kubulau district, Fiji. Adams et al. (2011) modelled the pattern of current and future fishing effort in Kubulau, which is likely to change in response to changing market dynamics as well other factors such as changing fish stocks. Photo courtesy of Stacy Jupiter, Wildlife Conservation Society - Fiji.

While adaptive management is widely recognised and applied, adaptive MPA planning is not well understood. One aspect of adaptive planning is the reconfiguration of MPA systems after review and evaluation. An even less well acknowledged aspect of adaptive planning is the likely need to adjust regional MPA designs during the process of implementing them[2]. Changes are likely to be necessary because of unanticipated constraints on, and opportunities for, conservation actions, and because regional-scale data are inevitably approximate and found wanting at local scales. This applies particularly to data on socio-economic costs. Regional MPA designs must usually utilise coarse-resolution data on costs (to stakeholders and implementing organisations), which often rely on surrogates for cost that are remote from the variables of real local importance.

While inclusion of socio-economic data in the design of MPAs has increased in the last decade, spatial variation in costs to stakeholder groups needs to be better understood[3]. The most prevalent type of socio-economic data in conservation planning for MPAs relates to fisheries catch, typically with catch per unit effort (CPUE) data. However, our recent study discusses the limitations of CPUE data in capturing future effort, which may be of particular concern in the face of climate change. More techniques for estimating current fishing effort and modelling future effort and expected changes in effort due to impacts such as climate change and expanding fisheries are needed[4].

The next important step in designing adaptive MPAs is moving beyond socio-economic costs to consider broader social impacts. The impacts of MPAs on local communities may not be captured by considering only loss of catch to fishers. MPAs can have both positive and negative social impacts on communities, with fishing behaviour being determined not only by catch value but by factors such as values on time, risk aversion, and cultural identity. These social impacts include fishers' lack of willingness to leave a fishery, the subsequent increase in fishing time to meet previous catch levels, crowding of fishing grounds, and loss of income. These effects have been recently documented with respect to marine park zoning in Moreton Bay, near Brisbane[5]. The Moreton Bay study emphasises the importance of exploring ways to account for social values other than the economic value of fisheries during the planning phase of MPAs.

With advances in research paving the way for MPA design to better account for the complex social-ecological systems within which MPAs must ultimately function, planners will have a better understanding of the positive and negative impacts of MPAs and how these should be accounted for in spatial decisions. But another challenge remains: it will typically be impossible to collect relevant social and economic data for communities across large planning regions. So implementation of regional MPA designs in many parts of the world, including the Coral Triangle, will rely on emerging capabilities in managing designs as evolving systems that adapt progressively to the mistakes and surprises inherent in their application.

For further information about this article please contact: Bob.Pressey@jcu.edu.au or vanessa.adams@cdu.edu.au

References

1. Ban NC, Adams VM, Almany GR, et al (2011) Designing, implementing and managing marine protected areas: Emerging trends and opportunities for coral reef nations. Journal of Experimental Marine Biology and Ecology doi:10.1016/j.jembe.2011.07.023. <http://www.sciencedirect.com/science/article/pii/S0022098111003467>

2. Mills M, Pressey RL, Weeks R, et al (2010) A mismatch of scales: challenges in planning for implementation of marine protected areas in the Coral Triangle. Conservation Letters 3:291-303. <http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2010.00134.x/full>

3. Adams VM, Pressey RL, Naidoo R (2010) Opportunity Costs: Who really pays for conservation? Biological Conservation 143: 439–448. <http://www.sciencedirect.com/science/article/pii/S0006320709004765>

4. Adams VM, Mills M, Jupiter SD, et al (2011). Improving social acceptability of marine protected area networks: a method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. Biological Conservation 144: 350-361. <http://www.sciencedirect.com/science/article/pii/S0006320710003939>

5. van de Geer C, (2011) An assessment of the socio-economic effects of a systematic conservation planning exercise: The rezoning of the Moreton Bay marine park. Masters Thesis, James Cook University, supervised by Pressey RL, Gardner M, Mills M, Adams VM.

Graduate Training

The ARC Centre is the world's largest provider of postgraduate training in coral reef research. In 2011, members at the four nodes of the Centre supervised, mentored and funded 181 postgraduate students. In addition to contributing research support costs for our postgraduate students, the Centre also provides targeted professional development for the students and financial assistance to attend conferences, Centre Symposia and, to visit other nodes of the Centre. The total investment in student activities is over 25% of the Centre's annual budget.

The ARC Centre again held a National Student Mentoring Day immediately prior to the annual Australian Coral Reef Society's August conference at the Novotel Twin Waters Resort, Sunshine Coast, Queensland. The mentoring program focused on developing the students' research and publication skills as well as preparing them for careers in either research or management agencies. A range of speakers from the Centre, including Andrew Baird, John Pandolfi, Morgan Pratchett, Laurence McCook and Jenny Lappin talked about career pathways and provided an informative day for the attendees. The 22 graduate students attending came from universities across the country as well as from overseas.

The Centre's graduate students organised a one day retreat on Rottnest Island prior to the 2011 ARC Centre's Symposium in Fremantle in October. The workshop was one of the largest gatherings of Centre postgraduate students since the Centre's establishment. Forty-six student attendees took part. The agenda, designed following consultation among the student body, commenced with invited speakers Tyrone Ridgeway (AIMS) and Adam Gatner (Oceanica Consulting) discussing 'careers in marine science' and 'funding your future career'. This was followed by a session to promote networking between students, and then a student meeting in which issues and ideas that were relevant to Centre students were discussed. Feedback from students indicated the retreat was a great success for student networking and developing thinking about careers after PhD completion. Outcomes included clarifying student affiliations with the Centre, improving website resources and developing options for a 2012 student retreat.

As part of the annual *Celebrating Research@JCU* in September the ARC Centre held a training session for graduate students who were participating in the Centre's internal 3M competition (My Research in 3 Minutes). Liz Tynan from the Graduate Research School generously donated her time and expertise to provide the students with valuable training in how to communicate their research to a lay audience.

The Student Committee have again been active over the past 12 months in a variety of issues including:

- Coordinating and representing student ideas and issues to Centre management
- Developing mechanisms and opportunities to encourage networking between students in the various nodes of the Centre and between students and Research Fellows
- Greening the Centre offices by working together with JCU's Environment Manager, with an emphasis on energy efficiency measures and an improved recycling program. The first steps of the program were implemented in 2011 and the Centre is used as a pilot study before similar measures are rolled out across the University campus.

Wine-ing Women in Science was launched by ARC Centre students in 2011. While the name suggests a tongue-in-cheek view of networking between women, the group was established to provide a support network for the Centre's female researchers in their pursuit of academic careers. Recognising that senior research positions are often dominated by men, this is one important mechanism supported by the Centre to ensure that the achievements and progress of female scientists are facilitated and recognised.

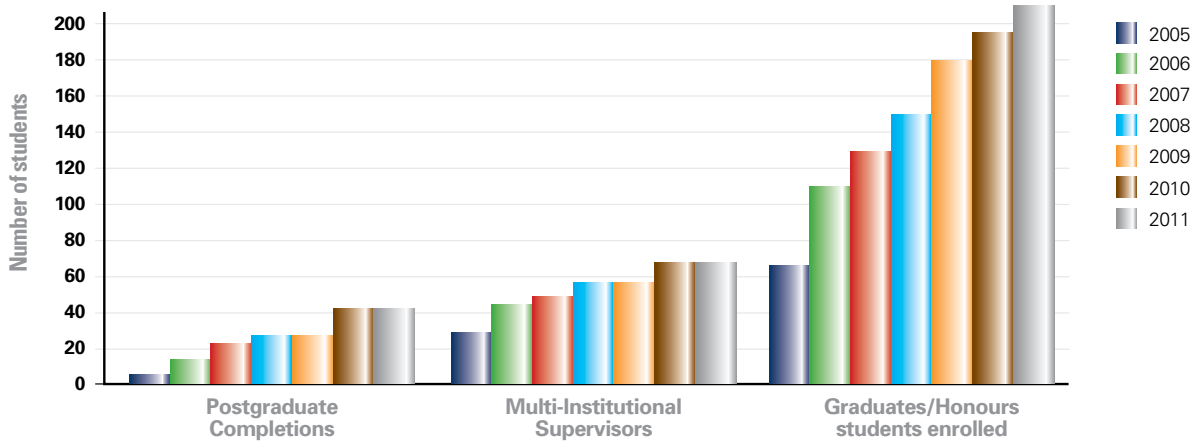
Awards to Centre students in 2011 include:

- Jennifer Donelson was the recipient of a *GBRMPA Science for Management Award* in 2011 adding to her success in 2009 and 2010. Ian McLeod and Jessica Stella were also recipients.
- Amelia Wenger was awarded the Terry Walker Prize by the *Australian Coral Reef Society* to support her ongoing research on Australian coral reefs. Melanie Trapon received the Danielle Simmons Award from the Society to undertake her field work at Heron Island. Yui Sato was also successful with a grant from the Society to support his research.
- Chia-Miin Chua, Rebecca Lawton and Jeroen van de Water received travel grants from the *Australian Coral Reef Society* to attend their annual meeting at Twin Waters on the Sunshine Coast, Queensland. Rebecca was awarded the Vicki Harriott Prize for the best student oral presentation at the meeting. At the same meeting, Yui Sato was awarded the Quicksilver Award for excellence in oral presentation.
- Mary Bonin, Rebecca Lawton, and Erika Woolsey have received travel grants from the *Australian Coral Reef Society* to attend the 12th International Coral Reef Symposium in Cairns in July 2012.
- Kirsty Nash won the student category for "My Research in 3 Minutes" during the JCU "Celebrating Research" month in September 2011. She went on to represent JCU with credit at the Australian finals in Perth, Western Australia.

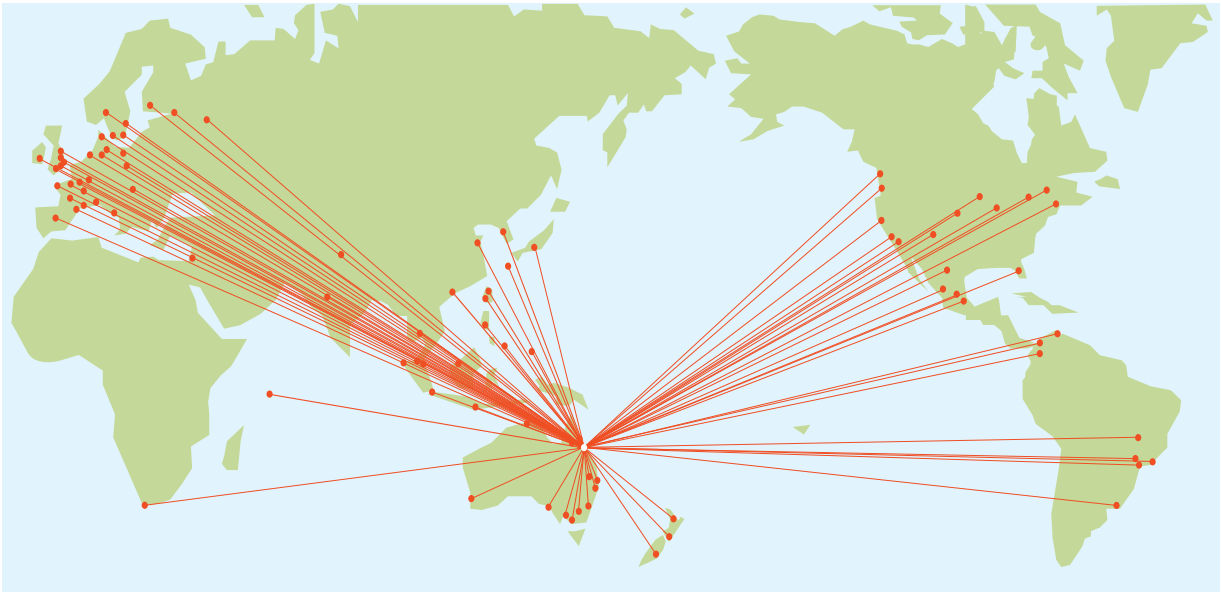
- Christina Hicks and Karen Chong Seng were presented with awards for their oral presentations at the 7th Western Indian Ocean Marine Science Association (WIOMSA) Symposium in Mombasa, Kenya.
- Christina Hicks received US$14,550 from WIOMSA to run a workshop in Kenya on *Ecosystem values and coastal governance*.
- Allison Paley was awarded an *Australian Academy of Technological Sciences and Engineering* "Young Science Ambassador Award".
- Dominique Roche won an Ian Potter Doctoral Fellowship at Lizard Island. He was also awarded University of Washington *University Friday Harbour Laboratories Award* to attend the 2011 Biol 533 Fish Swimming Course at the Friday Harbour Laboratories.
- Kirsty Nash won the Best Poster Award at the 2nd Resilience Conference in Arizona, USA.
- Paolo Rachello-Dolmen received a Mollusc Research Grant from the *Malacological Society of Australasia* to support her research studies.
- The Virginia Chadwick Awards are awarded to five ARC Centre of Excellence graduate students for the most outstanding publications in peer-reviewed international journals. Each attracts a prize of $1,000. The winners for 2011 were Jorge Alvarez-Romero, Jennifer Donelson, Andrew Hoey, Rebecca Lawton and Matt Lybolt.

The ARC Centre would like to acknowledge the valuable and critical contribution of the Student Committee during 2011. Along with Olga Bazaka, our graduate student co-ordinator, the Committee make an invaluable contribution to the success of the ARC Centre of Excellence. Members of the committee during the year were Pip Cohen (Chair), JCU; Renata Ferrari Legorreta, UQ; Dominique Roche and Sandra Binning, ANU; Amelia Wenger, Christina Hicks, and Chun (James) Hong Tan, JCU; and Jessie Short, UWA.

Rapid growth in the ARC Centre's graduate training program, 2005-2011.



The ARC Centre's international network of graduate students. In 2011, 139 overseas students came to Australia from 42 countries.



2011 Student members of the ARC Centre of Excellence for Coral Reef Studies

*Degree awarded during 2011

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Rene Abesamis*	JCU, Silliman University	Philippines	Demographic connectivity of reef fish populations in the Philippines. (PhD)	Prof G Russ, Prof G Jones
Vanessa Adams*	JCU	USA	Incorporating economic factors into systematic conservation planning. (PhD)	Prof R Pressey, Prof T Hughes
Novi Susetyo Adi	UQ	Indonesia	Assessment of coral reef productivity using remote sensing data. (PhD)	A/Prof S Dove, Prof O Hoegh-Guldberg
Siham Afatta*	UQ, AIMS	Indonesia	Resilience studies of Indonesian coral reefs: ecological and social assessments in Karimunjawa National Park. (MPhil)	Prof O Hoegh-Guldberg
Catalina Aguilar Hurtado	JCU	Colombia	The immune response of the coral *Acropora millepora* under CO_2 stress. (PhD)	Prof D Miller, Dr S Sprungala, Dr S Forêt
Jorge Alvarez-Romero	JCU	Mexico	Cross-system threats and competing values in coastal and marine conservation planning: an integrated land-sea approach to prioritize conservation actions in the Gulf of California. (PhD)	Prof R Pressey, Dr N Ban, Dr J Kool
Shelley Anthony	JCU, AIMS	USA	White Syndrome Disease and colony mortality in captive Indo-Pacific corals. (PhD)	Prof B Willis
Jennifer Atherton	JCU	United Kingdom	Impact of environmental change on fish populations through parental effects. (PhD)	Prof G Jones, Prof M McCormick
Maria Aurellado	UQ	Philippines	Effects of varying levels of fishing pressure on habitat-fish relations in marine protected areas and adjacent fished areas. (PhD)	Prof P Mumby
Stephen Ban	JCU	Canada	Multiple stressor effects on coral reef ecosystems. (PhD)	Prof R Pressey, Dr N Graham, Prof S Connolly
Lissa Barr	UQ, JCU	Australia	Measuring the effectiveness of marine protected areas. (PhD)	Prof R Pressey
Andrew Bauman	JCU, Nova South-Eastern, USA	USA	The ecology and dynamics of coral reef communities in marginal reef environments. (PhD)	Prof M Pratchett, Dr A Baird
Brian Beck*	UQ, JCU	USA	Palaeoecological dynamics of coral communities in the South Pacific. (PhD)	Prof J Pandolfi, Prof S Connolly
Roger Beeden	JCU	New Zealand	How healthy is the Great Barrier Reef in a warming world? (PhD)	Prof B Willis
Dorothea Bender*	UQ, Griffith	Germany	Impacts of climate change and ocean acidification on coral reef turf algae. (PhD)	A/Prof S Dove
Duan Biggs*	JCU, CSIR South Africa,	South Africa	Resilience of reef-based tourism to climate change and disturbance. (PhD)	Prof T Hughes, Dr J Cinner
Sandra Binning	ANU	Canada	Phenotypic plasticity in coral reef fish ecomorphology. (PhD)	Prof D Yellowlees Prof S Keogh
Chico Birrell	UQ	Australia	Understanding the spatial and temporal variation in macroalgal growth and assemblage development on coral reefs. (PhD)	Prof P Mumby
Shane Blowes	JCU	Australia	Territoriality, competition, and coexistence of butterflyfishes. (PhD)	Prof S Connolly, Prof M Pratchett
Teressa Bobeszko	JCU	Australia	The role of carbonic anhydrase in the coral-dinoflagellate symbiosis. (PhD)	Dr W Leggat, Prof D Yellowlees
Lynda Boldt	JCU	Australia	*Symbiodinium* photosynthetic genes and the effect of varying environmental conditions on photosynthetic processes. (PhD)	Dr W Leggat, Prof D Yellowlees
Mary Bonin*	JCU	USA	Causes and consequences of habitat specialisation in coral reef fish communities. (PhD)	Prof G Jones, Dr G Almany
Madeleine Bottrill	UQ, JCU	United Kingdom	Evaluating the effectiveness of conservation planning: when do plans work. (PhD)	Prof R Pressey

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Dominique Bradbury	JCU	USA	Bleaching susceptibility of corals: a hierarchy of causes and consequences. (PhD)	Prof M Pratchett, Dr A Baird, Prof T Hughes
Tom Brewer	JCU	Australia	Social and economic determinants of the exploitation and management of coral reef resources in Solomon Islands. (PhD)	Dr J Cinner, Prof T Hughes, Prof R Pressey, Dr S Foale
Rohan Brooker	JCU	New Zealand	Habitat specialisation and its consequences for a corallivorous filefish. (PhD)	Prof G Jones, Prof P Munday
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
Alexandra Carter	JCU	Australia	The effects of no-take zoning, region and year on reproductive output of the common coral trout, *Plectropomus leopardus*. (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
Napo Cayabyab	UWA	Philippines	Physiological response, nutrient allocation, and growth of seagrasses to varying levels of pCO_2 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)	Prof S Connolly
Neil Chan	JCU, UQ	Malaysia	Modelling the effects of pH, temperature and flow on calcification of reef corals. (PhD)	Prof S Connolly
Karen Chong-Seng	JCU	Seychelles	The mechanistics of regeneration in coral reef ecosystems. (PhD)	Dr N Graham, Prof D Bellwood, Prof M Pratchett
Chia-Miin Chua	JCU	Malaysia	Effects of elevated temperature and increased acidity on the early life history of corals. (PhD)	Dr A Baird, Dr W Leggat, Prof T Hughes
Tara Clark	UQ, AIMS	Australia	Historical mortality in Great Barrier Reef coral communities since European settlement. (PhD)	Prof J Pandolfi
Philippa Cohen	JCU	Australia	The contribution of locally-managed marine areas to food security of Solomon Islands. (PhD)	Dr S Foale, Prof T Hughes, Dr L Evans
Darren Coker	JCU, DEC WA, AIMS	New Zealand	The role of live coral in moderating key ecological processes for coral reef fishes. (PhD)	Prof M Pratchett, Dr N Graham
Andrew Cole*	JCU, DEC WA	Australia	The energetic cost of chronic fish predation on reef-building corals. (PhD)	Prof M Pratchett, Prof G Jones
Amy Coppock	JCU	United Kingdom	Olfactory discrimination in juvenile coral reef fishes. (MSc)	Prof G Jones
Melissa Cowlishaw	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
Peter Cowman	JCU	Ireland	Dating the evolutionary origins of trophic novelty in coral reef fishes. (PhD)	Prof D Bellwood
Alicia Crawley	UQ	Australia	The synergistic effect of rising ocean temperature and acidification on coral reef ecosystems. (PhD)	A/Prof S Dove
Peter Cross	JCU	USA	Changing stock-recruitment relationships following cyclone Yasi. (MSc)	Prof B Willis, Dr V Lukoschek
Vivian Cumbo	JCU, AIMS	Australia	Thermal tolerance in corals: the role of the symbiont. (PhD)	Dr A Baird, Dr M van Oppen, Prof T Hughes
Christopher Cvitanovic	JCU, ANU	Australia	Impacts of seasonal changes in temperature on the behaviour, performance and condition of coral reef butterflyfishes. (PhD)	Prof M Pratchett, Dr A Hoey
Kathryn Danaher	JCU	Australia	Oceanography and the condition of plankton. (PhD)	Prof M Kingsford
Sana Dandan	UWA	Denmark	Resilience of coral reef communities and coral metabolism in extreme environmental conditions. (PhD)	Prof M McCulloch

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Benjamin Davis	JCU	United Kingdom	Temporal nekton dynamics in tidal floodplain wetlands. (PhD)	Prof G Russ
Andrea de Leon	ANU, UWA	Australia	Palaeoceanographic records of the Southern Ocean: insights from the boron composition of biogenic silica. (PhD)	Prof M McCulloch
Anderson de Sevilha	JCU	Brazil	Systematic conservation planning for the Parana River Basin, Brazil. (PhD)	Prof R Pressey
Brynn Devine*	JCU	USA	Effects of ocean acidification on habitat selection in fish. (MSc)	Prof P Munday, Prof G Jones
Ayax Diaz-Ruiz	UQ	Mexico	The use of coral associated fauna as indicators of coral health. (PhD)	Prof O Hoegh-Guldberg, Prof J Pandolfi
Danielle Dixson	JCU	USA	Smelling home: the use of olfactory cues for settlement site selection by coral reef fish larvae. (PhD)	Prof P Munday, Prof G Jones, Prof M Pratchett
Juan Pablo D'Olivo	ANU, UWA	Mexico	Environmental and climate variability in seawater pH reconstructed from Boron isotopes in corals from the Pacific Ocean. (PhD)	Prof M McCulloch
Jennifer Donelson*	JCU, CSIRO	Australia	Climate change and the future for coral reef fishes: potential for acclimation. (PhD)	Prof P Munday, Prof M McCormick
Christopher Doropoulos	UQ, Griffith	Australia	Climate change effects on the recruitment and succession of algae and corals from the Great Barrier Reef. (PhD)	Prof PJ Mumby,
Michelle Dyer	JCU	Australia	Knowledge, power and fishery management in the Solomon Islands.(PhD)	Dr S Foale
Britt Edelman	JCU	USA	Trophodynamics of garfish (F. Hemiramphidae) in the tropics. (MSc)	Prof G Russ
Udo Engelhardt	UQ	Australia	Community-level ecological responses of coral reef biota to mass coral bleaching events. (PhD)	Prof O Hoegh-Guldberg
Kar-Hei Fang	UQ , UWA	China	Effects of climate change and eutrophication on the Indo-Pacific excavating sponge *Cliona orientalis* Thiele. (PhD)	A/Prof S Dove, Prof Ove Hoegh-Guldberg
Pepito Fernandez	ANU, JCU	Philippines	Political engagements in marine protected area governance in northeastern Liloilo, Philippines. (PhD)	Dr S Foale
Renata Ferrari Legorreta	UQ	Mexico	Management implications of grazing spatial distribution, ecosystem structural complexity and macroalgal competition for coral reef dynamics. (PhD)	Prof P Mumby
Simone Ferriera	JCU	Brazil	Spatial aggregation, competition for space and biodiversity maintenance in tropical reef corals. (PhD)	Prof S Connolly, Dr A Baird
Franz Martin Fingerlos	JCU	Austria	Interannual variations in species composition in Cleveland Bay. (MSc)	Prof G Russ
Taryn Foster	UWA	Australia	Potential impacts of higher ocean acidity and warmer water temperatures on Abrolhos Island coral reefs. (PhD)	Prof M McCulloch, Dr J Falter
Rebecca Fox	JCU	United Kingdom	Ecosystem function of rabbitfishes (F:Siganidae) on the Great Barrier Reef, Australia. (PhD)	Prof D Bellwood
Irene Fuertes Jerez	JCU	Spain	Larval connectivity from green to blue zone populations of *Epinephelus quoyanus* in Keppel Island's marine protected area network, southern Great Barrier Reef. (MSc)	Prof G Jones, Prof G Russ
Sarah Gierz	JCU	Australia	Acclimation of *Symbiodinium* to thermal stress. (PhD)	Dr W Leggat, Prof D Yellowlees
Chris Goatley	JCU	United Kingdom	The ecological role of sediments on coral reefs. (PhD)	Prof D Bellwood
Benjamin Gordon	JCU, AIMS	Australia	The metabolome of *Symbiodinium* phylotypes and their coral hosts. (PhD)	Dr W Leggat
Erin Graham	JCU	USA	Energetics of coral larvae and its implications for dispersal. (PhD)	Prof B Willis, Prof S Connolly, Dr A Baird

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Katie Grenchik	JCU	USA	Developmental thermal acclimation in reef fishes. (MAppSc)	Prof P Munday
Georgina Gurney	JCU	Australia	Improving the success of marine protected areas: integration of social considerations into conservation planning. (PhD)	Prof R Pressey, Dr J Cinner, Dr N Ban
Jessica Haapkyla	JCU, AIMS	Finland	Dynamics and drivers of coral diseases on Indo-Pacific reefs. (PhD)	Prof B Willis
Melanie Hamel	JCU, IRD Noumea	New Caledonia	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 *Pomacentrus coelestis*. (PhD)	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)	Prof G Jones, Prof G Russ, Dr S Planes
Tom Heintz	JCU	France	The impact of growth anomalies on growth and reproduction of corals. (MAppSc)	Prof B Willis
Christina Chemtai Hicks	JCU	United Kingdom	The interplay between economic values and societal settings in coral reef governance. (PhD)	Prof T Hughes, Dr J Cinner, Prof R Pressey
Jennifer Hodge	JCU	USA	Evolution and speciation processes in coral reef fishes. (PhD)	Prof D Bellwood
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, Dr S Foale
Emily Howells	JCU, AIMS	Australia	Coral symbionts in warming seas: population dynamics, adaptation and acclimatisation of *Symbiodinium*. (PhD)	Prof B Willis, Dr L Bay, Dr M van Oppen
Alec Hughes	JCU	Solomon Islands	Population biology and demography of the squaretail coral trout in Solomon Islands. (PhD)	Prof G Russ
Lotte Huisman*	JCU, U. Amsterdam	Netherlands	Combined effect of warming and ocean acidification on early life stages of corals. (MSc)	Prof D Miller
Fraser Januchowski-Hartley	JCU	United Kingdom	Biological mechanisms of customary management of Melanesian coral reefs and their consequences for the reef fish community. (PhD)	Prof G Russ, Dr N Graham, Dr J Cinner
Stephanie Januchowski-Hartley*	JCU	USA	Systematic conservation planning for fresh waters in the Wet Tropics bioregion Queensland Australia. (PhD)	Prof R Pressey
Young Koo Jin	JCU, AIMS	South Korean	Nature or nurture? Testing the correlation between physiological and genetic pollution stress indicators in corals on the Great Barrier Reef. (PhD)	Prof B Willis
Jacob Johansen	JCU	Denmark	Energetics of habitat choice in planktivorous coral reef fishes. (PhD)	Prof G Jones, Prof D Bellwood
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, UWA	Korea	Anthropogenic increase of atmospheric CO_2, ocean acidifying and global warming: implications for long-term changes in the calcification rate of coral reefs. (PhD)	Prof M McCulloch
Lisa Kelly	JCU	Canada	Understanding the impacts of growth anomalies on staghorn corals. (MAppSc)	Prof B Willis, Dr T Ainsworth
Marcelo Visentini Kitahara*	JCU, Smithsonian Institute	Brazil	Morphological and molecular systematics of scleractinian corals (Cnidaria, Anthozoa), with emphasis on deep-water species. (PhD)	Prof D Miller
Brent Knack*	JCU	Australia	Cell adhesion factors in Cnidarians. (PhD)	Prof D Miller, Dr W Leggat
Joleah Lamb	JCU, AIMS	USA	Influence of reef-based industries on coral health and disease. (PhD)	Prof B Willis, Prof G Russ
Rebecca Lawton	JCU, AIMS, KAUST	New Zealand	Geographic variation in the ecology of butterflyfishes and resilience to large scale disturbances. (PhD)	Prof M Pratchett, Dr L Bay, Prof T Hughes

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Angela Lawton	UQ	USA	The effects of micro-scale variation on the photosynthetic productivity of the symbiotic algae of reef building corals. (PhD)	Prof O Hoegh-Guldberg, A/Prof S Dove
Susannah Leahy	JCU	Australia	Do clouds save the Great Barrier Reef? (MAppSc)	Prof M Kingsford
Carine Lefèvre	JCU	France	The ecology of cryptobenthic fishes on the Great Barrier Reef. (PhD)	Prof D Bellwood
Anais Kimberley Lema	JCU, AIMS	Mexico	Nitrogen fixing bacteria associated with corals of the Great Barrier Reef. (PhD)	Prof B Willis
Tove Lemberget	JCU	Norway	Importance of body condition and growth to larval survival of a Caribbean lizardfish. (PhD)	Prof M McCormick, Prof G Jones
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
Jessica Levy	JCU	USA	Incorporating climate change modelling into marine conservation planning: an Indo-west Pacific example. (MAppSc)	Dr N Ban
Raechel Littman*	JCU, AIMS	USA	The dynamics of bacterial populations associated with corals and the role of bacterial pathogens in coral bleaching. (PhD)	Prof B Willis
Oona Lonnstedt	JCU	Sweden	Omnious odour - the role of olfactory cues in predator-prey interactions. (PhD)	Prof M Kingsford, Prof M McCormick, Prof P Munday
Adrian Lutz	JCU, AIMS	Switzerland	Coenzyme Q and plastoquinone redox balance as a physiological determinant of oxidative stress in coral algal symbiosis. (PhD)	Prof D Miller, Dr M van Oppen
Matt Lybolt	UQ	USA	Causes of change in coastal ecosystems: past, present and future. (PhD)	Prof J Pandolfi
Rafael Magris	JCU	Brazil	Applying biodiversity conservation planning tools into the design of a long term conservation strategy for Abrolhos Bank. (PhD)	Prof R L Pressey, Dr N Ban
Azusa Makino	UQ	Japan	Developing conservation planning for coral reefs: considering zone effectiveness, land-sea connectivity and range expansion due to climate change. (PhD)	Dr M Beger
Rachel Manassa	JCU, U. Saskatchewan	Australia	Importance of social systems and information transfer in coral reef fish. (PhD)	Prof M McCormick, Prof P Munday
Alyssa Marshell	UQ	Australia	The ecological role of herbivorous surgeonfish (Acanthuridae) on coral reefs. (PhD)	Prof P Mumby
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
Rachael Middlebrook	UQ	Australia	Determining thermal threshold dynamics and variability in reef building corals. (PhD)	A/Prof S Dove, Prof O Hoegh-Guldberg
Morana Mihaljevic	UQ	Croatia	Indo-Pacific coral evolution: Neogene reefs from the South China Sea. (PhD)	Prof J Pandolfi
Gabrielle Miller	JCU	Australia	The interacting effects of ocean acidification and increasing temperature on a coral reef fish. (PhD)	Prof P Munday, Prof M McCormick
Morena Mills*	JCU	Brazil	Implementation opportunity in systematic conservation planning. (PhD)	Prof R Pressey, Dr N Ban, Dr S Foale
Matthew Mitchell	JCU	United Kingdom	Antipredator defence through chemical alarm cues: how common amongst tropical marine fishes? (PhD)	Prof M McCormick
Anke Moesinger	ANU, JCU	Germany	Local perceptions and environmental protection: exploring the social dimensions of the Tetepare Marine Protected Area. (MAppSc)	Dr S Foale
Christopher Mooney	JCU	Australia	Statoliths of Cubozoan jellyfishes: their utility to discriminate taxa and elucidate population ecology. (PhD)	Prof M Kingsford

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Roshni Narayan*	UQ	Canada	Holocene to recent changes in the benthic foraminifera communities of subtropical Moreton Bay, Queensland and potential indicators for monitoring sediment/water quality in estuarine environments. (PhD)	Prof J Pandolfi
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
Crystal Neligh	JCU	USA	Links between metabolism, growth and performance. (MAppSc)	Prof M McCormick
Katia Nicolet	JCU	Switzerland	Corallivorous species as potential vectors of brown band disease on an inshore reef. (MAppSc)	Prof B Willis, Prof M Pratchett
Daisie Ogawa	JCU	USA	Synergistic effects of ocean acidification and elevated temperature on carbon-concentrating mechanisms and energy transfer in the coral holobiont. (PhD)	Dr W Leggat, Prof D Yellowlees
Allison Paley	JCU, AIMS	USA	Colour polymorphism and thermal resilience in the coral *Acropora millepora* on the Great Barrier Reef. (PhD)	Prof B Willis, Dr M van Oppen, Dr L Bay
Caroline Palmer*	JCU, Newcastle University	United Kingdom	Biological mechanisms of coral immunity. (PhD)	Prof B Willis
Christine Pam	JCU	Australia	The global discourse of climate change and small island states. (PhD)	Dr S Foale
Simone Pennafirme Ferreira	JCU	Brazil	Spatial aggregation competition for space and biodiversity maintenance in tropical reef corals. (PhD)	Prof S Connolly, Dr A Baird
Srisakul Piromvaragorn	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. (MSc)	Prof M Pratchett
F. Joseph Pollock	JCU, AIMS, College of Charleston (SC, USA)	USA	Phylogeny of the coral pathogen *Vibrio coralliilyticus* and the development of a qPCR-based diagnostic assay for its detection. (PhD)	Prof B Willis
Eneour Puill-Stephan*	JCU, AIMS	France	Chimerism and allorecognition in the broadcast spawning coral *Acropora millepora* on the Great Barrier Reef. (PhD)	Prof B Willis, Dr M van Oppen
Paola G. Rachello-Dolmen	UQ, AUSTMUS	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	Coral-associated bacteria and their role in the biogeochemical cycle of sulphur. (PhD)	Prof B Willis
Triez Razak	UQ	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)	A/Prof S Dove, Prof O Hoegh-Guldberg
Claire Reymond*	UQ, AIMS	Australia	Historical ecology and experimental biology of foraminifera from the inshore Great Barrier Reef, Australia. (PhD)	Prof J Pandolfi
Alma Ridep-Morris	JCU	Palau	Dynamics of coral diseases on Palauan reefs and the role of marine protected areas in mitigating their impacts. (MSc)	Prof B Willis, Prof G Jones
Jairo Rivera Posada	JCU	Colombia	Pathogenesis in crown-of-thorns starfish *(Acanthaster planci)*. (PhD)	Prof M Pratchett, Prof T Hughes
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
Dominique Roche	ANU, JCU	Canada	Bio-physical interactions and predator-prey relationships in coral reef fishes. (PhD)	Prof D Yellowlees Prof S Keogh
Melissa Rocker	JCU, AIMS	USA	Oxidative stress-related gene expression in juvenile *Acropora millepora* corals exposed to thermal stress. (MAppSc)	Prof B Willis

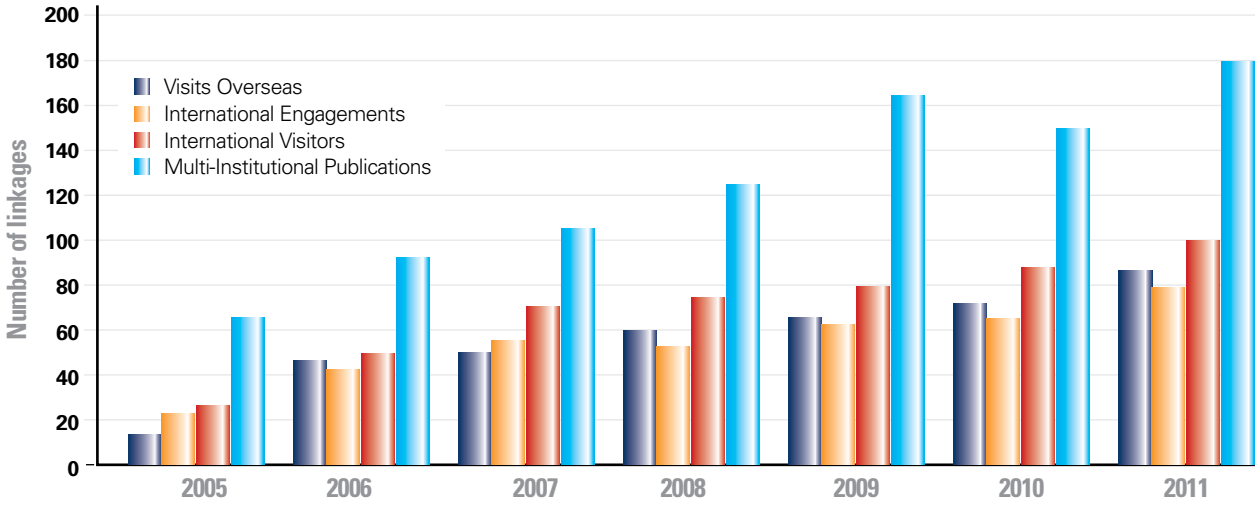
Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Alberto Rodriguez-Ramirez	UQ	Colombia	Inter-regional comparison of historical bleaching events in coral communities (Great Barrier Reef, South China Sea, and East Pacific): finding linkages to natural and anthropogenic factors. (PhD)	Prof J Pandolfi
Pablo Saenz-Agudelo*	JCU, U. Perpignan	Colombia	Estimating connectivity in coral reef fish populations: a tool for understanding stability and resilience of marine ecosystems. (PhD)	Prof G Jones, Dr S Planes
Jimena Samper-Villarreal	UQ	Costa Rica	Carbon sequestration by seagrasses in Moreton Bay. (PhD)	Prof P Mumby
Yui Sato	JCU, AIMS	Japan	Ecology and biology of black band disease in the scleractinian coral, *Montipora.* (PhD)	Prof B Willis
Shio Segi*	ANU, JCU	Japan	'Pinning our hope on the seas': conservation, resource depletion and livelihood in a Philippine fishing village. (PhD)	Dr S Foale
Adityo Setiawan*	JCU	Indonesia	Socioeconomic factors influencing success in customary management institutions in Aceh, Indonesia. (MSc)	Dr J Cinner
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
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
Brigitte Sommer	UQ, Southern Cross	Australia	Ecological dynamics and conservation of subtropical coral communities of eastern Australia under climate change. (PhD)	Prof J Pandolfi
Jessica Stella	JCU, Australian Museum	USA	Climate impacts on coral-associated invertebrates. (PhD)	Prof G Jones, Prof M Pratchett, Prof P Munday
Novi Susetyo Adi	UQ	Indonesia	Assessment of coral reef productivity using remote sensing data. (PhD)	A/Prof Dove, Prof O Hoegh-Guldberg
Chun Hong Tan	JCU	Malaysia	Environmental controls and evolutionary constraints on growth and reproduction in corals. (PhD)	Dr A Baird, Prof M Pratchett
Alifereti Tawake	JCU, CSIRO, USP	Fiji	Livelihood benefits of adaptive co-management of hand collectable fisheries in the Torres Strait and Fiji. (PhD)	Dr S Foale
Brett Taylor	JCU	USA	Parrotfish demography throughout Micronesia: effects of life histories on environmental and fishery-induced variability. (PhD)	Prof G Russ
Michelle Templeman	JCU	Australia	The role of jellyfish in cycling contaminants in the marine environment and their utility as biomonitors. (PhD)	Prof M Kingsford
Loic Thibaut	JCU, U. Pierre et Marie Curie	France	Resilience in coral reef and model ecosystems. (PhD)	Prof S Connolly, Prof T Hughes
Gergely Torda	JCU, AIMS	Hungary	Assessment of ecological connectivity in corals: implications for their recovery from major perturbations and their potential to adapt to climate change. (PhD)	Prof B Willis, Dr M van Oppen
Melanie Trapon	JCU	France	Variation in population dynamics of reef-building corals along the Great Barrier Reef. (PhD)	Prof M Pratchett, Dr A Baird
Lubna Ukani	JCU	India	Characterisation of DNA methylation systems in *Acropora* and other lower animals. (PhD)	Dr W Leggat
Svetlana Ukolova	JCU	Russia	Characterisation of the Wnt signalling system in *Acropora.* (PhD)	Prof D Miller, Dr W Leggat
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	Characterisations of genes, proteins, and the regulatory pathways involved in nitrogen uptake and the assimilation in *Acropora aspera* and its symbiont *Symbiodinium* sp. (PhD)	A/Prof S Dove, Dr W Leggat, Prof D Yellowlees
Martin van der Meer	JCU	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)	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 B Willis, Prof P Munday

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Jennifer Vick	JCU	USA	Spatial and temporal patterns in the foraging of carnivorous fishes on coral reefs. (MAppSc)	Prof G Jones
Ana Cecilia Villacorta Rath*	JCU, AIMS	Peru	Determinants of selective mortality during the early life history of *Spratelloides delicatulus* in the northern Great Barrier Reef. (MSc)	Prof M McCormick, Dr M Meekan
Piero Visconti*	JCU, U. La Sapienza, Rome	Italy	Addressing new challenges in dynamic conservation planning. (PhD)	Prof R Pressey, Dr N Ban
Patricia Warner	JCU, AIMS	USA	Reproductive ecology and population genetic approaches to assessing connectivity of the brooding coral, *Seriatopora hystrix*. (PhD)	Prof B Willis, Dr M van Oppen
Yvonne Weiss	JCU	Germany	The immune system of *Acropora millepora:* identification and characterisation of candidate genes. (PhD)	Prof D Miller, Dr W Leggat, Dr T Ainsworth
Justin Welsh	JCU	Canada	Evaluating the spatial scale of ecosystem functions on coral reefs. (PhD)	Prof D Bellwood, Prof S Connolly
Colin Wen	JCU	Taiwan	Recruitment hotspots and their role in the ecology and management of large exploited predatory fishes. (PhD)	Prof G Jones, Prof M Pratchett, Dr G Almany
Amelia Wenger	JCU	USA	Effects of sedimentation and turbidity on planktivorous fishes. (MSc)	Prof G Jones, Prof M McCormick
James Ryan White	JCU	USA	Proximate and ecological forces that shape behavioural syndromes in coral reef fishes. (MAppSc)	Prof M McCormick
Kumara Anura Wickrama Arachchige	JCU	Sri Lanka	Coral disease in Kimbe Bay, PNG. (MAppSc)	Prof B Willis
Laura Woodings	JCU, AIMS	Australia	Variation in gene expression, growth, and lipid content between colour morphs of *Acropora millepora*. (MAppSc)	Prof B Willis, Dr L Bay
Erika Woolsey	JCU, U. Sydney	USA	Reefs on the edge: coral biogeography and larval ecology in a warming ocean. (PhD)	Dr A Baird
Matthew Young	JCU	Australia	Reef fishing: a social ecological perspective. (PhD)	Prof D Bellwood, Dr S Foale
Salvador Zarco Perello	JCU	Mexico	Marine patch dynamics in conservation planning (PhD)	Prof R Pressey Dr N Ban
Huibin Zou	JCU	China	The characterisation of selenium containing protein families in coral *Acropora millepora*. (PhD)	Prof D Miller, Dr T Ainsworth

*Degree awarded during 2011

International Linkages

The Centre's international linkages in 2005 to 2011
All four metrics have shown strong growth



Since the establishment of our ARC Centre in 2005, there has been rapid growth in the engagement of the Centre with the international science community, as well as governments, agencies and NGOs in many countries. Research collaborations are exemplified by multi-institutional publications, visits to overseas institutions and visitors to all four nodes of the ARC Centre. The Centre's profile and reputation is increasingly attracting overseas postgraduate students who in 2011 have come to Australia from 42 different countries around the world (see Graduate training, p.36). Centre personnel are also actively involved in many international research consortia and activities such as consultancies and end-user engagement. In 2009, the *International Society for Reef Studies* appointed the ARC Centre Director, Terry Hughes, as the Convener of the next International Coral Reef Symposium, which will be held in Australia in 2012 (see p.49). Over 2,000 delegates from approximately 80 countries will be hosted by the ARC Centre during the week-long symposium.

In 2011, the ARC Centre produced 175 publications with cross-institutional co-authorship (compared to 88 in 2006), involving researchers from 274 institutions in 47 countries. The ARC Centre hosted 98 international visitors from 19 countries, and Centre personnel traveled to 25 countries. The ARC Centre participated in or hosted 34 international working groups during 2011. This year ARC Centre personnel were members of editorial boards for 24 international journals. 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),* and the *International Council for Science* (ICSU). Three of the Centre's Program Leaders are elected Fellows of the *Australian Academy of Science*.

Some of the ARC Centre's major international collaborations include:

International Programme on Ecosystem Change and Society (PECS)

The International Council for Science (ICSU), in collaboration with UNESCO and the United Nations University, has recently completed the planning for a new international interdisciplinary programme on ecosystem change and human wellbeing. ARC Centre Director, Terry Hughes has been appointed to the PECS Science Committee. The goal of PECS, the Programme on Ecosystem Change and Society, is to understand transformations toward or away from sustainable development, including mitigation of poverty and environmental degradation, by focusing on human development and sustainability of natural capital as a research agenda. Thus PECS aims to link scientific and environmental knowledge to society and policy. A core element of the capacity-building strategy for PECS will be training

workshops on core methods for place-based, long-term social-ecological research. PECS will complement existing efforts for research, assessment and policy for sustainable development. A few examples are:

- DIVERSITAS (*www.diversitas-international.org*) projects such as BioSustainability
- International Geosphere-Biosphere Programme, (*www.igbp.net/page.php?pid=113*) projects such as Analysis, Integration and Modeling of the Earth System
- International Human Dimensions Programme (IHDP, *www.ihdp.unu.edu*) projects such as Earth System Governance and Urbanization and Global Environmental Change
- Observation programs such of GEOSS (*www.earthobservations.org/geoss.shtml*)
- Existing global research networks such as UNESCO's Man and Biosphere Programme, the CGIAR network of partners and research projects on agriculture food production and natural resource management.

The Nature Conservancy

The Nature Conservancy (TNC), the world's largest non-profit conservation organisation, and the ARC Centre, signed a Memorandum of Understanding in 2008. It cements a growing level of engagement between the two organisations involving projects in numerous countries. The TNC depends on sound scientific knowledge to accomplish its mission, and works closely with the Centre on many fronts. For example in 2011, Future Fellow Glenn Almany from the Centre's JCU node collaborated closely with TNC researcher Alison Green and her teams in Melanesia - on reef connectivity and the design of networks of coral reef marine protected areas in the Coral Triangle region. The TNC and Program 6 Leader, Bob Pressey, also undertook ongoing collaborations in 2011, focusing on conservation planning and seascape approaches to coastal management in the Bismarck Sea and elsewhere in the Coral Triangle.

The Stockholm Resilience Centre

In 2007 the ARC Centre of Excellence for Coral Reef Studies signed a Memorandum of Understanding with the newly established Stockholm Resilience Centre (SRC) to cooperate and collaborate in areas of mutual interest in research. This new international centre advances trans-disciplinary research for governance of social-ecological systems with a special emphasis on resilience – the ability to deal with change and continue to develop. The SRC is a joint initiative between Stockholm University, the Stockholm Environment Institute and the Beijer International Institute of Ecological Economics at The Royal Swedish Academy of Sciences. The ARC Centre Director, Terry Hughes, is a Fellow and Board member of the Beijer Institute. As part of the agreement, more than a dozen postdoctoral fellows and PhD students have travelled between Australia and Sweden to work on joint projects, including, Orjan Bodin, Albert Norström, Magnus Nyström, Per Olsen, Terry Hughes, Natalie Ban, Joshua Cinner, Louisa Evans, Nick Graham and Christina Hicks.

The WorldFish Center

Established in 1977 as the International Center for Living Aquatic Resources Management (ICLARM), The WorldFish Center re-named and established its new headquarters in Penang, Malaysia in 2000. WorldFish have regional or country offices in Bangladesh, Cambodia, Egypt, Malawi, Malaysia, the Philippines, Solomon Islands, and Zambia. In 2009, James Cook University and The WorldFish Center established a Memorandum of Understanding to build new collaborative links. In 2011, WorldFish researcher David Mills moved from Penang to Australia, to take up a three-year secondment in the ARC Centre. Neil Andrews from WorldFish has joined the Centre's Advisory Board. Several of the ARC Centre's researchers, notably Louisa Evans, Pip Cohen, Bob Pressey and Simon Foale have substantial collaborative projects with WorldFish in the Solomon Islands, elsewhere in the Coral Triangle region, and in east Africa.

Overseas Visiting researchers

In 2011, almost 100 international visitors were hosted by one or more nodes of the ARC Centre, or attended working group meetings organised by the Centre.

Visitors to the Centre of Excellence for Coral Reef Studies in 2011

Visitor	Organisation	Country
Hon Jean-Paul Adam	Minister of Foreign Affairs	Seychelles
Dr Edward Allison	WorldFish Center	Malaysia
Dr Neil Andrew	WorldFish Center	Malaysia
Prof Jelle Atema	Boston University	USA
Dr Anthony Bertucci	Centre Scientifique de Monaco	Monaco
Dr Michael Berumen	King Abdullah University of Science and Technology	Saudi Arabia
Prof Thomas Bosch	University of Kiel	Germany
Dr Keith Brander	Danish Institute of Aquatic Resources	Denmark

Visitor	Organisation	Country
Prof Andrew Brierely	University of St Andrews	UK
Elsa Canard	University of Montpellier	France
Chia-Ling Chan	Academia Sinica	Taiwan
Prof Allen Chen	Academia Sinica	Taiwan
Lucas Corvacho	University of Santa Cecilia	Brazil
Dr Christine Couturier	University of Oslo	Norway
Sarah Davies	University of Texas	USA
Dr Julian DeBortoli	University of Montpellier	France

Visitor	Organisation	Country
Dr Rodolphe Devillers	Memorial University of Newfoundland	Canada
Dr Angela Douglas	Cornell University	USA
Dr Mark Eakin	National Oceanic and Atmospheric Administration	USA
Dick Esparon	High Commissioner for the Republic of Seychelles	Seychelles
Dr Ruth Gates	University of Hawaii	USA
Prof Gabi Gerlach	Oldenburg University	Germany
Prof Eric Gilson	University of Nice	France
Prof Benjamin Greenstein	Cornell College	USA
Dr Marea Hatziolos	World Bank	USA
Dr Andrew Hoey	King Abdullah University of Science and Technology	Saudi Arabia
Lotte Huisman	University of Amsterdam	Netherlands
Dr Akira Iguchi	University of the Ryukyus	Japan
Assoc Prof Suha Jabaji	McGill University	Canada
Prof Jeremy Jackson	Scripps Institute of Oceanography	USA
Srdjana Janosevic	Government of the Seychelles	Seychelles
Jennifer Jeans	Mount Allison University	Canada
Julie Jourdan	University of Montpellier	France
Dr Takeshi Kawashima	Okinawa Institute of Science and Technology	Japan
Emma Kennedy	Exeter University	UK
Dr Konstantin Khalturin	University of Kiel	Germany
Prof Wolfgang Kiessling	Museum für Naturkunde	Germany
Maurice Knight	Coral Triangle Support Partnership	USA
Maurits Kristian Rumbaker	Ampat Development Planning Board	Indonesia
Dr Vivian Lam	International Union for Conservation of Nature	USA
Dr Oren Levy	Bar Ilan University	Israel
Prof Yossi Loya	Tel Aviv University	Israel
Dr Olivier Lucas	University of South Florida	USA
Artemas Mambrisauw	Ampat Development Planning Board	Indonesia
Dr Stephanie Manel	Université de Provence	France
Dr Benjamin Mason	University of Miami	USA
Assoc Prof Mikhail Matz	University of Texas	USA
Dr Jeff Maynard	Maynard Consultancies	USA
Dr Kelton McMahon	Woods Hole Oceanographic Institution, King Abdullah University of Science and Technology	USA Saudi Arabia
James Michel	President of the Republic of Seychelles	Seychelles
Dr David Mills	WorldFish Center	Malaysia
Prof David Mouillot	University of Montpellier	France

Visitor	Organisation	Country
Gervais Moumou	Government of the Seychelles	Seychelles
Dr Nicolas Mouquet	University of Montpellier	France
Dr Aurélie Moya	University of Nice	France
Prof Goran Nilsson	University of Oslo	Norway
Rachmat M Nurjaya	Ampat Development Planning Board	Indonesia
Dr Claire Paris	University of Miami	USA
Dr Rolph Payet	University of Seychelles	Seychelles
Dr Lucie Penin	Insular Research Center and Environment Observatory (CRIOBE)	France
Prof Hans-Otto Poertner	Alfred Wegner Institute	Germany
Rebecca Prescott	University of Hawaii	USA
Dody Prianto Kamaruddin	Ministry of Culture and Tourism	Indonesia
Julia Purtov	University of Kiel	Germany
Klasina D Rumbekwan	Ministry of Culture and Tourism	Indonesia
Yusup Salim	Regional Secretariat of Raja Ampat	Indonesia
Abdul Samad Wajo	Regional Secretariat of Raja Ampat	Indonesia
Janes Sarwa	Ampat Development Planning Board	Indonesia
Dr Nori Satoh	Okinawa Institute of Science and Technology	Japan
Dr Keshavmurthy Shashank	Academia Sinica	Taiwan
Dr Chuya Shinzato	Okinawa Institute of Science and Technology	Japan
Dr Eiichi Shoguchi	Okinawa Institute of Science and Technology	Japan
Adrienne Simoes-Correa	Florida International University	USA
Dr Carl Simpson	Museum für Naturkunde	Germany
Dr Paul Snelgrove	Memorial University of Newfoundland	Newfoundland
Alain St Ange	Seychelles Tourism Board	Seychelles
Dr Jonathan Stecyk	University of Oslo	Norway
Dr Andrew Thurber	Oregon State University	USA
Ingrid van de Leemput	Wageningen University	Netherlands
Assistant Prof Rebecca Vega Thurber	Oregon State University	USA
Sandra Vegting	Australian High Commissioner	Mauritius
Dr Christian Voolstra	King Abdullah University of Science and Technology	Saudi Arabia
Denny Wahyu Novianto	Ampat Development Planning Board	Indonesia
Andrea Wallace	Imperial College	UK
James Waropen	Ampat Development Planning Board	Indonesia
Yohanes Warwe	Ampat Development Planning Board	Indonesia
Wiebke Wessels	University of Bremen	Germany
Syafyuddin Yusuf	Hasanuddin University	Indonesia
Rachel Zimmerman	University of Wisconsin	USA
Isnain	Ampat Development Planning Board	Indonesia

Photo by Tom Bridge

International Coral Reef Symposium 2012

The ARC Centre and James Cook University are looking forward to **hosting the 12th International Coral Reef Symposium (ICRS 2012) in Cairns, Australia from 9 – 13 July 2012.** The ICRS is the world's largest and most important coral reef meeting. Held every four years, it brings together coral reef scientists, educators, graduate students, resource managers and policy makers. ICRS 2012 is expected to attract over 2,000 delegates from 80 countries to the Cairns Convention Centre, an award-winning venue.

ICRS 2012 will provide the international science community with a critical platform to share recent research findings to advance global knowledge and interest in coral reef science, management and conservation. The Symposium is also fundamental in raising global awareness of reefs and informing international and national policies and protocols for sustainable use of coral reefs.

Activities at ICRS 2012 will include a comprehensive science program, a trade exhibition, and field trips both before and after the Symposium to the Great Barrier Reef, including to Heron Island, One Tree Island, Lizard Island and Orpheus Island Research Stations. Australian culture and food will be showcased at social events and the symposium banquet will provide additional opportunities for delegates to develop connections, collaborations and partnerships. ICRS 2012 will attract an extensive national and international media contingent, whose stories will increase awareness of coral reef science around the world.

The Symposium will be convened by the ARC Centre's Director, Terry Hughes. The Sub-Committees responsible for fundraising (led by David Yellowlees) and the scientific program (chaired by Terry Done) include representatives from 10 countries. We sincerely thank everyone who has volunteered their expertise and support.

In 2011, the Symposium's website at *www.icrs2012.com* received over 2.6 million hits. In September 2011, over 2100 abstracts were uploaded by delegates to the website.

We awarded over 100 grants to assist with the costs of registration, accommodation and travel. We are grateful to the *Australian Coral Reef Society*, the *International Society for Reef Studies, AusAID, The Ian Potter Foundation, The Nature Conservancy* and the *David & Lucile Packard Foundation* for making contributions towards supporting delegates to attend, particularly people from developing countries, students or those early in their career.

Fundraising for ICRS2012 was a major focus in 2011. We are grateful to all our sponsors, including major sponsorship received from the Australian Institute for Marine Science, the David & Lucile Packard Foundation, James Cook University, King Abdullah University of Science and Technology, National Oceanic and Atmospheric Administration, and the Queensland Government.

The unrivalled scientific program, comprising over 1500 presentations, will be finalised by April 2012.

Her Excellency Ms Penelope Wensley, AC, Governor of Queensland will officially open ICRS 2012.

For further information on the Symposium, contact:

Eliza Glasson, Conference Coordinator
ARC Centre of Excellence for Coral Reef Studies
James Cook University, Townsville, Queensland 4811, Australia
Phone: +61 7 4781 4844
Fax: +61 7 4781 3015
Email: *eliza.glasson@jcu.edu.au*

Media and Public Outreach

To increase public awareness of the importance of coral reef science and management, the ARC Centre engages with the wider community through the media and through a variety of public outreach activities. As part of our communications strategy, the Centre has developed an active media presence in consultation with Julian Cribb and Associates, our media advisor.

In 2011, researchers from the Centre participated in 56 public outreach events and programs, reaching audiences locally, nationally and internationally. The foremost of these was the Centre's annual two-day national symposium *Coral Reefs: Coast to Coast* in Fremantle on 20th – 21st October. A public forum chaired by the Centre's Professor David Bellwood attracted a capacity audience to the Western Australian Maritime Museum.

The Centre's website caters for multiple audiences, providing information, access to resources, research services, and downloads of research, teaching and educational materials and tools. The site received 7.6 million web hits in 2011, a ten-fold increase over the past five years. The website developed for the upcoming 12th International Coral Reef Symposium, which we will convene in Cairns in July 2012 (see p.49) contributed over 2.6m to this total. Social media, established to promote the symposium on Twitter and Facebook, has proved highly popular and will be incorporated into the Centre's new website in 2012. Next year, the upgraded website will have a cleaner, fresher look, be more easily navigable and searchable and more fully showcase the work of the Centre's students and other researchers.

Thirty five new talks were added to the Centre's highly popular webinar series in 2011 under the theme, Coral Reefs: Coast to Coast. These videos range from short, highly topical presentations on issues of interest to the general public to longer videos showcasing the latest, leading-edge science for a scientifically informed audience (*www.coralcoe.org.au/events/symposium11/program.html*).

Examples of other outreach activities include:

- In February 2011, Bob Pressey delivered the year's inaugural presentation at the Australian Ambassador's Visiting Speaker Series in Washington DC, introduced by Ambassador Kim Beazley. Bob's talk "Coral reef planning – biodiversity and fisheries in the Coral Triangle" attracted a large audience from the diplomatic corps and agencies as well as the university sector.
- ARC Centre researchers delivered public talks in more than 10 countries in 2011. Philip Munday presented "Economics of ocean acidification: bridging the gap between ocean acidification impacts and economic valuation" to policy and decision makers in Monaco, following up with a brochure released at the 17th Conference of the Parties (COP17) to the United Nations Framework Convention on Climate Change in Durban. Joshua Cinner presented at a fishers' forum in Mombasa in Kenya, Nick Graham delivered a public lecture hosted by the Seychelles Fishing Authority and Terry Hughes and Ove Hoegh-Guldberg each made public presentations on four continents on topics including climate change and the global importance of coral reefs.
- In Papua New Guinea, Glenn Almany led a series of discussions with seven local communities to discuss management recommendations arising from the results of a study on larval dispersal and population connectivity in Kekwa on the south coast of Manus Island.
- Activities aimed at school children are a continuing focus of the ARC Centre's outreach activities. In August, Tracy Ainsworth participated in the L'Oreal Australia Girls in Science Forum for Secondary Schools which targetted secondary school students. Four Centre researchers, Line Bay, Andrew Hoey, John Pandolfi and Morgan Pratchett continued in their rewarding roles as Queensland Scientists in Schools with Morgan giving classroom presentations at two primary schools entitled 'living versus dead with scleractinain corals'. Allison Paley, a Centre graduate student and the Australian Academy of Technological Sciences and Engineering (ATSE) Young Scientist for 2011 toured schools in the Torres Strait engaging students in hands-on marine science activities. Torres Strait was also the venue for the launch of Mariana Fuentes' book *Myrtle's Battle Against Climate Change* for primary school students. Simon Foale worked with secondary students in the Solomon Islands in developing and testing the impact of a DVD he is producing to demonstrate the life cycle of key reef organisms in the context of fishery management. In December, Perth high school teachers attended a public lecture by Jim Falter on "Changes in ocean and reef chemistry in a rising pCO_2 world".

Media stories

In 2011, the ARC Centre produced 30 media releases, generating 3086 media stories that reached local, national and international audiences. Examples include:

National Geographic Newswatch, *Global Fishing Communities Putting the Heat on Climate Change Talks,* 7/12/11, J Cinner

News24, *Fish adapt to higher temps – study,* 7/12/11, P Munday

Australasian Science, *Corals can sense what's coming*, 28/11/11, T Ainsworth, L Ukani, F Seneca, D Yellowlees, D Miller, and W Leggat

BBC News, *Australia plans huge marine reserve in Coral Sea*, 25/11/11, T Hughes

ABC Radio Australia News, *Joy of mass organism on Great Barrier Reef*, 08/11/11, B Willis

Seoul Times, *Sea Life "Must Swim Faster to Survive",* 4/11/11, J Pandolfi

Bio-Medicine, *Corals - More complex than you?* 29/10/11, D Miller

Innovations ABC radio, *Safeguarding Oceans*, 23/10/11, T Hughes

International Business Times, *Scientists Point to Dwindling Shark Numbers on Great Barrier Reef*, 29/9/11, S Connolly

Wild Singapore, *Discovery about overfishing 'can help save reefs'*, 28/9/11, N Graham

ECOS Magazine, *Breaking up not always bad for reefs,* 12/9/11, G Jones

New York Times, *Lobsters Find Utopia Where Biologists See Trouble* 22/8/11, T Hughes, R Steneck

Ocean News and Technology, *Climate Change will Damage Reefs 'At Different Rates*", 3/8/11, J Pandolfi and S Connolly

Berliner Morgenpost, *Great Barrier Reef viel robuster als angenommen*, 22/7/11 O Hoegh-Guldberg, S Connolly

Nature.com news, *Coral genomes could aid reef conservation*, 25/7/11, D Miller

The Conversation, *Climate change is real: an open letter from the scientific community*, 7/7/11, M McCulloch

The Bahamas Weekly, *New study that shows how grouper can help control the invasion of lionfish,* 19/6/11, P Mumby

Radio National Breakfast, *Behavioural effects on fish of ocean acidification*, 10/6/11, P Munday

The Age, *Reef fish face new climate threat*, 1/6/11, M Pratchett

InSciences Organisation, *CO_2 seeps in PNG give insights to the future of coral reefs in a world of increasing greenhouse gas emissions*, 30/5/11, J Lough

Science Magazine Daily News, *Weed-Eating Fish Key to Reef Survival,* 4/5/11, D Bellwood

The Age, *The turtle's scramble for survival*, 30/4/11, M Fuentes

New Scientist, *True sea snakes stick to one male only*, 20/4/11, V Lukoschek

The Australian, *Tropical fish able to adjust to climate change*, 6/4/11, J Donelson

Manila Bulletin Publishing Corp, *Biomass recovery in marine reserves*, 20/3/11, G Russ

The Hindu, *Weed-eating fish key to coral reefs' survival*, 11/3/11, D Bellwood

China Post, *Resilient reefs in fight for life against coral bleaching*, 7/3/11, O Hoegh-Guldberg

Enterprise Post News, *Marine 'Networks' Can Protect Fish Stocks*, 7/3/11, J Kool

The Jerusalem Post, *Coral rhythms help them beat night blues*, 20/2/11, D Miller

Laboratory Journal, *Ocean Acidification and Global Warming: Threats to Coral Reefs*, 17/2/11, K Anthony

R&D Mag, *Extinction predictor "will help protect coral reefs",* 16/2/11, N Graham

Telegraph.co.uk, *Great Barrier Reef under stress from floods and Cyclone Yasi*, 12/2/11, O Hoegh-Guldberg

Discovery News, *Australian Corals Predict More Rains*, 10/2/11 J Lough

U.S.News & World Report (AP), *Corals Moving North*, 25/1/11, J Pandolfi

The Australian, *Marine conservation, with a catch*, 6/1/11, G Russ

Reproduced with thanks to SWOT.
This article originally appeared in SWOT Report—*The State of the World's Sea Turtles*, Vol. VI (2011), available at *www.seaturtlestatus.org*.

How Will Sea Turtles Cope with Climate Change?

By MARIANA FUENTES and LUCY HAWKES

It is now widely accepted that climate change is a significant threat to biodiversity, especially to species like sea turtles whose life histories are sensitive to fluctuating environmental conditions. A growing number of studies have begun to investigate and predict how different climatic processes will affect sea turtles. Most of the studies have focused on the possible effects on turtle nesting beaches, which reflects the general terrestrial bias present in sea turtle research. Nevertheless, climate change is expected to affect turtles in multiple ways and at all life stages, from the loss of nesting beaches resulting from sea level rise and increased erosion, to feminization of turtle populations because of elevated nest temperatures, changes in reproductive periodicity, shifts in latitudinal ranges, and decreased reproductive success. Although some of these factors have received a fair amount of attention from researchers, much still remains unanswered about how climate change will affect things like hatchling dispersal and migration, foraging ecology, and the ways in which turtles will find new beaches if current beaches become unsuitable for nesting.

THIS PAGE: Small, low-lying islands, such as the one pictured above in Belize, are often used by sea turtles for nesting. Unfortunately, sea-level rise caused by climate change is already causing some low-lying islands to become inundated and, thus, unreliable and unfit nesting habitats for sea turtles. This trend is likely to continue. © KJELL SANDVED AT LEFT: Climate change is expected to cause increased erosion and nesting beach loss in some areas, which can directly affect sea turtle nesting habitats, as shown by this washed-out nest in Florida, U.S.A. Although the exact effects of climate change on sea turtles are uncertain, precautionary human actions can give sea turtles a better chance of adapting to such changes. © CHRIS JOHNSON / WWW.TURTLEIMAGES.ORG

The risk to sea turtle populations from climate change will depend on the turtles' ability to adapt to changing conditions. Sea turtles have survived climate fluctuations during their evolutionary history, but their ability to do so again is uncertain because current rates of climate change are much faster than historic rates. Today, there are many additional anthropogenic pressures to cope with as well. Nevertheless, sea turtles have evolved flexible life history traits and may adapt to climate change through shifts in the distribution of their nesting areas or through changes in nest site selection, nesting season, and nest depths. Other possible adaptation responses include changes in their pivotal temperatures (that is, the temperature at which a nest produces a 50:50 hatchling sex ratio) and alteration of migration routes.

Because of uncertainty about whether sea turtles will adapt on their own, precautionary human actions may be necessary to increase the turtles' chances of adjusting. A mix of different short-term and long-term approaches has been suggested to enhance sea turtle nesting success and reproduction, including reduction of egg harvesting, nest shading, revegetation, and sand renourishing, as well as preemptive protection of areas that are predicted to be optimal nesting sites under future climate scenarios.

Uncertainties about the feasibility and effectiveness of adaptation strategies make the selection of preemptive interventions challenging, as do unanswered questions such as "How many males are necessary to maintain a fertile population of females?" and "What beach characteristics are favored by nesting females?" These factors, as well as how current nesting areas may respond to predicted climate changes, need to be better understood if one is to accurately identify and protect areas that will provide suitable nesting conditions for turtles in the future.

We must continue gathering crucial scientific information to guide our efforts to enhance sea turtles' adaptive capacity. Until such comprehensive data exist, the most appropriate actions might include lobbying for reduction in greenhouse gas emissions and addressing the acute threats to sea turtles. As the negative effects of climate change become more extreme and apparent in the years ahead, more directed interventions may become necessary; the best options 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. Concerted efforts like these will be required across the globe to reduce the direct negative impacts and to increase the resilience of turtle populations to a rapidly changing climate. ■

National Benefits Case Study I

Climate change adaptation for Reef-dependent industries

Researchers in the ARC Centre's Programs 5 and 7 focus on the capacity of reef-dependent societies and economies to adapt to climate change. For example, in a project co-funded by the ARC Centre and the *National Climate Change Adaptation Research Facility*, a team of social scientists directed by Research Fellow Louisa Evans worked closely throughout 2011 with industry partners from Queensland to explore alternative future scenarios. The objective is to help communities, businesses and industries engaged with the Great Barrier Reef to understand, anticipate and react to climate change impacts on the Reef.

In a series of participatory workshops led by Evans and her team, four alternative future scenarios or storylines were developed. These explore the different responses that people engaged with Australia's Great Barrier Reef and its fishing and tourism industries might make to adapt to altered conditions under climate change. The purpose of scenarios is to generate discussion around alternative futures and the options available to individuals, businesses, industries and government for managing the GBR and continuing to benefit from it long into the future.

According to one of the Tourism industry participants "*I would say that most people on the reef, in tourism, actually understand the asset, and I wouldn't have said that 20 years ago. They understand that they need to protect the asset they are working on.*"

Briefly, the four main scenarios for 2050 identified by the participants were:

1. **Paradise perturbed** – climate change is minimised but adaptation is limited. Coral communities shift to massive and encrusting species. Due to habitat changes, marine biodiversity declines slightly. Fish, like coral trout, move further south and to deeper waters. The numbers of other fish species, such as barramundi, also vary with changing rainfall patterns. The fishing and tourism industries try to maintain the status quo of the early 21st century. As such, fishing and tourism remain profitable but the sustainability of the GBR declines.
2. **Reef relief** – climate change is minimised and adaptation is ideal. Coral communities still include heat-sensitive bushy, staghorn and table corals. Marine biodiversity is maintained. The fishing and tourism industries anticipate changes and pursue well planned adaptation. Both industries remain profitable, recreational fishers continue to enjoy fishing, and the GBR's sustainability improves.
3. **Coastal calamity** – climate change is not minimised and adaptation is limited. Corals are lost and reefs become dominated by seaweeds. Existing mangrove habitat is heavily eroded and new habitat fails to establish further south. Reef dependent species are affected and marine biodiversity declines significantly. The fishing and tourism industries are forced to react to the rate and degree of change and the adaptation strategies they follow are not well thought out. As a consequence many businesses fail and the health of the Reef is compromised.
4. **Volatile waters** – climate change is not minimised but human adaptation is ideal. Reefs are in a state of flux, shifting between coral and seaweeds. Existing mangrove habitat is heavily eroded but some new habitat establishes itself further south. Reef dependent species are affected and marine biodiversity declines periodically. The fishing and tourism industries anticipate changes and pursue a wide range of well planned adaptation strategies. The businesses that do adapt with forethought are the ones that survive. Climate conditions continue to challenge the sustainability of the GBR.

The participants concluded that if a worst case climate scenario is combined with a limited adaptation response, negative outcomes for both ecosystems and industries are likely. However, if progress in management and adaptation within the region continues, adaptation will play an integral part in reducing negative impacts even under the worst case climate change scenario.

These scenarios do not represent a pessimistic or optimistic outlook for the GBR. Rather, they capture a range of possible climate risks and impacts, to show what can happen with various types of adaptation by humans. This is based on the premise that social adaptation – how well we respond – will determine what ultimately happens to us.

Sample Publications

Adams, VM, Mills, M, Jupiter, SD and Pressey, RL (2011). Improving social acceptability of marine protected area networks: a method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. *Biological Conservation* 144(1): 350-361.

Alvarez-Romero, JG, Pressey, RL, Ban, NC, Vance-Borland, K, Willer, C, Klein, CJ and Gaines, SD (2011). Integrated land-sea conservation planning: the missing links. *Annual Review of Ecology, Evolution, and Systematics* 42(1): 381-409.

Biggs, D (2011). Understanding resilience in a vulnerable industry: the case of reef tourism in Australia. *Ecology and Society* 16(1): 30.

Evans, L., P. Fidelman, C. Hicks, A. Perry and R. Tobin. (2011). How the Great Barrier Reef and its industries can adapt to climate change: some scenarios. *National Climate Change Adaptation Research Facility*. 28pp.

Cinner, JE, Folke, C, Daw, T and Hicks, CC (2011). Responding to change: using scenarios to understand how socioeconomic factors may influence amplifying or dampening exploitation feedbacks among Tanzanian fishers. *Global Environmental Change* 21(1): 7-12.

McClanahan, T., and JE Cinner (2011). *Adapting to a Changing Environment - Confronting the Consequences of Climate Change*. Oxford University Press.

Pratchett, MS, Munday, PL, Graham, NA, Kronen, M, Pinca, S, Friedman, K, Brewer, TD, Bell, JD, Wilson, SK, Cinner, JE, Kinch, JP, Lawton, RJ, Williams, AJ, Chapman, L, Magron, F and Webb, A (2011). Vulnerability of coastal fisheries in the tropical Pacific to climate change. pp 493-576. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. J. D. Bell, J. E. Johnson and A. J. Hobday (Eds.). Secretariat of the Pacific Community, Noumea, New Caledonia.

Photo by Tom Bridge

Leaders urged to curb climate vulnerability

Representatives of the world's governments meeting in Durban this week have been advised by scientists that urgent action is needed to reduce the vulnerability of communities worldwide likely to be worst affected by the impacts of climate change.

In a new scientific paper and book, leading marine researchers Dr Josh Cinner of the ARC Centre of Excellence for Coral Reef Studies, and Tim McClanahan of the Wildlife Conservation Society propose a novel framework for helping millions of people most at risk to cope with massive changes in their jobs, lives, and environment driven by the warming climate.

Their proposal comes as representatives of 194 nations gather in Durban, South Africa, today for the critical 17th Conference of the Parties of the signatories to the Kyoto Protocol on Climate Change.

Based on a study of 1500 households in 29 coastal communities fringing the east African coast and islands of the western Indian Ocean, the researchers have developed a method for identifying the communities most vulnerable to climate change and prioritizing actions at local, national and international level to help them.

"We looked first at exposure – how likely it was a community would experience an extreme event caused by climate change, such as mass coral bleaching. This can be affected by sea surface temperature, currents, prevailing winds, and other oceanographic conditions," he explains. "Then we looked at the social components of people's vulnerability – for example, whether they had alternative sources of food or employment. And finally we looked at their capacity to adapt to the changes inflicted by a shifting climate."

"Together these three factors define how vulnerable a community and individuals are to climate change," adds Dr McClanahan.

"From there it is possible to identify the most appropriate actions that can be taken in the short, medium and long-term at local, national and global level to reduce that vulnerability, and equip these communities to cope better with what will happen to them."

"Hundreds of millions of people worldwide depend on coral reefs – for livelihoods in fishing and tourism, for food and for coastal protection," says co-author on the study Dr. Tim Daw of the University of East Anglia and Stockholm Resilience Centre.

"We studied communities that depend on coral reefs, because they typify those that are highly susceptible to climate change. However, our general approach applies equally to agricultural, desert, mountain and other communities, who will also be exposed to major changes in temperature and extreme events by the mid-century," says Dr Cinner.

McClanahan, TR and Cinner, JE (2011). Adapting to a changing environment: confronting the consequences of climate change. New York: Oxford University Press.

National Benefits Case Study 2

Coral Genome

2011 saw major advances in coral biology with the finalisation and release of two coral genome sequences; that of *Acropora digitifera*, from the laboratory of Nori Satoh at the Okinawa Institute of Science and Technology, and *Acropora millepora* from David Miller's laboratory in the ARC Centre of Excellence for Coral Reef Studies in collaboration with the lab of Centre adjunct Eldon Ball at the ANU. These newly described genomes will revolutionise our understanding not only of coral biology but also of the evolution of animal genomes. The *A. millepora* sequence is the first animal genome project to be carried out entirely in Australia and is an important milestone in Australian biotechnology.

In 2005, an unsuccessful application was made to the National Human Genome Research Institute to sequence the coral *Porites lobata* at a cost of US$9 million. Genome sequencing technologies have advanced enormously since then, leading to ever-increasing bioinformatic challenges in assembling the sequences. Whereas genome sequencing has traditionally relied on long (>800 base pairs) DNA reads, the "next generation" technologies generate very large numbers of much shorter sequences (100 base pairs or less) requiring much more sophisticated bioinformatics for assembly. The *A. millepora* genome was sequenced by the Australian Genome Research Facility using the Illumina "next-gen" sequencing technology at a cost of less than $30,000. A team of bioinformaticians, led by joint Centre/AIMS researcher Sylvain Forêt, refined the computer programs to allow efficient alignment of the DNA sequences from this data and to assemble the genome. The *A. millepora* DNA sequencing and assembly was completed in mid 2011, two years after the commencement of the project.

The *A. millepora* genome has around 400 million base pairs on its 28 chromosomes and contains around 23,000 protein-coding genes. By contrast, the human genome, which cost nearly $3 billion, possesses an order of magnitude more base pairs but only codes for approximately the same number of genes representing 1.5% of the total human genome. Miller says "It is still unclear why such apparently simple animals as corals require as many genes as humans, but *A. millepora* has dramatically indicated how genetically complex "simple" animals can be."

Where to from here? Research that was previously impossible can now be undertaken, as the coral genome becomes a platform which will allow researchers to address the functional biology of the coral and its symbiotic relationship. Key questions that are now tractable include:

- How does the coral distinguish photosynthetic algae, with which it can potentially form symbioses, from pathogens and parasites?
- How does the coral immune system work and why does it collapse under some conditions?
- How is the metabolism of the coral and symbiont integrated, and what roles do coral-associated bacteria play?
- What genes control calcification and production of the coral skeleton?

More generally, however, Miller says that "the genome project has not only scientific but also practical significance. It will help us to understand how corals build reefs – and why they fail to do so when they are under stress. It will enable us to predict with much greater confidence how corals are likely to respond to changes in the oceans such as global warming, acidification, the spread of coral diseases and various forms of pollution." His latest research stemming from the coral genome project examines the effect of ocean acidification (increase in atmospheric CO_2) on the expression of genes in primary coral polyps prior to recruitment of their symbiotic algae. Preliminary results demonstrate significant changes in the expression of around 19% of all coral genes, particularly in genes known or likely to be involved in controlling the deposition of the skeleton. How the biology of adult corals is affected is the next exciting step in this research.

"This is a first for Australian science. Here we show that Australia can unlock the genetic potential of its own unique fauna and flora for the national benefit," according to Dr Kirby Siemering from the AGRF.

Sample publications

Shinzato, C, Shoguchi, E, Kawashima, T, Hamada, M, Hisata, K, Tanaka, M, Fujie, M, Fujiwara, M, Koyanagi, R, Ikuta, T, Fujiyama, A, Miller, DJ and Satoh, N (2011). Using the *Acropora digitifera* genome to understand coral responses to environmental change. *Nature* 476(7360): 320-323.

Miller, DJ, Ball, EE, Foret, S and Satoh, N (2011). Coral genomics and transcriptomics - ushering in a new era in coral biology. *Journal of Experimental Marine Biology and Ecology* 408(1-2): 114-119.

Grasso, LC, Negri, AP, Forêt, S, Saint, R, Hayward, DC, Miller, DJ and Ball, EE (2011). The biology of coral metamorphosis: molecular responses of larvae to inducers of settlement and metamorphosis. *Developmental Biology* 353(2): 411-419.

Iguchi, A, Shinzato, C, Foret, S and Miller, DJ (2011). Identification of fast-evolving genes in the Scleractinian coral *Acropora* using comparative EST analysis. *PLoS ONE* 6(6): e20140.

Hayward DC, Hetherington S, Behm CA, Grasso L, Foret S, Miller DJ and Ball EE (2011). Differential gene expression at coral settlement and metamorphosis – a subtractive hybridization study. *PLoS One* 6, e26411.

Photo by Carlos Sanchez

Gene secrets of the reef revealed

Australian scientists today announced they have sequenced the genome of the staghorn coral *Acropora millepora*, a major component of the Great Barrier Reef and coral reefs worldwide.

This is the first animal genome project to be carried out entirely in Australia, and is an important milestone in Australian biotechnology and in the study of coral reefs, said the researchers from the ARC Centre of Excellence for Coral Reef Studies and the Australian Genome Research Facility (AGRF).

"This is a first for Australian science. Here we show that Australia can unlock the genetic potential of its own unique fauna and flora for the national benefit," says project coordinator Kirby Siemering from the AGRF.

Corals are the backbone of the Great Barrier Reef, fascinating millions of visitors with their spectacular variety of shapes and flamboyant colours. However, they are also under threat from the effects of climate change, pollution, and disease.

"This project has both practical and scientific significance. It will help us to understand how corals build reefs – and why they fail to do so when they are under stress" says David Miller of the ARC Centre of Excellence for Coral Reef Studies.

"Corals have iconic significance for Australia. We have the best-preserved coral reef system in the world and the Great Barrier Reef is a cornerstone of a $6 billion a year tourist industry. As reefs elsewhere in the world decline, this value will grow if we can keep our reefs healthy and intact" explains Eldon Ball from the Australian National University.

Their study shows that corals may look like simple animals, but their DNA is surprisingly complex. In fact, David Miller says, corals have about the same number of genes as man, and many of them are remarkably like ours.

"The Pacific coral, *Acropora millepora*, is already the best-characterised coral at the molecular level and has yielded important insights into the evolution of all animals," he explains. "The availability of the genome sequence will enable major advances in the understanding of many aspects of coral biology, including the responses of corals to climate change, ocean acidification, pollution and disease."

This project opens new opportunities at a critical time. In the last few years, the cost of genome sequencing has decreased by several orders of magnitude thanks to groundbreaking technological advances. "These new technologies present us with a unique opportunity to explore the DNA of our fascinating Australian animals," explains Sylvain Forêt, who led this initial analysis.

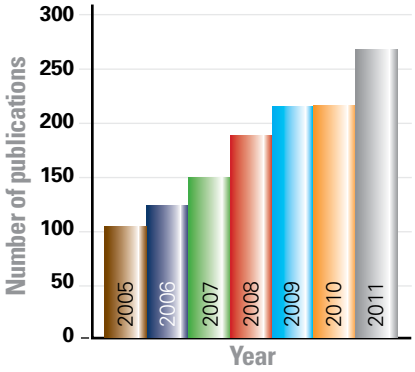
The coral genome sequence has been a national collaborative effort by the Australian Genome Research Facility and researchers in the ARC Centre of Excellence for Coral Reef Studies based at James Cook University, the Australian National University, Monash University, the Walter and Eliza Hall Institute and the University of Queensland, together with sequencing technology company Illumina. The project has brought together some of the best young minds in Australian genome science to tackle the daunting task of stitching together the approximately 400 million letters of DNA that make up the coral genome.

The first draft assembly of the *Acropora millepora* sequence is available to the scientific community under specific conditions.

Publications

The ARC Centre of Excellence for Coral Reef Studies produced 263 publications in 2011, continuing the rapid growth in output exhibited since the Centre began in 2005. According to *ISI Web of Science*, the ARC Centre is the first-ranked institution globally for both the number of journal publications and citations in coral reef science. The average Impact Factor for all 241 journal articles published in 2011 was 4.72. Ninety-five of the 2011 articles are in journals with Impact Factors greater than four, including top-tier journals such as *Science,* the *Nature* journals, *PLoS Biology*, *Ecology Letters* and *PNAS*.

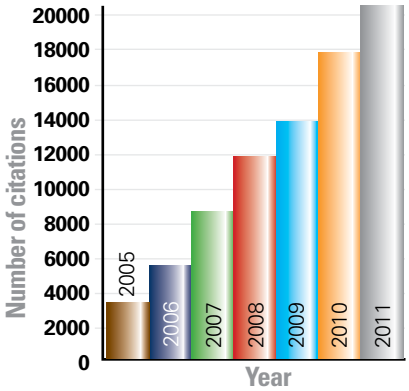
Number of publications by members of the ARC Centre of Excellence each year for 2005-2011.



The Centre's research outputs were published in a total of 93 journals, spanning many fields of research. For example, the titles of these journals refer to each of the following disciplines: archaeology, biochemistry, botany, conservation biology, ecology, evolution, fisheries, immunology, modelling, oceanography, palaeobiology, petrology, photobiology, physiology, genomics, geochemistry, social science, systematics, and many more.

Citations of the Centre's publications continue to grow, increasing more than 10-fold since 2005. Twenty-eight researchers were each cited >200 times in 2011, thirteen of the Centre members had >500 citations, and five had >1000 citations in the 12-month reporting period.

Summed citations to members of the ARC Centre of Excellence each year for 2005-2011.



League table achievements in 2011 include:

- Four Program Leaders in the Centre are recognised by ISI as *Highly Cited Researchers:* in Earth Sciences (Malcolm McCulloch), in Plant & Animal Science (Ove Hoegh-Guldberg), and in Ecology/ Environment (Terry Hughes and Bob Pressey).
- John Pandolfi was ranked #1 in the world by ISI *Web of Science* for citations per paper in Ecology/ Environment over the past 10 years.
- A Thomson Reuters *ScienceWatch* analysis of climate change ranked James Cook University #2 in the world for citations per paper in climate change research.
- *The Faculty of 1000 Biology* highlighted 14 of the ARC Centre's publications for review in 2011.
- Australian Postdoctoral Fellow Nick Graham was awarded the *Scopus Young Researcher of the Year Award* for exceptional citations in the Life Sciences category.
- *ISI Essential Science Indicators* identified five of the Centre's recent articles as *Hot Papers*:

Hobday, A.J., and J.M. Lough (2011). Projected climate change in Australian marine and freshwater environments. *Mar. Freshwater Res.* 62: 1000-1014.

Hughes, T.P., N. Graham, J.B.C. Jackson, P.J. Mumby, and R.S. Steneck (2010). Rising to the challenge of sustaining coral reef resilience. *Trends Ecol. Evol.* 25: 633-642.

Lough, J.M and A.J. Hobday (2011). Observed climate change in Australian marine and freshwater environments, *Mar. Freshwater Res.* 62: 984-999.

Pankhurst, N.W. and P.L. Munday (2011). Effects of climate change on fish reproduction and early life history stages. *Mar. Freshwater Res.* 62: 1015-1026.

Pratchett, M., L.K. Bay, P.C. Gehrke, J.D. Koehn, K. Osborne, R.L. Pressey, H. Sweatman, and D. Wachenfeld (2011). Contribution of climate change to degradation and loss of critical fish habitats in Australian marine and freshwater environments. *Mar. Freshwater Res*, 62: 1062-1081.

- *ISI Essential Science Indicators* identified three *Research Fronts* at the end of 2011 in which the Centre's research is highlighted. A research front is a group of highly cited papers, referred to as core papers, in an emerging topic defined by a cluster analysis. Core papers in these *Research Fronts* were authored by Glenn Almany, David Bellwood, Sean Connolly, Sophie Dove, Carl Folke, Nick Graham, Ove Hoegh-Guldberg, Terry Hughes, Geoff Jones, Michael Kingsford, Janice Lough, Laurence McCook, Peter Mumby, Morgan Pratchett, Bob Pressey, Bob Steneck, and Bette Willis. The Research Fronts are:
  - Ocean acidification
  - Coral reef connectivity
  - Trophic cascades and phase-shifts.

PUBLICATIONS LIST

Book (1)

1. McClanahan, TR and Cinner, JE (2011). Adapting to a changing environment: confronting the consequences of climate change. New York: Oxford University Press.

Book Section (15)

1. Bell, JD, Andrew, NL, Batty, MJ, Chapman, LB, Dambacher, JM, Dawson, B, Ganachaud, AS, Gehrke, PC, Hampton, J, Hobday, AJ, Hoegh-Guldberg, O, Johnson, JE, Kinch, JP, Borgne, RL, Lehodey, P, Lough, JM, Pickering, TD, Pratchett, MS, Vunisea, A and Waycott, M (2011). Adapting tropical Pacific fisheries and aquaculture to climate change: management measures, policies and investments. pp 803-876. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. J. D. Bell, J. E. Johnson and A. J. Hobday (Eds.). Secretariat of the Pacific Community, Noumea, New Caledonia.
2. Coles, R, Grech, A, Rasheed, M, McKenzie, L, Unsworth, R and Short, F (2011). Seagrass ecology and threats in the Tropical Indo-Pacific bioregion. pp 225-239. In *Seagrass: Ecology, Uses and Threats*. R. S. Pirog (Ed.). Nova Science Publishers, Hauppauge.
3. Connolly, SR and Dornelas, M (2011). Fitting and empirical evaluation of models for species abundance distributions. pp123-140. In *Biological Diversity: Frontiers in measurement and assessment*. A. E. Magurran and B. J. McGill (Eds.). Oxford University Press, New York.
4. Ferrier-Pages, C, Hoogenboom, M and Houlbreque, F (2011). The role of plankton in coral trophodynamics. pp215-229. In *Coral Reefs: An Ecosystem in Transition*. Z. Dubinsky and N. Stambler (Eds.). Springer, Netherlands.
5. Fuentes, M (2011). Turtles: from eggs to ocean. pp235-239. In *National Geographic Reach* National Geographic Science Program, Monterey, CA.
6. Herler, J, Munday, P and Hernaman, V (2011). Gobies on coral reefs. pp493-529. In *The Biology of Gobies* Science Publishers.
7. Hoegh-Guldberg, O (2011). Coral reefs, climate change, and mass extinction. pp261-283. In *Saving a Million Species: Extinction Risk from Climate Change*. L. Hannah (Ed.). Island Press, Washington, D.C.
8. Hoegh-Guldberg, O, Andréfouet, S, Fabricius, KE, Diaz-Pulido, G, Lough, JM, Marshall, PA and Pratchett, MS (2011). Vulnerability of coral reefs in the tropical Pacific to climate change. pp251-296. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. J. D. Bell, J. E. Johnson and A. J. Hobday (Eds.). Secretariat of the Pacific Community, Noumea, New Caledonia.
9. Hughes, TP (2011). Invited commentary on: are we consuming too much? pp163-164. In *Bringing Ecologists and Economists Together*. T. Soderqvist, A. Sundbaum, C. Folke and K. G. Maler (Eds.). Springer, Berlin.
10. Lough, JM (2011). Climate change and coral reefs. pp198-210. In *Encyclopedia of Modern Coral Reefs*. D. Hopley (Ed.). Springer Netherlands.
11. Lough, JM, Meehl, GA and Salinger, MJ (2011). Observed and projected changes in surface climate of the tropical Pacific. pp49-100. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. J. D. Bell, J. E. Johnson and A. J. Hobday (Eds.). Secretariat of the Pacific Community, Noumea, New Caledonia.
12. Mumby, PJ and Steneck, RS (2011). The resilience of coral reefs and its implications for reef management. pp509-519. In *Coral Reefs: An Ecosystem in Transition*. Z. Dubinsky and N. Stambler (Eds.). Springer Science.
13. Pandolfi, JM (2011). Historical ecology of coral reefs. pp554-558. In *Encyclopedia of Modern Coral Reefs*. D. Hopley (Ed.). Springer Netherlands.
14. Pandolfi, JM (2011). The paleoecology of coral reefs. pp13-24. In *Coral Reefs: An Ecosystem in Transition*. Z. Dubinsky and N. Stambler (Eds.). Springer Science+Business Media.
15. Pratchett, MS, Munday, PL, Graham, NA, Kronen, M, Pinca, S, Friedman, K, Brewer, TD, Bell, JD, Wilson, SK, Cinner, JE, Kinch, JP, Lawton, RJ, Williams, AJ, Chapman, L, Magron, F and Webb, A (2011). Vulnerability of coastal fisheries in the tropical Pacific to climate change. pp493-576. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. J. D. Bell, J. E. Johnson and A. J. Hobday (Eds.). Secretariat of the Pacific Community, Noumea, New Caledonia.

Conference Paper (2)

1. Adams, VM and Pressey, RL. (2011). An info-gap model to examine the robustness of cost-efficient budget allocations. pp 118-118. Proceedings of First International Conference on Vulnerability and Risk Analysis and Management. Hyattsville, MD: ASCE.
2. Baird, A, Campbell, S, Fadli, N, Hoey, A and Rudi, E, The shallow water hard corals of Pulau Weh, Aceh, Indonesia., in *Annual International Conference Syiah Kuala University*, Z. Muchlisin, A. Baird, A. Nayaya, M. Musman, T. Alvisyahrin and S. Mudatsir, Editors. 2011, Syiah Kuala University: Banda Aceh, Indonesia. p. 76-82.

Conference Proceedings (1)

1. Muchlisin, Z, Baird, A, Nayaya, A, Musman, M, Alvisyahrin, T and Mudatsir, S. (2011). Annual International Conference Syiah Kuala University. pp 272. Proceedings. Banda Aceh, Indonesia: Syiah Kuala University.

Journal Article (241)

1. Abel, N, Gorddard, R, Harman, B, Leitch, A, Langridge, J, Ryan, A and Heyenga, S (2011). Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study. *Environmental Science & Policy* 14(3): 279-288.
2. Adams, VM, Mills, M, Jupiter, SD and Pressey, RL (2011). Improving social acceptability of marine protected area networks: a method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. *Biological Conservation* 144(1): 350-361.
3. Adams, VM, Segan, DB and Pressey, RL (2011). How much does it cost to expand a protected area system? Some critical determining factors and ranges of costs for Queensland. *PLoS ONE* 6(9): e25447.
4. Aeby, GS, Williams, GJ, Franklin, EC, Haapkyla, J, Harvell, CD, Neale, S, Page, CA, Raymundo, L, Vargas-Angel, B, Willis, BL, Work, TM and Davy, SK (2011). Growth anomalies on the coral genera *Acropora* and *Porites* are strongly associated with host density and human population size across the Indo-Pacific. *PLoS ONE* 6(2): e16887.
5. Ainsworth, TD, Wasmund, K, Ukani, L, Seneca, F, Yellowlees, D, Miller, D and Leggat, W (2011). Defining the tipping point. A complex cellular life/death balance in corals in response to stress. *Nature Scientific Reports* 1: 160.
6. Albouy, C, Guilhaumon, F, Villeger, S, Mouchet, M, Mercier, L, Culioli, JM, Tomasini, JA, Le Loc'h, F and Mouillot, D (2011). Predicting trophic guild and diet overlap from functional traits: statistics, opportunities and limitations for marine ecology. *Marine Ecology-Progress Series* 436: 17-28.
7. Alvarez-Romero, JG, Pressey, RL, Ban, NC, Vance-Borland, K, Willer, C, Klein, CJ and Gaines, SD (2011). Integrated land-sea conservation planning: the missing links. *Annual Review of Ecology, Evolution, and Systematics* 42(1): 381-409.
8. Anthony, KRN, Maynard, JA, Diaz-Pulido, G, Mumby, PJ, Marshall, PA, Cao, L and Hoegh-Guldberg, O (2011). Ocean acidification and

warming will lower coral reef resilience. *Global Change Biology* 17(5): 1798-1808.

9. Ateweberhan, M, McClanahan, T, Graham, N and Sheppard, C (2011). Episodic heterogeneous decline and recovery of coral cover in the Indian Ocean. *Coral Reefs* 30(3): 739-752.
10. Baird, A, Blakeway, D, Hurley, T and Stoddart, J (2011). Seasonality of coral reproduction in the Dampier Archipelago, northern Western Australia. *Marine Biology* 158(2): 275-285.
11. Ban, NC, Adams, V, Pressey, RL and Hicks, J (2011). Promise and problems for estimating management costs of marine protected areas. *Conservation Letters* 4(3): 241-252.
12. Ban, NC, Adams, VM, Almany, GR, Ban, S, Cinner, JE, McCook, LJ, Mills, M, Pressey, RL and White, A (2011). Designing, implementing and managing marine protected areas: emerging trends and opportunities for coral reef nations. *Journal of Experimental Marine Biology and Ecology* 408(1-2): 21-31.
13. Bannister, R, Hoogenboom, M, Anthony, K, Battershill, C, Whalan, S, Webster, N and de Nys, R (2011). Incongruence between the distribution of a common coral reef sponge and photosynthesis. *Marine Ecology Progress Series* 423: 95-100.
14. Barr, LM, Pressey, RL, Fuller, RA, Segan, DB, McDonald-Madden, E and Possingham, HP (2011). A new way to measure the world's protected area coverage. *PLoS ONE* 6(9): e24707.
15. Bauman, A, Baird, A and Cavalcante, G (2011). Coral reproduction in the world's warmest reefs: southern Persian Gulf (Dubai, United Arab Emirates). *Coral Reefs* 30(2): 405-413.
16. Bay, LK, Cumbo, VR, Abrego, D, Kool, JT, Ainsworth, TD and Willis, BL (2011). Infection dynamics vary between *Symbiodinium* types and cell surface treatments during establishment of endosymbiosis with coral larvae. *Diversity* 3(3): 356-374.
17. Beger, M, Babcock, R, Booth, DJ, Bucher, D, Condie, SA, Creese, B, Cvitanovic, C, Dalton, SJ, Harrison, P, Hoey, A, Jordan, A, Loder, J, Malcolm, H, Purcell, SW, Roelfsma, C, Sachs, P, Smith, SDA, Sommer, B, Stuart-Smith, R, Thomson, D, Wallace, CC, Zann, M and Pandolfi, JM (2011). Research challenges to improve the management and conservation of subtropical reefs to tackle climate change threats. *Ecological Management & Restoration* 12(1): e7-e10.
18. Bejarano, S, Mumby, P and Sotheran, I (2011). Predicting structural complexity of reefs and fish abundance using acoustic remote sensing (RoxAnn). *Marine Biology* 158(3): 489-504.
19. Bellwood, D and Choat, J (2011). Dangerous demographics: the lack of juvenile humphead parrotfishes *Bolbometopon muricatum* on the Great Barrier Reef. *Coral Reefs* 30(2): 549-554.
20. Bennett, S and Bellwood, DR (2011). Latitudinal variation in macroalgal consumption by fishes on the Great Barrier Reef. *Marine Ecology Progress Series* 426: 241-269.
21. Berumen, M, Pratchett, M and Goodman, B (2011). Relative gut lengths of coral reef butterflyfishes (Pisces: Chaetodontidae). *Coral Reefs* 30(4): 1005-1010.
22. Beukers-Stewart, B, Beukers-Stewart, J and Jones, G (2011). Behavioural and developmental responses of predatory coral reef fish to variation in the abundance of prey. *Coral Reefs* 30(3): 855-864.
23. Biggs, D (2011). Understanding resilience in a vulnerable industry: the case of reef tourism in Australia. *Ecology and Society* 16(1): 30.
24. Biggs, D, Abel, N, Knight, AT, Leitch, A, Langston, A and Ban, NC (2011). The implementation crisis in conservation planning: could "mental models" help? *Conservation Letters* 4(3): 169-183.
25. Biggs, D, Biggs, R, Dakos, V, Scholes, RJ and Schoon, M (2011). Are we entering an era of concatenated global crises? *Ecology and Society* 16(2): 27.
26. Binning, SA and Fulton, CJ (2011). Non-lethal measurement of pectoral fin aspect ratio in coral-reef fishes. *Journal of Fish Biology* 79(3): 812-818.
27. Bonaldo, R and Bellwood, D (2011). Parrotfish predation on massive *Porites* on the Great Barrier Reef. *Coral Reefs* 30(1): 259-269.
28. Bonaldo, R and Bellwood, D (2011). Spatial variation in the effects of grazing on epilithic algal turfs on the Great Barrier Reef, Australia. *Coral Reefs* 30(2): 381-390.
29. Bonaldo, RM, Krajewski, JP and Bellwood, DR (2011). Relative impact of parrotfish grazing scars on massive *Porites* corals at Lizard Island, Great Barrier Reef. *Marine Ecology Progress Series* 423: 223-233.
30. Bongaerts, P, Bridge, T, Kline, D, Muir, P, Wallace, C, Beaman, R and Hoegh-Guldberg, O (2011). Mesophotic coral ecosystems on the walls of Coral Sea atolls. *Coral Reefs* 30(2): 335.
31. Bongaerts, P, Riginos, C, Hay, KB, van Oppen, MJH, Hoegh-Guldberg, O and Dove, S (2011). Adaptive divergence in a scleractinian coral: physiological adaptation of *Seriatopora hystrix* to shallow and deep reef habitats. *BMC Evolutionary Biology* 11: 303.
32. Bongaerts, P, Sampayo, EM, Bridge, TCL, Ridgway, T, Vermeulen, F, Englebert, N, Webster, JM and Hoegh-Guldberg, O (2011). *Symbiodinium* diversity in mesophotic coral communities on the Great Barrier Reef: a first assessment. *Marine Ecology Progress Series* 439: 117-126.
33. Bonin, M, Almany, G and Jones, G (2011). Contrasting effects of habitat loss and fragmentation on coral-associated reef fishes. *Ecology* 92(7): 1503-1512.
34. Bonin, MC, Almany, G and Jones, G (2011). Coral-associated reef fishes. *Bulletin of the Ecological Society of America* 92(3): 289-289.
35. Bourne, DG, Muirhead, A and Sato, Y (2011). Changes in sulfate-reducing bacterial populations during the onset of black band disease. *ISME Journal* 5(3): 559-564.
36. Bromfield, K and Renema, W (2011). Comparison of 87Sr/86Sr isotope and biostratigraphic ages of uplifted fossil reefs in the Indo-Pacific: Indonesia, Papua New Guinea and Fiji. *Australian Journal of Earth Sciences* 58(1): 61-73.
37. Brooker, R, Munday, P and Jones, G (2011). Coral obligate filefish masquerades as branching coral. *Coral Reefs* 30(3): 803.
38. Brown, CJ, Schoeman, DS, Sydeman, WJ, Brander, K, Buckley, LB, Burrows, M, Duarte, CM, Moore, PJ, Pandolfi, JM, Poloczanska, E, Venables, W and Richardson, AJ (2011). Quantitative approaches in climate change ecology. *Global Change Biology* 17(12): 3697-3713.
39. Burrows, MT, Schoeman, DS, Buckley, LB, Moore, P, Poloczanska, ES, Brander, KM, Brown, C, Bruno, JF, Duarte, CM, Halpern, BS, Holding, J, Kappel, CV, Kiessling, W, O'Connor, MI, Pandolfi, JM, Parmesan, C, Schwing, FB, Sydeman, WJ and Richardson, AJ (2011). The pace of shifting climate in marine and terrestrial ecosystems. *Science* 334(6056): 652-655.
40. Burt, JA, Feary, DA, Bauman, AG, Usseglio, P, Cavalcante, GH and Sale, PF (2011). Biogeographic patterns of reef fish community structure in the northeastern Arabian Peninsula. *Ices Journal of Marine Science* 68(9): 1875-1883.
41. Burton, T, Hoogenboom, MO, Armstrong, JD, Groothuis, TGG and Metcalfe, NB (2011). Egg hormones in a highly fecund vertebrate: do they influence offspring social structure in competitive conditions? *Functional Ecology* 25(6): 1379-1388.
42. Cabioch, G, Wallace, C, McCulloch, M, Zibrowius, H, Laboute, P and de Forges, B (2011). Disappearance of *Acropora* from the Marquesas (French Polynesia) during the last deglacial period. *Coral Reefs* 30(4): 1101-1105.
43. Cavalcante, GH, Kjerfve, B, Feary, DA, Bauman, AG and Usseglio, P (2011). Water currents and water budget in a coastal megastructure, Palm Jumeirah Lagoon, Dubai, UAE. *Journal of Coastal Research* 27(2): 384-393.
44. Ceccarelli, DM, Jones, GP and McCook, LJ (2011). Interactions between herbivorous fish guilds and their influence on algal succession on a coastal coral reef. *Journal of Experimental Marine Biology and Ecology* 399(1): 60-67.
45. Ceccarelli, DM, Richards, ZT, Pratchett, MS and Cvitanovic, C (2011). Rapid increase in coral cover on an isolated coral reef, the Ashmore Reef National Nature Reserve, north-western Australia. *Marine and Freshwater Research* 62(10): 1214-1220.
46. Cetina-Heredia, P and Connolly, S (2011). A simple approximation for larval retention around reefs. *Coral Reefs* 30(3): 593-605.
47. Chong-Seng, K, Cole, A, Pratchett, M and Willis, B (2011). Selective feeding by coral reef fishes on coral lesions associated with brown band and black band disease. *Coral Reefs* 30(2): 473-481.
48. Cinner, JE (2011). Social-ecological traps in reef fisheries. *Global Environmental Change-Human and Policy Dimensions* 21(3): 835-839.
49. Cinner, JE and David, G (2011). The human dimensions of coastal and marine ecosystems in the Western Indian Ocean. *Coastal Management* 39(4): 351-357.
50. Cinner, JE, Folke, C, Daw, T and Hicks, CC (2011). Responding to change: using scenarios to understand how socioeconomic factors may influence amplifying or dampening exploitation feedbacks among Tanzanian fishers. *Global Environmental Change* 21(1): 7-12.

51. Clague, GE, Cheney, KL, Goldizen, AW, McCormick, MI, Waldie, PA and Grutter, AS (2011). Long-term cleaner fish presence affects growth of a coral reef fish. *Biology Letters* 7(6): 863-865.

52. Clode, PL, Lema, K, Saunders, M and Weiner, S (2011). Skeletal mineralogy of newly settling *Acropora millepora* (Scleractinia) coral recruits. *Coral Reefs* 30(1): 1-8.

53. Cohen, P and Foale, S (2011). Fishing taboos: Securing Pacific fisheries for the future? *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* 28: 3-13.

54. Cole, A, Lawton, R, Pratchett, M and Wilson, S (2011). Chronic coral consumption by butterflyfishes. *Coral Reefs* 30(1): 85-93.

55. Cole, A and Pratchett, M (2011). Effects of juvenile coral-feeding butterflyfishes on host corals. *Coral Reefs* 30(3): 623-630.

56. Cole, A and Pratchett, M (2011). Inter-specific variation in susceptibility to grazing among common reef corals. *Marine Ecology Progress Series* 422: 155-164.

57. Cooper, TF, Berkelmans, R, Ulstrup, KE, Weeks, S, Radford, B, Jones, AM, Doyle, J, Canto, M, O'Leary, RA and van Oppen, MJH (2011). Environmental factors controlling the distribution of *Symbiodinium* harboured by the coral *Acropora millepora* on the Great Barrier Reef. *PLoS ONE* 6(10): e25536.

58. Cooper, TF, Lai, M, Ulstrup, KE, Saunders, SM, Flematti, GR, Radford, B and van Oppen, MJH (2011). *Symbiodinium* genotypic and environmental controls on lipids in reef building corals. *PLoS ONE* 6(5): e20434.

59. Cooper, TF, Ulstrup, KE, Dandan, SS, Heyward, AJ, Kuhl, M, Muirhead, A, O'Leary, RA, Ziersen, BEF and van Oppen, MJH (2011). Niche specialization of reef-building corals in the mesophotic zone: metabolic trade-offs between divergent *Symbiodinium* types. *Proceedings of the Royal Society B: Biological Sciences* 278(1713): 1840-1850.

60. Cowman, PF and Bellwood, DR (2011). Coral reefs as drivers of cladogenesis: expanding coral reefs, cryptic extinction events, and the development of biodiversity hotspots. *Journal of Evolutionary Biology* 24(12): 2543-2562.

61. Cripps, IL, Munday, PL and McCormick, MI (2011). Ocean acidification affects prey detection by a predatory reef fish. *PLoS ONE* 6(7): e22736.

62. Daw, TM, Cinner, JE, McClanahan, TR, Graham, NAJ and Wilson, SK (2011). Design factors and socioeconomic variables associated with ecological responses to fishery closures in the Western Indian Ocean. *Coastal Management* 39(4): 412-424.

63. Daw, TM, Robinson, J and Graham, NAJ (2011). Perceptions of trends in Seychelles artisanal trap fisheries: comparing catch monitoring, underwater visual census and fishers' knowledge. *Environmental Conservation* 38(1): 75-88.

64. Diaz-Pulido, G, Gouezo, M, Tilbrook, B, Dove, S and Anthony, KRN (2011). High CO_2 enhances the competitive strength of seaweeds over corals. *Ecology Letters* 14(2): 156-162.

65. Dickens, LC, Goatley, CHR, Tanner, JK and Bellwood, DR (2011). Quantifying relative diver effects in underwater visual censuses. *PLoS ONE* 6(4): e18965.

66. Dixson, D, Munday, P, Pratchett, M and Jones, G (2011). Ontogenetic changes in responses to settlement cues by anemonefish. *Coral Reefs* 30(4): 903-910.

67. Dixson, DL, Jones, GP, Munday, PL, Pratchett, MS, Srinivasan, M, Planes, S and Thorrold, SR (2011). Terrestrial chemical cues help coral reef fish larvae locate settlement habitat surrounding islands. *Ecology and Evolution* 1(4): 586-595.

68. Donelson, JM, Munday, PL, McCormick, MI and Nilsson, GE (2011). Acclimation to predicted ocean warming through developmental plasticity in a tropical reef fish. *Global Change Biology* 17(4): 1712-1719.

69. Dornelas, M, Phillip, DAT and Magurran, AE (2011). Abundance and dominance become less predictable as species richness decreases. *Global Ecology and Biogeography* 20(6): 832-841.

70. Dressler, WH and Fabinyi, M (2011). Farmer gone fish'n? Swidden decline and the rise of grouper fishing on Palawan Island, the Philippines. *Journal of Agrarian Change* 11(4): 536-555.

71. Edwards, HJ, Elliott, IA, Eakin, CM, Irikawa, A, Madin, JS, McField, M, Morgan, JA, van Woesik, R and Mumby, PJ (2011). How much time can herbivore protection buy for coral reefs under realistic regimes of hurricanes and coral bleaching? *Global Change Biology* 17(6): 2033-2048.

72. Emslie, M, Pratchett, M and Cheal, A (2011). Effects of different disturbance types on butterflyfish communities of Australia's Great Barrier Reef. *Coral Reefs* 30(2): 461-471.

73. Eriksen, MS, Faerevik, G, Kittilsen, S, McCormick, MI, Damsgard, B, Braithwaite, VA, Braastad, BO and Bakken, M (2011). Stressed mothers - troubled offspring: a study of behavioural maternal effects in farmed *Salmo salar*. *Journal of Fish Biology* 79(3): 575-586.

74. Evans, L, Cherrett, N and Pemsl, D (2011). Assessing the impact of fisheries co-management interventions in developing countries: a meta-analysis. *Journal of Environmental Management* 92(8): 1938-1949.

75. Evans, LS, Brown, K and Allison, EH (2011). Factors influencing adaptive marine governance in a developing country context: a case-study of southern Kenya. *Ecology and Society* 16(2): 21.

76. Fabinyi, M and Dalabajan, D (2011). Policy and practice in the live reef fish for food trade: a case study from Palawan, Philippines. *Marine Policy* 35(3): 371-378.

77. Fabricius, KE, Langdon, C, Uthicke, S, Humphrey, C, Noonan, S, De'ath, G, Okazaki, R, Muehllehner, N, Glas, MS and Lough, JM (2011). Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations. *Nature Climate Change* 1(3): 165-169.

78. Falter, J, Atkinson, M, Schar, D, Lowe, R and Monismith, S (2011). Short-term coherency between gross primary production and community respiration in an algal-dominated reef flat. *Coral Reefs* 30(1): 53-58.

79. Feary, DA, Cinner, JE, Graham, NAJ and Januchowski-Hartley, FA (2011). Effects of customary marine closures on fish behavior, spear-fishing success, and underwater visual surveys. *Conservation Biology* 25(2): 341-349.

80. Ferrari, MCO, Dixson, DL, Munday, PL, McCormick, MI, Meekan, MG, Sih, A and Chivers, DP (2011). Intrageneric variation in antipredator responses of coral reef fishes affected by ocean acidification: implications for climate change projections on marine communities. *Global Change Biology* 17(9): 2980-2986.

81. Ferrari, MCO, McCormick, MI, Munday, PL, Meekan, MG, Dixson, DL, Lonnstedt, O and Chivers, DP (2011). Putting prey and predator into the CO_2 equation - qualitative and quantitative effects of ocean acidification on predator-prey interactions. *Ecology Letters* 14(11): 1143-1148.

82. Fidelman, P, Evans, L, Fabinyi, M, Foale, S, Cinner, J and Rosen, F (2011). Governing large-scale marine commons: contextual challenges in the Coral Triangle. *Marine Policy* 36(1): 42-53.

83. Field, I, Meekan, M, Speed, C, White, W and Bradshaw, C (2011). Quantifying movement patterns for shark conservation at remote coral atolls in the Indian Ocean. *Coral Reefs* 30(1): 61-71.

84. Foale, S, Cohen, P, Januchowski-Hartley, S, Wenger, A and Macintyre, M (2011). Tenure and taboos: origins and implications for fisheries in the Pacific. *Fish and Fisheries* 12(4): 357-369.

85. Forêt, S, Seneca, F, de Jong, D, Bieller, A, Hemmrich, G, Augustin, R, Hayward, DC, Ball, EE, Bosch, TCG, Agata, K, Hassel, M and Miller, DJ (2011). Phylogenomics reveals an anomalous distribution of USP genes in metazoans. *Molecular Biology and Evolution* 28(1): 153-161.

86. Foster, G, Ticzon, VS, Riegl, BM and Mumby, PJ (2011). Detecting end-member structural and biological elements of a coral reef using a single-beam acoustic ground discrimination system. *International Journal of Remote Sensing* 32(22): 7749-7776.

87. Fox, RJ and Bellwood, DR (2011). Unconstrained by the clock? Plasticity of diel activity rhythm in a tropical reef fish, *Siganus lineatus*. *Functional Ecology* 25(5): 1096-1105.

88. Frisch, A and Hobbs, J-P (2011). Effects of autotomy on long-term survival and growth of painted spiny lobster *Panulirus versicolor* on the Great Barrier Reef, Australia. *Marine Biology* 158(7): 1645-1652.

89. Fuentes, MMPB, Bateman, BL and Hamann, M (2011). Relationship between tropical cyclones and the distribution of sea turtle nesting grounds. *Journal of Biogeography* 38(10): 1886-1896.

90. Fuentes, MMPB, Limpus, CJ and Hamann, M (2011). Vulnerability of sea turtle nesting grounds to climate change. *Global Change Biology* 17(1): 140-153.

91. Gates, RD and Ainsworth, TD (2011). The nature and taxonomic composition of coral symbiomes as drivers of performance limits in scleractinian corals. *Journal of Experimental Marine Biology and Ecology* 408(1-2): 94-101.

92. Goatley, CHR and Bellwood, DR (2011). The roles of dimensionality, canopies and complexity in ecosystem monitoring. *PLoS ONE* 6(11): e27307.

93. Gonzalez-Rivero, M, Yakob, L and Mumby, PJ (2011). The role of sponge competition on

coral reef alternative steady states. *Ecological Modelling* 222(11): 1847-1853.

94. Graham, NAJ, Ainsworth, TD, Baird, AH, Ban, NC, Bay, LK, Cinner, JE, De Freitas, DM, Diaz-Pulido, G, Dornelas, M, Dunn, SR, Fidelman, PIJ, Forêt, S, Good, TC, Kool, J, Mallela, J, Penin, L, Pratchett, MS and Williamson, DH (2011). From microbes to people: tractable benefits of no-take areas for coral reefs. *Oceanography and Marine Biology: an Annual Review* 49: 105-135.

95. Graham, NAJ, Chabanet, P, Evans, RD, Jennings, S, Letourneur, Y, Aaron MacNeil, M, McClanahan, TR, Ohman, MC, Polunin, NVC and Wilson, SK (2011). Extinction vulnerability of coral reef fishes. *Ecology Letters* 14(4): 341-348.

96. Graham, NAJ, Nash, KL and Kool, JT (2011). Coral reef recovery dynamics in a changing world. *Coral Reefs* 30(2): 283-294.

97. Grantham, HS, Game, ET, Lombard, AT, Hobday, AJ, Richardson, AJ, Beckley, LE, Pressey, RL, Huggett, JA, Coetzee, JC, van der Lingen, CD, Petersen, SL, Merkle, D and Possingham, HP (2011). Accommodating dynamic oceanographic processes and pelagic biodiversity in marine conservation planning. *PLoS ONE* 6(2): e16552.

98. Grasso, LC, Negri, AP, Forêt, S, Saint, R, Hayward, DC, Miller, DJ and Ball, EE (2011). The biology of coral metamorphosis: molecular responses of larvae to inducers of settlement and metamorphosis. *Developmental Biology* 353(2): 411-419.

99. Grech, A and Coles, R (2011). Interactions between a trawl fishery and spatial closures for biodiversity conservation in the Great Barrier Reef World Heritage Area, Australia. *PLoS ONE* 6(6): e21094.

100. Grech, A, Coles, R and Marsh, H (2011). A broad-scale assessment of the risk to coastal seagrasses from cumulative threats. *Marine Policy* 35(5): 560-567.

101. Grech, A, Sheppard, J and Marsh, H (2011). Informing species conservation at multiple scales using data collected for marine mammal stock assessments. *PLoS ONE* 6(3): e17993.

102. Grutter, AS, Crean, AJ, Curtis, LM, Kuris, AM, Warner, RR and McCormick, MI (2011). Indirect effects of an ectoparasite reduce successful establishment of a damselfish at settlement. *Functional Ecology* 25(3): 586-594.

103. Gusmao, LFM and McKinnon, AD (2011). Nucleic acid indices of egg production in the tropical copepod *Acartia sinjiensis*. *Journal of Experimental Marine Biology and Ecology* 396(2): 122-137.

104. Haapkyla, J, Unsworth, RKF, Flavell, M, Bourne, DG, Schaffelke, B and Willis, BL (2011). Seasonal rainfall and runoff promote coral disease on an inshore reef. *PLoS ONE* 6(2): e16893.

105. Hamann, M, Grech, A, Wolanski, E and Lambrechts, J (2011). Modelling the fate of marine turtle hatchlings. *Ecological Modelling* 222(8): 1515-1521.

106. Hansen, GJA, Ban, NC, Jones, ML, Kaufman, L, Panes, HM, Yasue, M and Vincent, ACJ (2011). Hindsight in marine protected area selection: a comparison of ecological representation arising from opportunistic and systematic approaches. *Biological Conservation* 144(6): 1866-1875.

107. Hayward, DC, Hetherington, S, Behm, CA, Grasso, LC, Forêt, S, Miller, DJ and Ball, EE (2011). Differential gene expression at coral settlement and metamorphosis - a subtractive hybridization study. *PLoS ONE* 6(10): e26411.

108. Hermoso, V, Januchowski-Hartley, S, Linke, S and Possingham, HP (2011). Reference vs. present-day condition: early planning decisions influence the achievement of conservation objectives. *Aquatic Conservation-Marine and Freshwater Ecosystems* 21(6): 500-509.

109. Hicks, CC (2011). How do we value our reefs? Risks and tradeoffs across scales in "biomass-based" economies. *Coastal Management* 39(4): 358-376.

110. Hisano, M, Connolly, SR and Robbins, WD (2011). Population growth rates of reef sharks with and without fishing on the Great Barrier Reef: robust estimation with multiple models. *PLoS ONE* 6(9): e25028.

111. Hobbs, JPA, Jones, GP and Munday, PL (2011). Extinction risk in endemic marine fishes. *Conservation Biology* 25(5): 1053-1055.

112. Hobday, AJ and Lough, JM (2011). Projected climate change in Australian marine and freshwater environments. *Marine and Freshwater Research* 62(9): 1000-1014.

113. Hoegh-Guldberg, O (2011). Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change* 11(Supp 1): 215-227.

114. Hoegh-Guldberg, O, Hegerl, G, Root, T, Zwiers, F, Stott, P, Pierce, D and Allen, M (2011). Difficult but not impossible. *Nature Climate Change* 1(2): 72-72.

115. Hoegh-Guldberg, O, Ortiz, JC and Dove, S (2011). The future of coral reefs. *Science* 334(6062): 1494-1495.

116. Hoey, AS and Bellwood, DR (2011). Suppression of herbivory by macroalgal density: a critical feedback on coral reefs? *Ecology Letters* 4(3): 267-273.

117. Hoey, AS, Pratchett, MS and Cvitanovic, C (2011). High macroalgal cover and low coral recruitment undermines the potential resilience of the world's southernmost coral reef assemblages. *PLoS ONE* 6(10): e25824.

118. Holmes, TH and McCormick, MI (2011). Response across a gradient: behavioural reactions of newly settled fish to predation cues. *Animal Behaviour* 81(3): 543-550.

119. Hoogenboom, MO, Armstrong, JD, Miles, MS, Burton, T, Groothuis, TGG and Metcalfe, NB (2011). Implantation of cocoa butter reduces egg and hatchling size in *Salmo trutta*. *Journal of Fish Biology* 79(3): 587-596.

120. Hoogenboom, MO, Connolly, SR and Anthony, KRN (2011). Biotic and abiotic correlates of tissue quality for common scleractinian corals. *Marine Ecology Progress Series* 438: 119-128.

121. Hsieh, HJ, Chen, K-S, Lin, YI, Huang, YA, Baird, AH, Tsai, W-S, Su, W-C and Chen, CA (2011). Establishment of a No-Take Area (NTA) could not guarantee the preservation of coral communities in Chinwan Inner Bay, Penghu, Taiwan. *Zoological Studies* 50(4): 443-453.

122. Huang, D, Licuanan, WY, Baird, AH and Fukami, H (2011). Cleaning up the 'Bigmessidae': molecular phylogeny of scleractinian corals from Faviidae, Merulinidae, Pectiniidae and Trachyphylliidae. *BMC Evolutionary Biology* 11: 37.

123. Hubert, N, Paradis, E, Bruggemann, H and Planes, S (2011). Community assembly and diversification in Indo-Pacific coral reef fishes. *Ecology and Evolution* 1(3): 229-277.

124. Hughes, T, Bellwood, D, Baird, A, Brodie, J, Bruno, J and Pandolfi, J (2011). Shifting base-lines, declining coral cover, and the erosion of reef resilience. *Coral Reefs* 30(3): 653-660.

125. Iguchi, A, Shinzato, C, Forêt, S and Miller, DJ (2011). Identification of fast-evolving genes in the Scleractinian coral *Acropora* using comparative EST analysis. *PLoS ONE* 6(6): e20140.

126. Janiszewska, K, Stolarski, J, Benzerara, K, Meibom, A, Mazur, M, Kitahara, MV and Cairns, SD (2011). A unique skeletal microstructure of the deep-sea micrabaciid scleractinian corals. *Journal of Morphology* 272(2): 191-203.

127. Januchowski-Hartley, FA, Graham, NAJ, Feary, DA, Morove, T and Cinner, JE (2011). Fear of fishers: human predation explains behavioral changes in coral reef fishes. *PLoS ONE* 6(8): e22761.

128. Januchowski-Hartley, SR, Hermoso, V, Pressey, RL, Linke, S, Kool, J, Pearson, RG, Pusey, BJ and VanDerWal, J (2011). Coarse-filter surrogates do not represent freshwater fish diversity at a regional scale in Queensland, Australia. *Biological Conservation* 144(10): 2499-2511.

129. Januchowski-Hartley, SR, Visconti, P and Pressey, RL (2011). A systematic approach for prioritizing multiple management actions for invasive species. *Biological Invasions* 13(5): 1241-1253.

130. Johansen, JL and Jones, GP (2011). Increasing ocean temperature reduces the metabolic performance and swimming ability of coral reef damselfishes. *Global Change Biology* 17(9): 2971-2979.

131. Jones, NA, Ross, H, Lynam, T, Perez, P and Leitch, A (2011). Mental models: an interdisciplinary synthesis of theory and methods. *Ecology and Society* 16(1): 46.

132. Kaniewska, P, Magnusson, SH, Anthony, KRN, Reef, R, Kuhl, M and Hoegh-Guldberg, O (2011). Importance of macro- versus microstructure in modulating light levels inside coral colonies. *Journal of Phycology* 47(4): 846-860.

133. Karlson, RH, Connolly, SR and Hughes, TP (2011). Spatial variance in abundance and occupancy of corals across broad geographic scales. *Ecology* 92(6): 1282-1291.

134. Kayal, M, Lenihan, H, Pau, C, Penin, L and Adjeroud, M (2011). Associational refuges among corals mediate impacts of a crown-of-thorns starfish *Acanthaster planci* outbreak. *Coral Reefs* 30(3): 827-837.

135. Kerr, AM, Baird, AH and Hughes, TP (2011). Correlated evolution of sex and reproductive mode in corals (Anthozoa: Scleractinia). *Proceedings of the Royal Society B: Biological Sciences* 278(1702): 75-81.

136. Kingsford, M, Smith, F and Flood, M (2011). Growth and pelagic larval duration of presettlement and newly settled neon damselfish, *Pomacentrus coelestis* at multiple spatial scales. *Coral Reefs* 30(1): 203-214.

137. Kininmonth, S, Beger, M, Bode, M, Peterson, E, Adams, VM, Dorfman, D, Brumbaugh, DR and Possingham, HP

(2011). Dispersal connectivity and reserve selection for marine conservation. *Ecological Modelling* 222(7): 1272-1282.

138. Kittinger, JN, Pandolfi, JM, Blodgett, JH, Hunt, TL, Jiang, H, Maly, K, McClenachan, LE, Schultz, JK and Wilcox, BA (2011). Historical reconstruction reveals recovery in Hawaiian coral reefs. *PLoS ONE* 6(10): e25460.

139. Koehn, JD, Hobday, AJ, Pratchett, MS and Gillanders, BM (2011). Climate change and Australian marine and freshwater environments, fishes and fisheries: synthesis and options for adaptation. *Marine and Freshwater Research* 62(9): 1148-1164.

140. Konow, N and Bellwood, DR (2011). Evolution of high trophic diversity based on limited functional disparity in the feeding apparatus of marine angelfishes (f. Pomacanthidae). *PLoS ONE* 6(9): e24113.

141. Kool, JT, Paris, CB, Barber, PH and Cowen, RK (2011). Connectivity and the development of population genetic structure in Indo-West Pacific coral reef communities. *Global Ecology and Biogeography* 20(5): 695-706.

142. Krajewski, JP, Floeter, SR, Jones, GP and Leite, FPP (2011). Patterns of variation in behaviour within and among reef fish species on an isolated tropical island: influence of exposure and substratum. *Journal of the Marine Biological Association of the UK* 91(6 - Fish Ecology): 1359-1368.

143. Lamb, JB and Willis, BL (2011). Using coral disease prevalence to assess the effects of concentrating tourism activities on offshore reefs in a tropical marine park. *Conservation Biology* 25(5): 1044-1052.

144. Lange, C, Hemmrich, G, Klostermeier, UC, Lopez-Quintero, JA, Miller, DJ, Rahn, T, Weiss, Y, Bosch, TCG and Rosenstiel, P (2011). Defining the origins of the NOD-like receptor system at the base of animal evolution. *Molecular Biology and Evolution* 28(5): 1687-1702.

145. Lawton, RJ, Messmer, V, Pratchett, MS and Bay, LK (2011). High gene flow across large geographic scales reduces extinction risk for a highly specialised coral feeding butterflyfish. *Molecular Ecology* 20(17): 3584-3598.

146. Lawton, RJ, Pratchett, MS and Bay, LK (2011). Cross-species amplification of 44 microsatellite loci developed for *Chaetodon trifascialis, C. lunulatus* and *C. vagabundus* in 22 related butterflyfish species. *Molecular Ecology Resources* 11(2): 323-327.

147. Leahy, SM, McCormick, MI, Mitchell, MD and Ferrari, MCO (2011). To fear or to feed: the effects of turbidity on perception of risk by a marine fish. *Biology Letters* 7(6): 811-813.

148. Lefevre, C and Bellwood, D (2011). Temporal variation in coral reef ecosystem processes: herbivory of macroalgae by fishes. *Marine Ecology Progress Series* 422: 239-251.

149. Leggat, W, Seneca, F, Wasmund, K, Ukani, L, Yellowlees, D and Ainsworth, TD (2011). Differential responses of the coral host and their algal symbiont to thermal stress. *PLoS ONE* 6(10): e26687.

150. Leggat, W, Yellowlees, D and Medina, M (2011). Recent progress in *Symbiodinium* transcriptomics. *Journal of Experimental Marine Biology and Ecology* 408(1-2): 120-125.

151. Leis, JM, Siebeck, U and Dixson, DL (2011). How nemo finds home: the neuroecology of dispersal and of population connectivity in larvae of marine fishes. *Integrative and Comparative Biology* 51(5): 826-843.

152. Levy, O, Kaniewska, P, Alon, S, Eisenberg, E, Karako-Lampert, S, Bay, LK, Reef, R, Rodriguez-Lanetty, M, Miller, DJ and Hoegh-Guldberg, O (2011). Complex diel cycles of gene expression in coral-algal symbiosis. *Science* 331(6014): 175.

153. Linares, C, Pratchett, MS and Coker, DJ (2011). Recolonisation of *Acropora hyacinthus* following climate-induced coral bleaching on the Great Barrier Reef. *Marine Ecology Progress Series* 438: 97-104.

154. Littman, R, Willis, BL and Bourne, DG (2011). Metagenomic analysis of the coral holobiont during a natural bleaching event on the Great Barrier Reef. *Environmental Microbiology Reports* 3(6): 651-660.

155. Loennstedt, O and McCormick, M (2011). Growth history and intrinsic factors influence risk assessment at a critical life transition for a fish. *Coral Reefs* 30(3): 805-812.

156. Loennstedt, OM and McCormick, MI (2011). Chemical alarm cues inform prey of predation threat: the importance of ontogeny and concentration in a coral reef fish. *Animal Behaviour* 82(2): 213-218.

157. Lough, J (2011). Measured coral luminescence as a freshwater proxy: comparison with visual indices and a potential age artefact. *Coral Reefs* 30(1): 169-182.

158. Lough, JM (2011). Great Barrier Reef coral luminescence reveals rainfall variability over northeastern Australia since the 17th century. *Paleoceanography* 26(2): PA2201.

159. Lough, JM and Cooper, TF (2011). New insights from coral growth band studies in an era of rapid environmental change. *Earth-Science Reviews* 108(3–4): 170-184.

160. Lough, JM and Hobday, AJ (2011). Observed climate change in Australian marine and freshwater environments. *Marine and Freshwater Research* 62(9): 984-999.

161. Lourival, R, Watts, M, Pressey, RL, Mourao, GdM, Padovani, CR, Silva, MPd and Possingham, HP (2011). What is missing in biosphere reserves accountability? *Brazilian Journal of Nature Conservation* 9(2): 160-178.

162. Lukoschek, V and Avise, JC (2011). Development of ten polymorphic microsatellite loci for the sea snake *Hydrophis elegans* (Elapidae: Hydrophiinae) and cross-species amplification for fifteen marine hydrophiine species. *Conservation Genetics Resources* 3(3): 497-501.

163. Lukoschek, V and Avise, JC (2011). Genetic monandry in 6 viviparous species of true sea snakes. *Journal of Heredity* 102(3): 347-351.

164. Lukoschek, V, Osterhage, JL, Karns, DR, Murphy, JC and Voris, HK (2011). Phylogeography of the Mekong mud snake (*Enhydris subtaeniata*): the biogeographic importance of dynamic river drainages and fluctuating sea levels for semiaquatic taxa in Indochina. *Ecology and Evolution* 1(3): 330-342.

165. Lybolt, M, Neil, D, Zhao, J, Feng, Y, Yu, K-F and Pandolfi, J (2011). Instability in a marginal coral reef: the shift from natural variability to a human-dominated seascape. *Frontiers in Ecology and the Environment* 9(3): 154-160.

166. Mallela, J, Hermann, J, Rapp, R and Eggins, S (2011). Fine-scale phosphorus distribution in coral skeletons: combining X-ray mapping by electronprobe microanalysis and LA-ICP-MS. *Coral Reefs* 30(3): 813-818.

167. Mason, HE, Montagna, P, Kubista, L, Taviani, M, McCulloch, M and Phillips, BL (2011). Phosphate defects and apatite inclusions in coral skeletal aragonite revealed by solid-state NMR spectroscopy. *Geochimica et Cosmochimica Acta* 75(23): 7446-7457.

168. Maynard, J, Anthony, K, Harvell, C, Burgman, M, Beeden, R, Sweatman, H, Heron, S, Lamb, J and Willis, B (2011). Predicting outbreaks of a climate-driven coral disease in the Great Barrier Reef. *Coral Reefs* 30(2): 485-495.

169. McClanahan, TR, Graham, NAJ, MacNeil, MA, Muthiga, NA, Cinner, JE, Bruggemann, JH and Wilson, SK (2011). Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences* 108(41): 17230-17233.

170. McClanahan, TR and Hicks, CC (2011). Changes in life history and ecological characteristics of coral reef fish catch composition with increasing fishery management. *Fisheries Management and Ecology* 18(1): 50-60.

171. Messmer, V, Jones, GP, Munday, PL, Holbrook, SJ, Schmitt, RJ and Brooks, AJ (2011). Habitat biodiversity as a determinant of fish community structure on coral reefs. *Ecology* 92(12): 2285-2298.

172. Miller, DJ, Ball, EE, Forêt, S and Satoh, N (2011). Coral genomics and transcriptomics - ushering in a new era in coral biology. *Journal of Experimental Marine Biology and Ecology* 408(1-2): 114-119.

173. Miller-Sims, VC, Atema, J, Gerlach, G and Kingsford, MJ (2011). How stable are the reef odor preferences of settling reef fish larvae? *Marine and Freshwater Behaviour and Physiology* 44(3): 133-141.

174. Mills, DJ, Adhuri, DS, Phillips, MJ, Ravikumar, B and Padiyar, AP (2011). Shocks, recovery trajectories and resilience among aquaculture-dependent households in post-tsunami Aceh, Indonesia. *Local Environment* 16(5): 425-444.

175. Mills, M, Jupiter, SD, Pressey, RL, Ban, NC and Comley, J (2011). Incorporating effectiveness of community-based management in a national marine gap analysis for Fiji. *Conservation Biology* 25(6): 1155-1164.

176. Mills, M, Rasch, R, Siebeck, UE and Collin, SP (2011). Exogenous material in the inner ear of the adult Port Jackson Shark, *Heterodontus portusjacksoni* (Elasmbranchii). *Anatomical Record-Advances in Integrative Anatomy and Evolutionary Biology* 294(3): 373-378.

177. Mitchell, MD, McCormick, MI, Ferrari, MCO and Chivers, DP (2011). Coral reef fish rapidly learn to identify multiple unknown predators upon recruitment to the reef. *PLoS ONE* 6(1): e15764.

178. Mitchell, MD, McCormick, MI, Ferrari, MCO and Chivers, DP (2011). Friend or foe? The role of latent inhibition in predator and non-predator labelling by coral reef fishes. *Animal*

Cognition 14(5): 707-714.

179. Mora, C, Aburto-Oropeza, O, Ayala Bocos, A, Ayotte, PM, Banks, S, Bauman, AG, Beger, M, Bessudo, S, Booth, DJ, Brokovich, E, Brooks, A, Chabanet, P, Cinner, JE, Cortes, J, Cruz-Motta, JJ, Cupul Magana, A, DeMartini, EE, Edgar, GJ, Feary, DA, Ferse, SCA, Friedlander, AM, Gaston, KJ, Gough, C, Graham, NAJ, Green, A, Guzman, H, Hardt, M, Kulbicki, M, Letourneur, Y, Lopez Perez, A, Loreau, M, Loya, Y, Martinez, C, Mascarenas-Osorio, I, Morove, T, Nadon, M-O, Nakamura, Y, Paredes, G, Polunin, NVC, Pratchett, MS, Reyes Bonilla, H, Rivera, F, Sala, E, Sandin, SA, Soler, G, Stuart-Smith, R, Tessier, E, Tittensor, DP, Tupper, M, Usseglio, P, Vigliola, L, Wantiez, L, Williams, I, Wilson, SK and Zapata, FA (2011). Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. *PLoS Biology* 9(4): e1000606.

180. Mumby, PJ, Elliott, IA, Eakin, CM, Skirving, W, Paris, CB, Edwards, HJ, Enriquez, S, Iglesias-Prieto, R, Cherubin, LM and Stevens, JR (2011). Reserve design for uncertain responses of coral reefs to climate change. *Ecology Letters* 14(2): 132-140.

181. Mumby, PJ, Harborne, AR and Brumbaugh, DR (2011). Grouper as a natural biocontrol of invasive lionfish. *PLoS ONE* 6(6): e21510.

182. Mumby, PJ, Iglesias-Prieto, R, Hooten, AJ, Sale, PF, Hoegh-Guldberg, O, Edwards, AJ, Harvell, CD, Gomez, ED, Knowlton, N, Hatziolos, ME, Kyewalyanga, MS and Muthiga, N (2011). Revisiting climate thresholds and ecosystem collapse. *Frontiers in Ecology and the Environment* 9(2): 94-96.

183. Mumby, PJ, Vitolo, R and Stephenson, DB (2011). Temporal clustering of tropical cyclones and its ecosystem impacts. *Proceedings of the National Academy of Sciences* 108(43): 17626-17630.

184. Munday, PL, Gagliano, M, Donelson, JM, Dixson, DL and Thorrold, SR (2011). Ocean acidification does not affect the early life history development of a tropical marine fish. *Marine Ecology Progress Series* 423: 211-221.

185. Munday, PL, Hernaman, V, Dixson, DL and Thorrold, SR (2011). Effect of ocean acidification on otolith development in larvae of a tropical marine fish. *Biogeosciences* 8(6): 1631-1641.

186. Mydlarz, LD and Palmer, CV (2011). The presence of multiple phenoloxidases in Caribbean reef-building corals. *Comparative Biochemistry and Physiology a-Molecular & Integrative Physiology* 159(4): 372-378.

187. Negri, AP and Hoogenboom, MO (2011). Water contamination reduces the tolerance of coral larvae to thermal stress. *PLoS ONE* 6(5): e19703.

188. Palmer, CV, Bythell, JC and Willis, BL (2011). A comparative study of phenoloxidase activity in diseased and bleached colonies of the coral *Acropora millepora*. *Developmental & Comparative Immunology* 35(10): 1098-1101.

189. Palmer, CV, McGinty, ES, Cummings, DJ, Smith, SM, Bartels, E and Mydlarz, LD (2011). Patterns of coral ecological immunology: variation in the responses of Caribbean corals to elevated temperature and a pathogen elicitor. *Journal of Experimental Biology* 214(24): 4240-4249.

190. Palmer, CV, Traylor-Knowles, NG, Willis, BL and Bythell, JC (2011). Corals use similar immune cells and wound-healing processes as those of higher organisms. *PLoS ONE* 6(8): e23992.

191. Pandolfi, JM, Connolly, SR, Marshall, DJ and Cohen, AL (2011). The future of coral reefs response. *Science* 334(6062): 1495-1496.

192. Pandolfi, JM, Connolly, SR, Marshall, DJ and Cohen, AL (2011). Projecting coral reef futures under global warming and ocean acidification. *Science* 333(6041): 418-422.

193. Pankhurst, NW and Munday, PL (2011). Effects of climate change on fish reproduction and early life history stages. *Marine and Freshwater Research* 62(9): 1015-1026.

194. Pantos, O and Hoegh-Guldberg, O (2011). Shared skeletal support in a coral-hydroid symbiosis. *PLoS ONE* 6(6): e20946.

195. Penin, L, Michonneau, F, Carroll, A and Adjeroud, M (2011). Effects of predators and grazers exclusion on early post-settlement coral mortality. *Hydrobiologia* 663(1): 259-264.

196. Pernice, M, Dunn, SR, Miard, T, Dufour, S, Dove, S and Hoegh-Guldberg, O (2011). Regulation of apoptotic mediators reveals dynamic responses to thermal stress in the reef building coral *Acropora millepora*. *PLoS ONE* 6(1): e16095.

197. Pollock, FJ, Morris, PJ, Willis, BL and Bourne, DG (2011). The urgent need for robust coral disease diagnostics. *Plos Pathogens* 7(10): e1002183.

198. Pratchett, M, Trapon, M, Berumen, M and Chong-Seng, K (2011). Recent disturbances augment community shifts in coral assemblages in Moorea, French Polynesia. *Coral Reefs* 30(1): 183-193.

199. Pratchett, MS, Bay, LK, Gehrke, PC, Koehn, JD, Osborne, K, Pressey, RL, Sweatman, HPA and Wachenfeld, D (2011). Contribution of climate change to degradation and loss of critical fish habitats in Australian marine and freshwater environments. *Marine and Freshwater Research* 62(9): 1062-1081.

200. Pratchett, MS, Hoey, AS, Wilson, SK, Messmer, V and Graham, NAJ (2011). Changes in biodiversity and functioning of reef fish assemblages following coral bleaching and coral loss. *Diversity* 3(3): 424-452.

201. Puill-Stephan, E, van Oppen, MJH, Pichavant-Rafini, K and Willis, BL (2011). High potential for formation and persistence of chimeras following aggregated larval settlement in the broadcast spawning coral, *Acropora millepora*. *Proceedings of the Royal Society B: Biological Sciences* 279(1729): 699-708.

202. Reymond, C, Uthicke, S and Pandolfi, J (2011). Inhibited growth in the photosymbiont-bearing foraminifer *Marginopora vertebralis* from the nearshore Great Barrier Reef, Australia. *Marine Ecology Progress Series* 435: 97-109.

203. Reymond, CE, Bode, M, Renema, W and Pandolfi, J (2011). Ecological incumbency impedes stochastic community assembly in Holocene foraminifera from the Huon Peninsula, Papua New Guinea. *Paleobiology* 37(4): 670-685.

204. Richards, Z and Hobbs, JP (2011). Prehistoric Pacific Island kings entombed in truncated coral pyramids. *Coral Reefs* 30(3): 737.

205. Riegl, BM, Purkis, SJ, Al-Cibahy, AS, Abdel-Moati, MA and Hoegh-Guldberg, O (2011). Present limits to heat-adaptability in corals and population-level responses to climate extremes. *PLoS ONE* 6(9): e24802.

206. Rivera-Posada, J, Pratchett, M and Owens, L (2011). Injection of *Acanthaster planci* with thiosulfate-citrate-bile-sucrose agar (TCBS). II. Histopathological changes. *Diseases of Aquatic Organisms* 97(2): 95-102.

207. Rivera-Posada, JA, Pratchett, M, Cano-Gomez, A, Arango-Gomez, JD and Owens, L (2011). Injection of *Acanthaster planci* with thiosulfate-citrate-bile-sucrose agar (TCBS). I. Disease induction. *Diseases of Aquatic Organisms* 97(2): 85-94.

208. Rivera-Posada, JA, Pratchett, M, Cano-Gomez, A, Arango-Gomez, JD and Owens, L (2011). Refined identification of *Vibrio* bacterial flora from *Acanthasther planci* based on biochemical profiling and analysis of housekeeping genes. *Diseases of Aquatic Organisms* 96(2): 113-123.

209. Roff, G, Ledlie, MH, Ortiz, JC and Mumby, PJ (2011). Spatial patterns of parrotfish corallivory in the Caribbean: the importance of coral taxa, density and size. *PLoS ONE* 6(12): e29133.

210. Rosic, N, Pernice, M, Dove, S, Dunn, S and Hoegh-Guldberg, O (2011). Gene expression profiles of cytosolic heat shock proteins Hsp70 and Hsp90 from symbiotic dinoflagellates in response to thermal stress: possible implications for coral bleaching. *Cell Stress and Chaperones* 16(1): 69-80.

211. Rosic, N, Pernice, M, Rodriguez-Lanetty, M and Hoegh-Guldberg, O (2011). Validation of housekeeping genes for gene expression studies in *Symbiodinium* exposed to thermal and light stress. *Marine Biotechnology* 13(3): 355-365.

212. Rosic, NN and Dove, S (2011). Mycosporine-like amino acids from coral dinoflagellates. *Applied and Environmental Microbiology* 77(24): 8478-8486.

213. Russ, G and Alcala, A (2011). Enhanced biodiversity beyond marine reserve boundaries: the cup spillith-over. *Ecological Applications* 21(1): 241-250.

214. Saenz-Agudelo, P, Jones, G, Thorrold, S and Planes, S (2011). Detrimental effects of host anemone bleaching on anemonefish populations. *Coral Reefs* 30(2): 497-506.

215. Saenz-Agudelo, P, Jones, GP, Thorrold, SR and Planes, S (2011). Connectivity dominates larval replenishment in a coastal reef fish metapopulation. *Proceedings of the Royal Society B: Biological Sciences* 278(1720): 2954-2961.

216. Sale, P, Feary, D, Burt, J, Bauman, A, Cavalcante, G, Drouillard, K, Kjerfve, B, Marquis, E, Trick, C, Usseglio, P and Van Lavieren, H (2011). The growing need for sustainable ecological management of marine communities of the Persian Gulf. *Ambio* 40(1): 4-17.

217. Sato, Y, Bourne, D and Willis, B (2011). Effects of temperature and light on the progression of black band disease on the reef coral, *Montipora hispida*. *Coral Reefs* 30(3): 753-761.

218. Schneider, K, Silverman, J, Woolsey, E, Eriksson, H, Byrne, M and Caldeira, K

(2011). Potential influence of sea cucumbers on coral reef $CaCO_3$ budget: a case study at One Tree Reef. *Journal Geophysical Research* 116(G4): G04032.

219. Shinzato, C, Shoguchi, E, Kawashima, T, Hamada, M, Hisata, K, Tanaka, M, Fujie, M, Fujiwara, M, Koyanagi, R, Ikuta, T, Fujiyama, A, Miller, DJ and Satoh, N (2011). Using the *Acropora digitifera* genome to understand coral responses to environmental change. *Nature* 476(7360): 320-323.

220. Simpson, SD, Munday, PL, Wittenrich, ML, Manassa, R, Dixson, DL, Gagliano, M and Yan, HY (2011). Ocean acidification erodes crucial auditory behaviour in a marine fish. *Biology Letters* 7(6): 917-920.

221. Skinner, MP, Brewer, TD, Johnstone, R, Fleming, LE and Lewis, RJ (2011). Ciguatera fish poisoning in the Pacific Islands (1998 to 2008). *PLoS Neglected Tropical Diseases* 5(12): e1416.

222. Souter, P, Bay, LK, Andreakis, N, Csaszar, N, Seneca, FO and van Oppen, MJH (2011). A multilocus, temperature stress-related gene expression profile assay in *Acropora millepora*, a dominant reef-building coral. *Molecular Ecology Resources* 11(2): 328-334.

223. Stella, J, Munday, P and Jones, G (2011). Effects of coral bleaching on the obligate coral-dwelling crab *Trapezia cymodoce*. *Coral Reefs* 30(3): 719-727.

224. Stella, JS, Pratchett, MS, Hutching, PA and Jones, GP (2011). Coral-associated invertebrates: diversity, ecological importance and vulnerability to disturbance. *Oceanography and Marine Biology: an Annual Review* 49: 43-116.

225. Stoeckl, N, Hicks, CC, Mills, M, Fabricius, K, Esparon, M, Kroon, F, Kaur, K and Costanza, R (2011). The economic value of ecosystem services in the Great Barrier Reef: our state of knowledge. *Annals of the New York Academy of Sciences* 1219(1): 113-133.

226. Stolarski, J, Kitahara, MV, Miller, DJ, Cairns, SD, Mazur, M and Meibom, A (2011). The ancient evolutionary origins of Scleractinia revealed by azooxanthellate corals. *BMC Evolutionary Biology* 11: 316.

227. Trapon, ML, Pratchett, MS and Penin, L (2011). Comparative effects of different disturbances in coral reef habitats in Moorea, French Polynesia. *Journal of Marine Biology* 2011: Article ID 807625.

228. Trotter, J, Montagna, P, McCulloch, M, Silenzi, S, Reynaud, S, Mortimer, G, Martin, S, Ferrier-Pages, C, Gattuso, J-P and Rodolfo-Metalpa, R (2011). Quantifying the pH 'vital effect' in the temperate zooxanthellate coral *Cladocora caespitosa*: validation of the boron seawater pH proxy. *Earth and Planetary Science Letters* 303(3-4): 163-173.

229. Ulstrup, KE, Kuhl, M, van Oppen, MJH, Cooper, TF and Ralph, PJ (2011). Variation in photosynthesis and respiration in geographically distinct populations of two reef building coral species. *Aquatic Biology* 12(3): 241-248.

230. Vail, AL and McCormick, MI (2011). Metamorphosing reef fishes avoid predator scent when choosing a home. *Biology Letters* 7(6): 921-924.

231. van Oppen, MJH, Bongaerts, P, Underwood, JN, Peplow, LM and Cooper, TF (2011). The role of deep reefs in shallow reef recovery: an assessment of vertical connectivity in a brooding coral from west and east Australia. *Molecular Ecology* 20(8): 1647-1660.

232. van Oppen, MJH, Peplow, LM, Kininmonth, S and Berkelmans, R (2011). Historical and contemporary factors shape the population genetic structure of the broadcast spawning coral, *Acropora millepora*, on the Great Barrier Reef. *Molecular Ecology* 20(23): 4899-4914.

233. van Oppen, MJH, Souter, P, Howells, EJ, Heyward, A and Berkelmans, R (2011). Novel genetic diversity through somatic mutations: fuel for adaptation of reef corals? *Diversity* 3(3): 405-423.

234. Venera-Ponton, DE, Diaz-Pulido, G, McCook, LJ and Rangel-Campo, A (2011). Macroalgae reduce growth of juvenile corals but protect them from parrotfish damage. *Marine Ecology Progress Series* 421: 109-115.

235. Verges, A, Vanderklift, MA, Doropoulos, C and Hyndes, GA (2011). Spatial patterns in herbivory on a coral reef are influenced by structural complexity but not by algal traits. *PLoS ONE* 6(2): e17115.

236. Villeger, S, Novack-Gottshall, PM and Mouillot, D (2011). The multidimensionality of the niche reveals functional diversity changes in benthic marine biotas across geological time. *Ecology Letters* 14(6): 561-568.

237. Walther, BD, Dempster, T, Letnic, M and McCulloch, MT (2011). Movements of diadromous fish in large unregulated tropical rivers inferred from geochemical tracers. *PLoS ONE* 6(4): e18351.

238. Wenger, A, Johansen, J and Jones, G (2011). Suspended sediment impairs habitat choice and chemosensory discrimination in two coral reef fishes. *Coral Reefs* 30(4): 879-887.

239. Wild, C, Hoegh-Guldberg, O, Naumann, MS, Florencia Colombo-Pallotta, M, Ateweberhan, M, Fitt, WK, Iglesias-Prieto, R, Palmer, C, Bythell, JC, Ortiz, J-C, Loya, Y and van Woesik, R (2011). Climate change impedes scleractinian corals as primary reef ecosystem engineers. *Marine and Freshwater Research* 62(2): 205-215.

240. Yakob, L and Mumby, PJ (2011). Climate change induces demographic resistance to disease in novel coral assemblages. *Proceedings of the National Academy of Sciences* 108(5): 1967-1969.

241. Young, MAL and Bellwood, DR (2011). Diel patterns in sea urchin activity and predation on sea urchins on the Great Barrier Reef. *Coral Reefs* 30(3): 729-736.

Magazine Article (2)

1. Fuentes, M and Hawkes, L, How will sea turtles cope with climate change?, in *The State of the World's Sea Turtles*. 2011, State of the Worlds Sea turtles: Arlington, USA. p. 12-13.

2. Hughes, T, The future of marine governance in *Solutions: for a sustainable and desirable future*. 2011. p. 3-5.

Report (1)

1. Brewer, T (2011). Coral reef fish value chains in Solomon Islands: Market opportunities and market effects on fish stocks. Report for Ministry of Fisheries and Marine Resources, Solomon Islands Government, Honiara. 46pp.

Recognition of Excellence by Centre Members

2011 has been marked by the recognition of the achievements of several ARC Centre members, particularly our postdoctoral fellows. Tracy Ainsworth, Natalie Ban, Mariana Fuentes and Nick Graham were all recipients of prestigious national awards during the year.

Examples of awards and peer-recognition include:

- Peter Mumby was the 2011 recipient of The Rosenstiel Award. The award is one of the top honours of the University of Miami's Rosenstiel School of Marine and Atmospheric Science. It recognises scientists who, in the past decade, have made significant and growing impacts in their field. The award is targeted at researchers who are already making outstanding scientific contributions in their early to mid-career stages.
- Tracy Ainsworth was one of three recipients of L'Oreal Australia Fellowships *"For Women in Science"*. The awards were presented by the Managing Director of L'Oreal Australia (Johan Berg) at a reception at the Melbourne Convention Centre in August. Johan congratulated the recipients indicating the "three young women are excellent examples of researchers building their careers in fields which are so important to Australia". (see p.68)
- Natalie Ban and Mariana Fuentes were recipients of 2011 Queensland Tall Poppy Science Awards presented by the Premier, Anna Bligh, at the Queensland Premier's Science and Innovation Reception in November.
- Nick Graham was the winner of the "Life Sciences and Biological Sciences" category of the *Scopus Young Researcher of the Year Australia* award sponsored by Elsevier and the Australian Research Management Society. The formal presentation was at the ARMS Conference 2011 in Sydney in September.
- Natalie Ban, Nick Graham and Mia Hoogenboom were selected by the Australian Academy of Science to participate in the Theo Murphy High Flyer Think Tank on *Stressed ecosystems: better decisions for Australia's future* which was held in Brisbane in September.
- Morgan Pratchett was awarded The University of Oxford Fellowship by The Association of Commonwealth Universities.
- Tracy Ainsworth was awarded the John and Laurine Proud 2011 Fellowship to work at the Lizard Island Research Station operated by the Australian Museum. She was also successful with her application to The Ian Potter Foundation.
- Bob Pressey delivered the first lecture in the 2011 Australian Ambassador's Speakers Series in Washington DC in February. The lecture series, hosted by the Australian Ambassador to the US, The Hon Kim Beazley AC, highlights "eight of Australia's great thinkers speaking on issues of interest and importance both in the United States and Australia such as the environment, science, health and power relationships in the Asia-Pacific region". Bob's lecture was entitled "Coral Reef Planning – Biodiversity and Fisheries" and focussed on the Coral Triangle.

At James Cook University, several of the Centre's researchers were recognised within the University:

- The Coral Genome Team, consisting of Sylvain Forêt and David Miller, were awarded the Vice-Chancellor's Awards for Excellence for their work on sequencing the DNA in the *Acropora millepora* genome. This is the first all-Australian sequence of an animal or plant genome.
- Kirsty Nash was the winner of the Postgraduate Student Award in the "My Research in 3 Minutes" competition during the annual "Celebrating Research@JCU" in September.
- Mia Hoogenboom was one of ten early career researchers at JCU who were recipients of the university's inaugural "Rising Star" award.
- Morgan Pratchett's nomination in the Supervisor of the Year awards was "highly commended".

> I commend the very important research undertaken by the Centre and the role it plays globally in the protection and management of our coral reefs. It is pleasing to note that the Centre's newest 'node' at the University of Western Australia, is continuing to expand and play a significant part in global reef research.

Colin Barnett MLA
Premier, Western Australia
17 May 2011

Photo by Tom Bridge

Reproduced with thanks to L'Oreal Australia/ScienceInPublic
www.scienceinpublic.com/loreal/fellows/tracy-ainsworth

L'Oreal Australia Fellowships for Women In Science

The complex life of coral

Coral interactions more complex than ever suspected.

Dr Tracy Ainsworth's research is changing our understanding of the life of the tiny coral animals that built Australia's iconic Great Barrier Reef.

Her work comes at a critical time for the future of coral reefs—threatened by a warming ocean and by coral bleaching.

Just three years out from her PhD and now at James Cook University, Tracy has already demonstrated that the interactions between corals, their communities and their environment are far more intricate and subtle than we ever imagined.

She has shown, for instance, that bacteria as well as algae play a significant role in the life of the coral and in how it responds to changing temperatures. She has also found that coral bleaching is a far more complex process than previously thought.

And she's done so by applying skills in modern cell biology which she picked up working in neuroscience laboratories.

Her achievements have won her a $20,000 L'Oréal Australia *For Women in Science* Fellowship which she will use to study the low light, deep water reefs that underlie tropical surface reefs at depths of 100 metres or more.

Coral calling

Tracy has always been a beach girl. "I love oceans and beaches and reefs."

Growing up on the beaches of New South Wales, she has spent almost her entire life playing, learning, studying and working by the sea.

Now she is giving something back—her research is changing how we understand and manage coral reefs.

When she moved to James Cook University in Townsville to study marine biology, Tracy first worked on prawns and aquaculture. But she became increasingly interested in how marine creatures cope with stress and disease and came to admire coral.

"This small, simple animal builds large and beautiful structures that attract life and create a rich ecosystem. And the world's reefs are also important to the human communities who live near them: for food, for protection and for tourism," she says.

In surface reefs, the coral polyps—relatives of jellyfish and anemones—that construct the reef's limestone scaffolding form a symbiotic relationship with single-celled algae called dinoflagellates. In return for sugars from their photosynthesis, the colourful algae gain a home. Bleaching indicates the algae have left home.

Coral home for bacteria too.

But the reef also supports communities of bacteria living in a mucous coating which the polyps secrete to protect themselves from wave action and the scouring of sand and sediments. The mucous is an ideal home for bacteria, and an environment the polyps can manipulate to their advantage by means of nutrients and inhibitors. And the bacteria themselves provide another layer of protection, producing chemical defences against less benign infective bacteria and microbes that can cause disease. The interaction with these bacteria seems to be important for corals.

In deciding to study the coral bacteria, however, Tracy realised she needed the skills and sophisticated tools of modern cell biology. So she went south, to Brisbane and worked as a research assistant in two different neurobiology laboratories, acquiring the techniques of modern molecular biology and genomic research.

Armed with these skills, she returned to the reef and to the Australian Research Council Centre of Excellence for Reef Studies at James Cook University to investigate the diversity of the bacterial communities by sequencing the species involved and using fluorescent tags to pick them out with a confocal microscope. That allowed her to study what happened to the bacterial communities in times of stress, such as when water temperature began to rise.

Conventional wisdom held that symbiotic algae began to abandon their coral at a threshold temperature of about 32°C, leading to bleaching. But Tracy found things were much more complex, and the coral more sensitive. "Coral begins to respond at temperatures much lower than the bleaching threshold. For instance, at temperatures below 30°C you start seeing programmed cell death in the coral polyps, and the symbiotic relationships with the bacteria and algae begin to break down."

She will use the Fellowship to study the low light, deep water reefs that underlie tropical surface reefs at depths of 100 metres or more.

This is a world far removed from the bright, colourful, sunlit environment we associate with coral. It's a place with little or no photosynthesis to provide the energy for reef construction and maintenance. But the biological communities there are still diverse, and still include algae. They may even serve as refuges from which devastated shallow reefs can repopulate.

"The low light environment is really very different. These are large reef structures and we know very little about how they function."

Tracy has taken her techniques and analyses to reefs in different environments worldwide. During a six-month stint at Tel Aviv and Haifa universities in Israel, she was able to show that the annual summer coral bleaching in the Mediterranean was not due to disease and infective bacteria, as had been supposed. In fact, no bacteria were involved. She has also worked on reefs in Hawaii, and the extremely hot and saline Red Sea.

"The fact that there is so much diversity in the ocean gives us hope for the future. But such diversity doesn't change the need for us to minimise our impact. It highlights the importance of protecting it."

Fortunately, her seaside work environment is one to which she has no hesitation in taking her two-year-old daughter and, when it arrives soon, her second child. One suspects another generation of beach children is being launched.

Tracy Ainsworth
James Cook University

Performance Measures

Research findings

Measure	Target 2011	Outcome 2011
Number of publications (p.58)	180	263
Publications in journals with an impact factor > 4	40	95
Number of citations (p.58)	11,000	19,880
Invitations to provide plenary addresses at international conferences	30	49
Invitations to provide review articles	36	44
Number and nature of commentaries about the Centre's achievements (p.50)	1,250	3,086
Awards, prizes or recognition (p.66)	21	37

Research training and professional education

Measure	Target 2011	Outcome 2011
Number of postgraduates enrolled (p.36)	135 over 5 years	181 enrolled in 2011 346 enrolled 2006-2011
Number of postgraduate completions	90 over 5 years	41 in 2011 163 completions 2006-2011
Number of Honours students	60 over 5 years	27 enrolled in 2011 84 enrolled 2006-2011
Number of professional workshops	18	30
Participation in professional workshops	22	78
Number and level of graduate student courses and workshops in the priority area(s)	12	34

International, national and regional links and networks

Measure	Target 2011	Outcome 2011
Number of international visitors (p.46)	75	98
Number of national and international Working Groups	16	60 researcher participations in 34 working groups
Number of visits to overseas laboratories and research facilities (p.46)	55	98
Membership of national and international boards and advisory committees	45	79
Number of cross-institutional publications	100	175
Number of multi-institutional supervisory arrangements of graduate students (p.36)	52	66
Number of internationally funded students **Number of consultancies and contract research**	50 over 5 years 15	72 in 2011 33
Number of government, industry and business briefings	55	79
Number of Centre trained/ing personnel in knowledge/ technology transfer and commercialisation	7	5
Public awareness programs **Website hits** **Public awareness presentations**	 3.0 million 22	 7.6 million 56

Organisational support

Measure	Target 2011	Outcome 2011
Annual cash contributions from Collaborating Organisations	$1.6M	$2.7M
Annual in-kind contributions from Collaborating Organisations	$4.0M	$8M
Number of new Organisations recruited to or involved in the Centre	6	13
Level and quality of infrastructure provided to the Centre	$1.15M	$1.2M
Annual cash contributions from other organisations	$0.62M	$3.3M

Governance

Measure	Target 2011	Outcome 2011
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. 4 Scientific Management Committee meetings p.a.	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 Monthly nodal leader phone or video conferences Annual rotational visits to the nodes Annual research retreats for all Centre participants Annual research program planning meetings with cross-nodal attendance Number of co-supervisory arrangements for students Number of multi-nodal seminar and discussion groups	All research programs represented at Scientific Management Committee meetings Regular nodal and program leader meetings held There were 46 cross-nodal visits in 2011. Additionally, members travelled to Fremantle for the Centre's annual meeting and symposium Research planning meetings were held by each research program Cross-nodal attendance at all research planning meetings 66 46
The adequacy of the Centre's Key Performance Measures	International benchmarking to research in top international marine research centres	The Centre is ranked #1 in the world for citations and outputs in coral reef science

National Benefit

Measure	Target 2011	Outcome 2011
Measures of expansion of Australia's capability in the priority area(s)	150% increase on 2004 benchmark by 2013	A 300% increase on the 2004 publications benchmark A 570% increase on the 2004 citations benchmark
	55 briefings to government, business and industry groups	79 briefings
	17 cross-nodal publications	40 cross-nodal publications
	100 cross-institutional publications	175 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 54–57

Financial Statement

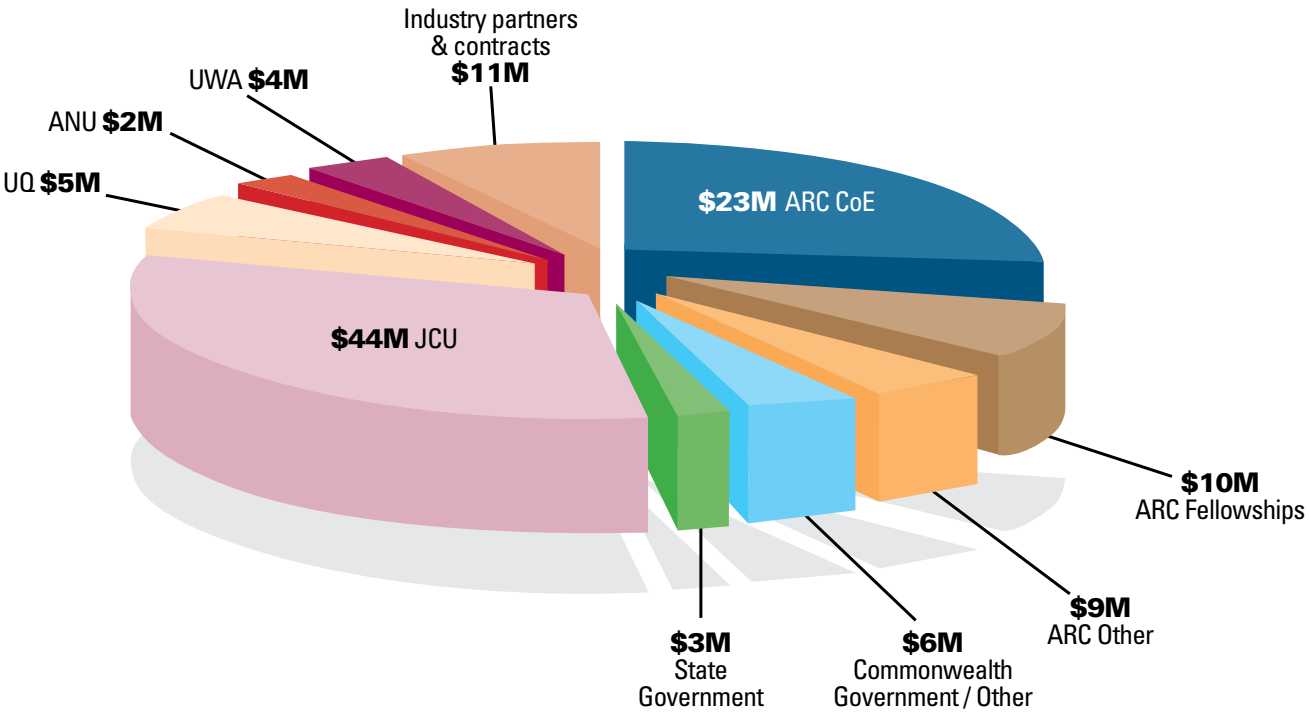
ARC Centre of Excellence for Coral Reef Studies
Statement of Operating Income and Expenditure for year ended 31 December 2011

	2010 $	2011 $
Income		
ARC Centre Grant	2,811,038	2,961,905
ARC Fellowships	1,376,341	1,739,402
ARC Discovery	166,481	129,072
ARC Linkages	155,665	232,998
Host Institutions cash support	2,673,902	2,628,057
State Government	244,000	402,213
Commonwealth Government other grants	436,343	853,280
International and other contracts	570,480	590,279
Total Income	**8,434,241**	**9,537,205**
Expenditure		
Salaries	4,379,076	5,851,678
Equipment	429,470	503,966
Travel	1,305,139	1,541,497
Research maintenance and consumables	1,035,491	1,214,888
Scholarships	92,375	85,629
Public outreach and administration	176,482	209,656
Total Expenditure	**7,418,034**	**9,407,313**
Surplus (Deficit)	**1,016,207**	**129,892**

Financial Outlook

As at 31 December 2011, the total cash and in-kind budget for the ARC Centre of Excellence for 1 July 2005 to 31 December 2013 total $119M, more than 3.5 times the 2005 funding outlook. The chart below indicates the budgeted level of income from all funding sources.

ARC Centre of Excellence funding outlook 2005-2013: total $119M



Acknowledgements

The ARC Centre of Excellence for Coral Reef Studies thanks the following organisations and partners for their ongoing support:

- Australian Institute of Nuclear Science and Engineering Inc (AINSE), NSW
- American-Australian Association, New York
- ARC Research Network for Earth System Science (ARCNESS), NSW
- Australian Academy of Science, Canberra
- Australian Genome Research Facility (AGRF), Brisbane
- Australian Government: AusAID
- Australian Institute of Marine Science, Townsville
- Australian Coral Reef Society, Australia
- Australian Marine Mammal Centre, Hobart
- Australian Museum, Sydney
- Beijer Institute for Ecological Economics, Stockholm
- Centre for Marine and Fisheries Studies, Syiah Kuala University, Indonesia
- Centre National de la Recherche Scientifique, France
- Coastal Conservation and Education Foundation, Philippines
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) Flagship Collaboration Fund, Australia
- Conservation International, USA
- Coral Reef Initiatives for the Pacific (CRISP), Noumea
- Department of Foreign Affairs and International Trade, Canada
- Cairns Regional Council
- Commonwealth Department of Sustainability, Environment, Water, Population and Communities
- David & Lucile Packard Foundation, USA
- Deutsche Forschungsgemeinschaft Excellence Cluster, University of Kiel, Germany
- European Commission, Brussels
- Fisheries Research and Development Corporation, Canberra
- Fundação para a Ciência e a Tecnologia (FCT), Portugal
- Georgia Institute of Technology, USA
- GHD, International
- Government of the Republic of Indonesia
- Great Barrier Reef Foundation, Brisbane
- Great Barrier Reef Marine Park Authority, Townsville
- Ian Potter Foundation, Melbourne
- IDP Education Australia
- Illumina Pty Ltd, Australia
- Institute of Sustainable Marine Resources, National Fisheries College, Papua New Guinea
- John D. and Catherine T. MacArthur Foundation, USA
- Khaled bin Sultan Living Oceans Foundation, USA
- King Abdullah University of Science and Technology, Saudi Arabia
- Lizard Island Research Station, Queensland
- L'Oreal Australia
- Marine Conservation Biology Institute (MCBI), USA
- Marine Parks Authority, Lord Howe Island Marine Park
- National Aeronautics and Space Administration (NASA), USA
- National Climate Change Adaptation Research Facility (NCCARF), Brisbane
- National Coral Reef Institute, USA
- National Environment Research Program, Australia
- National Fish & Wildlife Foundation, USA
- National Oceanic and Atmospheric Administration, USA
- National Parks Association of Queensland
- New York University Abu Dhabi Institute, United Arab Emirates
- Nguna-Pele Marine Protected Area Network, Vanuatu
- Palawan State University, Philippines
- Passions of Paradise, Cairns
- Project AWARE Foundation, Australia
- Queensland Department of the Premier and Cabinet
- Queensland Department of Employment, Economic Development & Innovation
- Queensland Department of Environment and Resource Management
- Reef Catchments Mackay Whitsunday Inc, Queensland
- Resilience Alliance, Sweden
- Royal Swedish Academy of Science, Sweden
- Rufford Small Grants Association, United Kingdom
- Sea World, Gold Coast
- Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Japan
- Seychelles Fishing Authority
- Silliman University, Philippines
- Smithsonian Marine Network, USA
- Stockholm Resilience Centre, Sweden
- Telekom Television Ltd, Solomon Islands
- The CASS Foundation, Melbourne
- The Computational Biology Group, University of Amsterdam
- The Nature Conservancy, USA
- Torres Strait Regional Authority, Queensland
- University of Delaware, USA
- University of Maine, USA
- University of Montpellier 2, Sciences and Technology, France
- University of Perpignan, France
- Western Australian Department of Environment and Conservation
- Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, New York
- Wildlife Preservation Society of Australia, Sydney
- Winston Churchill Memorial Trust, Canberra
- World Wide Fund for Nature, Australia
- World Wildlife Fund (International), USA

ARC Centre of Excellence
Coral Reef Studies

ARC Centre of Excellence for Coral Reef Studies
James Cook University
Townsville
Queensland 4811
AUSTRALIA

Phone: +61 7 4781 4000
Fax: +61 7 4781 6722
Email: *info@coralcoe.org.au*

www.coralcoe.org.au