ARC Centre of Excellence
Coral Reef Studies

ANNUAL REPORT 2012

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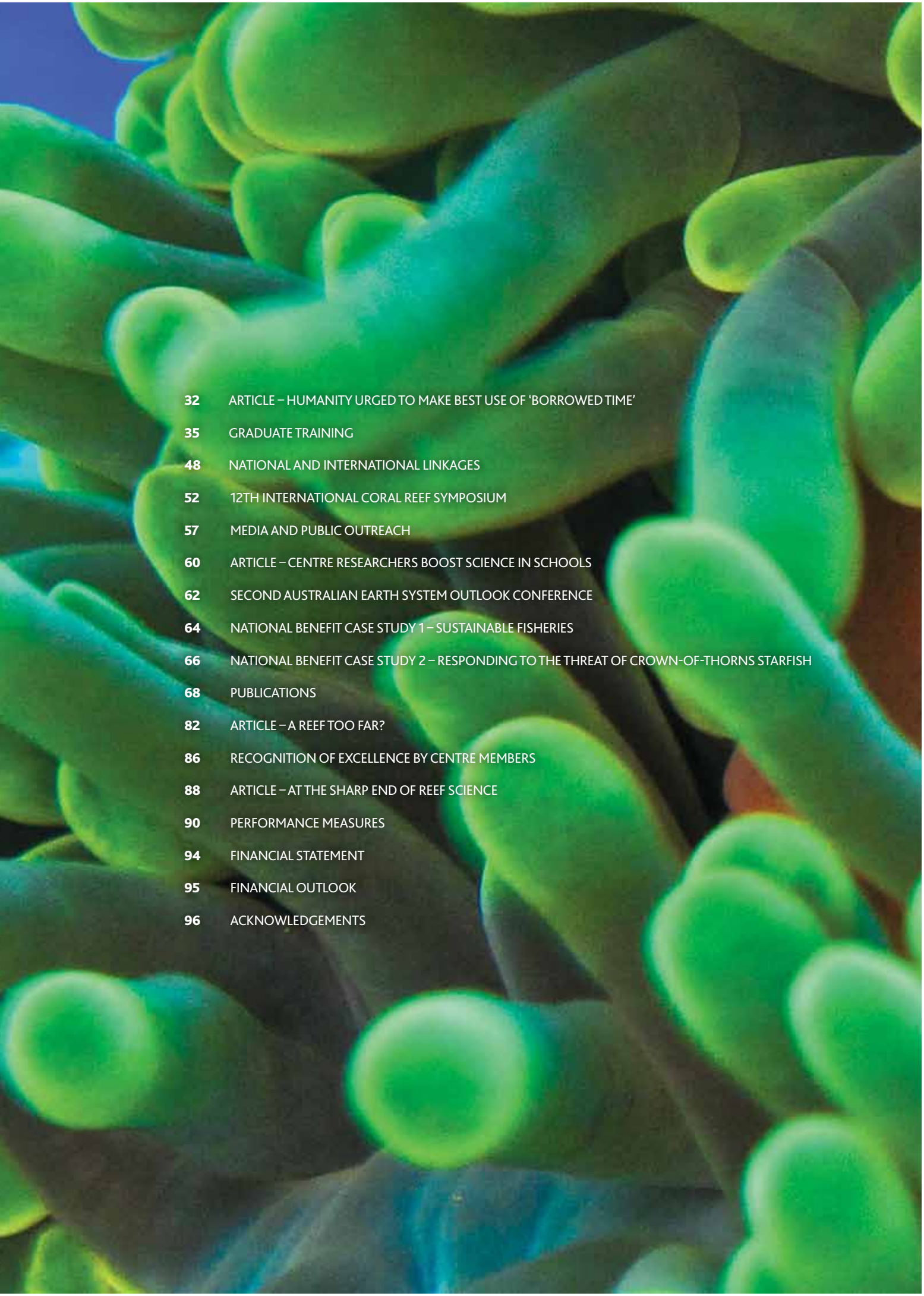


Photo by: Mullica Jaroensutasinee

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 Activites**
   Commercial activities and research contracts undertaken by the ARC Centre extend knowledge transfer, nationally and globally.

OVERVIEW

7. Commercial Activities

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 2012, the Centre has collaborative links to 334 institutions in 56 countries.

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

DIRECTOR'S REPORT

The need for coral reef research has never been greater. Here in Australia, the World Heritage Status of the Great Barrier Reef is now under review by UNESCO, and there is a very real risk that our iconic reef system could be listed soon as "in danger". Overseas, many nations increasingly recognise the importance of coral reefs for the food security and livelihoods they provide to many millions of people, and the global effort to improve how we manage these important natural resources is accelerating. For example, the *Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security* (CTI) is a developing partnership of six countries to the north of Australia: Indonesia, the Philippines, Malaysia, Papua New Guinea, the Solomon Islands and Timor Leste. With the support of donors, NGOs and the international science community, the CTI is aimed at securing sustainable development and improving stewardship of coastal and marine resources in the world's richest biodiversity hotspot (p26, p29). Our Centre's goal is ambitious - to provide and communicate the scientific knowledge that underpins sustainable use of the world's coral reefs.

Our ARC Centre was established in 2005, and since then our research, publications, outreach and training activities have all grown very substantially. This report documents our progress to date. At the end of 2012, the Centre's membership includes 62 Chief Investigators and full-time Research Fellows and 221 postgraduate and Honours students. We were delighted to receive three new Laureate Fellowships in the 2012 round, awarded to Malcolm McCulloch, Ove Hoegh-Guldberg and myself (p87). Along with other new and existing awards, this brings the number of current ARC Fellows in the Centre to 20.

In 2012, as the Centre continues to expand and mature, our fieldwork was undertaken in 25 tropical countries. The Centre's research program summaries on pp18-31 provide many examples of our recent and current activities at home and abroad.

We are now the largest provider of graduate training in coral reef research in the world, and in 2012, our research students came to Australia from 45 countries (p35). The Centre's publication output also continues to grow, with a record 325 publications in 2012 (p68) – almost one per day! Since 2005, we have produced a total of 1,611 publications. Our co-authors this year come from 334 institutions in 56 countries, reflecting an extensive, and growing, collaborative network around the world. We also hosted 104 overseas researchers during the year (p50).

In July this year, after several years of planning, we convened the *12th International Coral Reef Symposium* (ICRS) in Cairns, Queensland. These 4-yearly meetings are the world's largest and premiere forum for the dissemination and discussion of coral reef science and management (p52), and we were proud to host more than 2,100 delegates from 80 countries. One highlight of the Symposium was the brilliant speech by the Governor of Queensland, the Honorable Penny Wensley (*www.govhouse.qld.gov.au/the_governor/120709_coral_spch.aspx*). Another was the launch of an *International Consensus Statement,* endorsed so far by >3200 researchers, calling for government action globally to secure the future of corals reefs in the face of anthropogenic climate change (p56).

The Centre's website is one of the major ways we communicate to a range of audiences around the world. In 2012, it received 14.3 million hits and >450,000 visits. The Centre's press coverage, boosted by the media we organised for ICRS, has also continued to grow rapidly during the past year - well over 7,500 stories featuring our research were published or broadcast around the world over the past year (p57).

We also provided more than 100 briefings, workshops and consultancies during the year to governments, management agencies, Non-Government Organisations and business organisations. Examples include Australian Commonwealth Departments, the Queensland and Western Australian governments, International Union for Conservation of Nature, National Oceanic and Atmospheric Administration, Great Barrier Reef Marine Park Authority, The Nature Conservancy, UNESCO, USAID, and many more. This year's report includes two national benefit case studies that exemplify the uptake and impact of our research (pp66–67).

Lastly, I'd like to express my gratitude to our many other friends around the world for their many contributions to an outstanding year, to the Centre's Advisory Board, and our research partners and end-users (particularly the *Australian Institute of Marine Science*, the *Great Barrier Reef Marine Park Authority, The Nature Conservancy*, the *Center for Ocean Solutions,* the *Stockholm Resilience Center, and WorldFish)*. I am especially grateful to our Centre's talented administrative team – Jenny Lappin, David Yellowlees, Olga Bazaka, Rose-Marie Vasiljuk, Janet Swanson, Eliza Glasson, Andrew Lo-A-Tgong and Hayley Ware - for their enthusiastic support.

Terry Hughes
Director

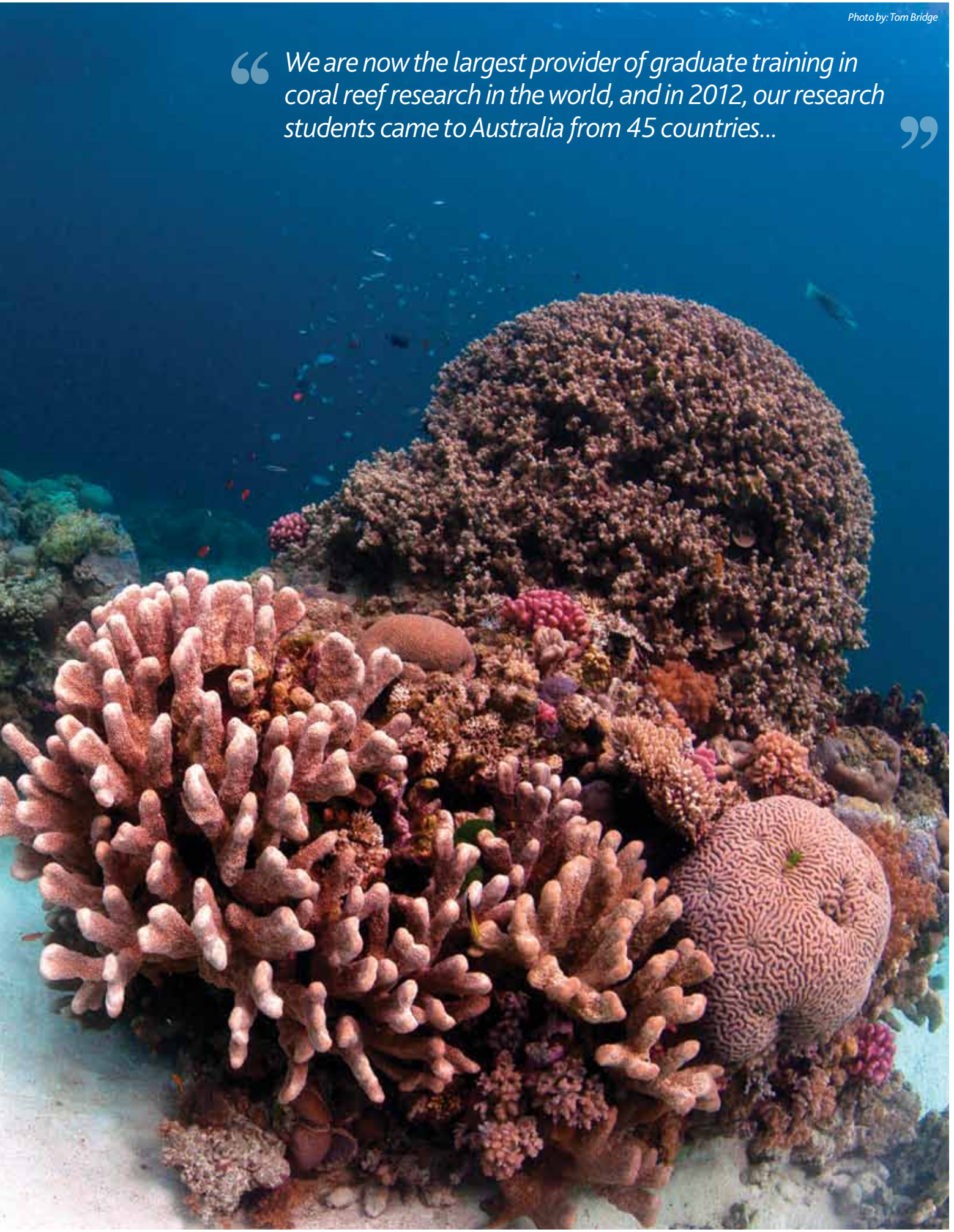


Photo by: Tom Bridge

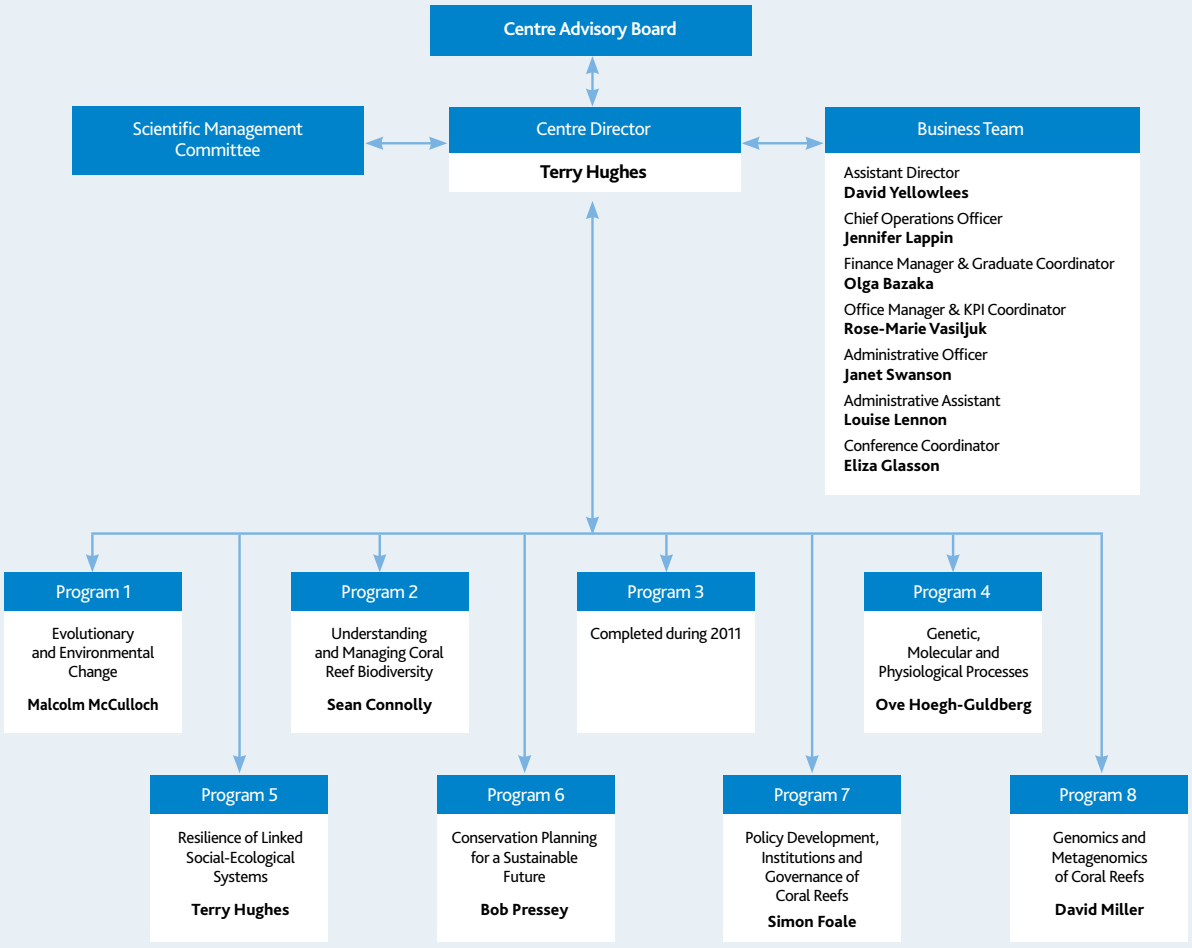
“We are now the largest provider of graduate training in coral reef research in the world, and in 2012, our research students came to Australia from 45 countries...”

GOVERNANCE

The Centre's governance structures are responsive and reflect the Centre's research profile and involve stakeholders in planning and management processes. The chart below illustrates the current governance structure and relationships. In 2012, Program 3 *Marine reserves and connectivity* was discontinued as a Research Program because its research themes are increasingly being considered across all of the Programs of the Centre. In 2013, the governance structure will be revised further with the planned restructuring of Program 5: *Resilience of linked social-ecological systems* and Program 7: *Policy development, institutions and governance of coral reefs*.

James Cook University is the administering organisation for the Centre of Excellence, and the Centre Director, Terry Hughes reports directly to Professor Chris Cocklin, the Senior Deputy Vice-Chancellor with responsibility for the Division of Research and Innovation. Day-to-day operations are managed by the Chief Operations Officer, Jenny Lappin, in consultation with the Centre Director and Assistant Director, Professor David Yellowlees.

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



CENTRE ADVISORY BOARD

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

Membership of the ARC Centre Advisory Board reflects the Centre's strong international linkages and multi-disciplinary research activities. We are privileged to have access to the expertise and experience of these leaders and extend our thanks to them for their advice and support. In 2012, the Board welcomed the new Chief Executive Officer of the Australian Institute of Marine Science, John Gunn. The Board met twice in Townsville in 2012, on 4th April and 3rd December.

The Centre Advisory Board's membership comprises:

Dr Brian Walker (Chair)
CSIRO Ecosystem Sciences

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

Professor Terry Hughes
Director, ARC Centre

John Gunn
Chief Executive Officer, Australian Institute of Marine Science

Andrew Skeat
General Manager, Great Barrier Reef Marine Park Authority

John Tanzer
Director, WWF Global Marine Program, Switzerland

Professor Mandy Thomas
Pro Vice-Chancellor (Research and Graduate Studies), Australian National University, and *Director* – Strategic Research Projects, Creative Industries Faculty, Queensland University of Technology.

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 seven Research Programs, and Dr David Wachenfeld, the Director, Ecosystem Conservation and Sustainable Use at the Great Barrier Reef Marine Park Authority, the Centre's principal end-user in Australia. Priorities for each meeting include reviewing the objectives, impact and funding for the Centre's research programs, developing international collaborations and engagements, recruiting high-quality research fellows, and effectively communicating the Centre's research to government, industry and the broader community. The Committee met formally three times in 2012: on 3rd April and 2nd October in Townsville, and 8th July in Cairns during the *12th International Coral Reef Symposium* (ICRS2012) hosted by the Centre.

In 2012, the Scientific Management Committee focused on research program planning and development, strategic recruitment of research fellows, planning for ICRS2012 (pp52–56) and longer term positioning of the Centre for its business continuity.

Scientific Management Committee Members are:

Professor Yossi Loya (Chair)
The Raynor Chair for Environmental Conservation Research
Tel Aviv University
Israel

Dr David Wachenfeld
Director, Ecosystem Conservation and Sustainable Use
Great Barrier Reef Marine Park Authority

ARC Australian Laureate Fellow Malcolm McCulloch FAA FRS
Leader, Research Program 1
University of Western Australia

ARC Australian Professorial Fellow Sean Connolly
Leader, Research Program 2
James Cook University

ARC Australian Laureate Fellow Ove Hoegh-Guldberg
Leader, Research Program 4
University of Queensland

ARC Australian Laureate Fellow Terry Hughes FAA
Leader, Research Program 5
James Cook University

Distinguished Professor Bob Pressey FAA
Leader, Research Program 6
James Cook University

Dr Simon Foale
Leader, Research Program 7
James Cook University

Professor David Miller
Leader, Research Program 8
James Cook University

MEMBERSHIP

RESEARCHERS

In 2012, the Centre's membership comprised 62 Chief Investigators and Research Fellows, 8 Partner Investigators, 8 resident international scholars and 20 adjunct researchers. This year, 20 of the Centre's research fellows are funded by ARC awards (Federation, Laureate, Future, DECRA and Super Science Fellows, and Discovery and Linkage Grant Fellowships). Four more are Queensland Smart Futures Fellows, one is a Queensland Premier's Fellow and one is a Western Australian Premier's Fellow.

Chief Investigators and Research Fellows

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

Dr Tracy Ainsworth
ARC Super Science Fellow, James Cook University

Dr Glenn Almany
ARC Future Fellow, James Cook University

Dr Jorge Alvarez-Romero
Research Fellow, James Cook University

Dr Amélie Augé
Research Fellow, James Cook University

Dr Andrew Baird
ARC Future Fellow, James Cook University

Dr Natalie Ban
ARC Australian Postdoctoral Fellow, James Cook University

Professor David Bellwood
Chief Investigator, James Cook University

Dr Anthony Bertucci
ARC Super Science Fellow, James Cook University

Dr Pim Bongaerts
Research Fellow, University of Queensland

Dr Mary Bonin
Research Associate, James Cook University

Dr Tom Bridge
Research 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

Dr Juan Pablo D'Olivo Cordero
Research Fellow, University of Western Australia

Assoc Professor Sophie Dove
Chief Investigator, University of Queensland

Dr Simon Dunn
Research Fellow, University of Queensland

Dr Louisa Evans
Research Fellow, James Cook University

Dr Michael Fabinyi
Society in Science Research Fellow, James Cook University

Dr James Falter
Research Fellow, University of Western Australia

Dr Joana Figueiredo
Queensland Smart Futures Fellow, James Cook University

Dr Simon Foale
Research Fellow, James Cook University

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

Dr Ashley Frisch
ARC Super Science Fellow, James Cook University

Dr Mariana Fuentes
ARC Super Science Fellow, James Cook University

Dr Christopher Fulton
Chief Investigator, Australian National University

Dr Nick Graham
ARC Australian Postdoctoral Fellow, James Cook University

Dr Alana Grech
Research Fellow, James Cook University

Dr Alistair Harborne
Discovery Early Career Researcher Award, University of Queensland

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

Dr Andrew Hoey
Research Fellow, James Cook University

Dr Michael Holcomb
ARC Super Science Fellow, University of Western Australia

Professor Geoffrey Jones
Chief Investigator, James Cook University

Dr Sally Keith
Research Fellow, James Cook University

Professor Michael Kingsford
Chief Investigator, James Cook University

Dr Bill Leggat
Chief Investigator, James Cook University

Dr Vimoksalehi Lukoschek
Queensland Smart Futures Fellow, James Cook University

Dr Mark McCormick
Chief Investigator, James Cook University

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

Dr Vanessa Messmer
Research Fellow, James Cook University

Professor David Miller
Chief Investigator, James Cook University

Professor Peter Mumby
ARC 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

Professor Morgan Pratchett
Queensland Smart Futures Fellow, James Cook University

Professor Bob Pressey
Research Fellow, James Cook University

Dr Jairo Rivera Posada
Research Fellow, James Cook University and Australian Institute of Marine Science

Dr Jodie Rummer
ARC Super Science Fellow, James Cook University

Professor Garry Russ
Chief Investigator, James Cook University

Dr Eugenia Sampayo
Research Fellow, University of Queensland

Dr Susanne Sprungala
Research Associate, James Cook University

Dr Ruth Thurstan
Research Fellow, University of Queensland

Dr Linda Tonk
Research Fellow, University of Queensland

Dr Stefan Walker
Research Fellow, James Cook University

Dr 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
ARC Super Science Fellow, University of Western Australia

Resident International Scholars

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

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

Professor Bruno Lapeyre
Professor, Centre National de la Recherche Scientifique, France

Dr David Mills
Senior Research Fellow, WorldFish, Malaysia

Dr Benjamin Mason
National Science Foundation International Research Fellow, USA

Professor David Mouillot
Marie Curie Fellow, Montpellier University, France

Dr Aurélie Moya
Marie Curie Fellow, Centre National de la Recherche Scientifique, France

Dr Mathieu Pernice
Marie Curie Fellow, Université Pierre et Marie Curie, France

Partner Investigators and Adjunct Researchers

Dr Vanessa Adams
Charles Darwin University

Professor Serge Andréfouët
Institut de Recherche pour le Développement, New Caledonia

Professor Eldon Ball
Australian National University

Dr Line Bay
Australian Institute of Marine Science

Professor Linda Blackall
Swinburne University of Technology

Dr Guillermo Diaz-Pulido
Griffith University

Dr Leanne Fernandes
Earth to Ocean Consultants

Professor Carl Folke
Stockholm University, Sweden

Dr Sylvain Forêt
Australian National University

Dr Alison Green
The Nature Conservancy

Dr Richard Hamilton
The Nature Conservancy

Professor Ronald Karlson
University of Delaware, USA

Dr Alexander Kerr
University of Guam, USA

Maurice Knight
World Wildlife Fund, Indonesia

Professor Janice Lough
Australian Institute of Marine Science

Professor Yossi Loya
Tel Aviv University, Israel

Dr Tim McClanahan
Wildlife Conservation Society, Kenya

Dr Laurence McCook
Great Barrier Reef Marine Park Authority

Dr Mark Meekan
Australian Institute of Marine Science

Dr Serge Planes
University of Perpignan, France

Professor Robert Steneck
University of Maine, USA

Dr Shunichi Takahashi
Australian National University

Professor John Tanzer
World Wildlife Fund, Switzerland

Professor Madeleine van Oppen
Australian Institute of Marine Science

Dr David Wachenfeld
Great Barrier Reef Marine Park Authority

GRADUATE STUDENTS (SEE PAGE 35)

RESEARCH SUPPORT STAFF

Lewis Anderson
James Cook University

Giovanni Bernal Carrillo
University of Queensland

Andrea Biondo
University of Western Australia

Aaron Chai
University of Queensland

Dr Vivian Cumbo
James Cook University

Maria Gomez-Cabrera
University of Queensland

Mizue Hisano
James Cook University

Cindy Huchery
James Cook University

Mirjam Maughan
James Cook University

Kai Rankenburg
University of Western Australia

Sophie Rankenburg
University of Western Australia

Dr Maya Srinivasan
James Cook University

Annamieke 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

Professor 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
Project 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 >60 publications in leading international journals, including five 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 in 2009 was awarded the *Fenner Medal* of the Australian Academy of Science, 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 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) and in 2012 he was awarded an ARC Australian Laureate Fellowship.

Professor Terry Hughes

Professor Terry Hughes is the Director of the ARC Centre of Excellence and Leader of *Program 5: Resilience of linked social-ecological systems*. He received his PhD in 1984 from Johns Hopkins University in Baltimore, USA and was an NSF Postdoctoral Fellow at the University of California, Santa Barbara before moving to Australia and James Cook University in 1990. Terry was elected a Fellow of the Australian Academy of Science in 2001 in recognition of "a career which has significantly advanced the world's store of scientific knowledge". In 2008, he was awarded the prestigious quadrennial *Darwin Medal* by the International Society for Reef Studies. 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*. 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*. In 2012, Terry was the Convenor of the *12th International Coral Reef Symposium* which attracted 2,100 delegates from 81 countries. He has been awarded three Federation/Laureate Fellowships by the Australian Research Council, from 2002-2017, and is a Fellow of the *Beijer Institute for Ecological Economics,* in Stockholm.

Professor Malcolm McCulloch

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

Professor David Miller

Professor David Miller is Leader of Program 8: *Genomics and metagenomics of coral reefs*. David studies the molecular biology of corals and other "simple" marine animals. His research interests span a broad range of topics from marine biology to genomics, and include the biochemistry and molecular biology of coral symbioses, the evolution of developmental mechanisms ("evo-devo"), immune system evolution, and the molecular bases of coral responses to stressors such as disease, ocean acidification and climate change. David obtained his PhD in genetics and biochemistry from the University of Kent (UK). He subsequently undertook post-doctoral research at the University of Bristol (UK) and then the University of Adelaide. David moved to James Cook University in 1984 and is currently a Professor in molecular genetics and genomics. David's main claim to fame is the discovery that "simple" animals such as corals have genomes as complex as those of man and other vertebrates, and his discoveries 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 T*he 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. In 2010 he was elected as a Fellow of the Australian Academy of Science, for his contributions to the field of systematic conservation planning. His understanding of conservation applications was recognised in 2012 by his appointment to the WWF Australia's Eminent Scientists Group. Bob is leading research projects in the Asia-Pacific region, from the Philippines to Fiji, and further afield in Brazil, Costa Rica, Ecuador and Mexico.

BUSINESS LEADERS

Jennifer Lappin

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

Professor David Yellowlees

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

RESEARCHER PROFILE
PROFESSOR BETTE WILLIS

Bette has been a Chief Investigator in the ARC Centre since its inception in 2005. She began her tertiary education in Ontario, Canada (500 miles from the ocean) and her introduction to marine biology was of the temperate kind. With her degree in hand and dreaming of coral reefs, she misguidedly took a job trudging across the frozen wilds of Ontario measuring water quality. Presciently, she moved to Australia where she taught science in Victoria before achieving her dream and enrolling in a PhD at James Cook University. In those heady years as a postgraduate student, Bette was part of the group that discovered the synchronous spawning of corals on the Great Barrier Reef. This was a landmark discovery, which resulted in Bette and four of her colleagues being awarded the ***Pol Eureka Prize for Environmental Science*** in 1992.

Bette's passion for the past 30 years has been coral reef science, and she addresses some of the most fundamental questions in coral biology and ecology. In particular, her research has focused on the processes that underpin the capacity of corals to respond to environmental change.

Her pioneering efforts in the field of coral disease ecology on the Great Barrier Reef have made significant contributions to the study of this growing worldwide problem. Among her achievements was her role as co-chair of the Coral Disease working group funded by the Global Environment Facility Coral Reef Targeted Research Program. From her initial, ecologically-focused studies, Bette has taken research in this field into new cellular, microbiological and molecular areas. She says, "Currently, my major efforts are to determine the ecological significance and climate drivers of coral disease, and how microbial symbioses affect coral health". As part of this focus, her group is investigating innate immunity in corals and its influence on disease resistance. Bette has also taken time to collaborate with others to develop a guide to coral diseases, and has led workshops to educate coral scientists worldwide on coral disease.

Recently, Bette has been exploring the relationships between corals and their unicellular partners. This focus has encompassed a range of novel and important questions. For instance, her group was the first to demonstrate that flexibility in coral–*Symbiodinium* partnerships can significantly alter the physiology and health of corals. This research has expanded to include other microbial partners, and to explore interactions between algal symbionts and bacteria.

Many coral reef scientists owe their research career to Bette. So far, she has supervised over 100 postgraduate students – an extraordinary effort by anyone's standards. Reflecting her ongoing commitment to students, she commented that "their work has been integral to the success of my research programs".

Bette comments that, "I am acutely aware of the need to provide science that underpins the sustainable management of coral reefs. It's a key responsibility for researchers who work on this important ecosystem". Whether she is researching larval dispersal and recruitment of corals or the role of marine protected areas in ameliorating coral disease, over the past 30 years Bette has made a major contribution to the sustainability of the Great Barrier Reef and reefs worldwide. Her research today is much more satisfying than collecting water samples 45° north of the equator.

RESEARCH FELLOW

PROFILE

DR ALANA GRECH

Alana was awarded an undergraduate degree in Environmental Science from the University of Adelaide, and a PhD from James Cook University in 2010. Her keen interest in applied research in northern Australia led to her taking up a Postdoctoral Fellowship in Program 6: ***Conservation planning for a sustainable future*** at the ARC Centre in Townsville. In collaboration with Professors Bob Pressey and Helene Marsh, she is developing new approaches to inform systematic conservation planning in the Land and Sea Country of Indigenous Australians.

Alana's research blends traditional and local knowledge with the latest science to inform the management of coastal and marine resources, such as coral reefs, seagrasses, mangroves, dugongs, marine turtles and coastal dolphins. Her research takes her to some of the remotest parts of northern Australia, including the Cape York Peninsula, Northern Territory and Torres Strait. There she has worked on a variety of projects, including traditional knowledge mapping with the Yanyuwa People in the Gulf of Carpentaria, and collaborations with Indigenous ranger groups in Arnhem Land and Torres Strait (see picture of Alana on Mabuiag Island, Torres Strait).

Alana's postdoctoral fellowship has enabled her to develop a novel approach for risk assessments that incorporates the knowledge of Aboriginal and Torres Strait Islanders. Applying this approach in the Torres Strait, she discovered that the biggest threats to the environment were driven by coastal development and shipping. Alana said that this conclusion might not have been reached but for her novel approach. "Most expert-based risk assessments are limited to recording the knowledge of scientists because of social and linguistic barriers that exclude traditional knowledge" she said. "Our approach has enabled a much better understanding of the major impacts to coastal and marine resources, because we have been able to capture the knowledge of local people as well as scientists".

Alana's passion is the transfer of her research findings to management action and policy. According to Alana, "Managers of coastal and marine resources are routinely asked to decide quickly and in an uncertain environment". Her aim is to deliver the information that managers need to make good decisions in the face of this uncertainty. Alana achieves this by combining risk-based approaches with computer mapping and modelling. "My research focuses on two questions - how sensitive are coastal and marine resources to threats, and where are the threats located? With this information, managers can identify and prioritise 'hot spots' for action".

Alana's desire to improve management of natural resources has driven her to establish multiple partnerships that deliver the outputs of her research directly to end-users. Alana has a close working relationship with the Torres Strait Regional Authority and the Great Barrier Reef Marine Park Authority. She provides regular briefings to them and other agencies and she has convened several workshops with stakeholders, including an international workshop in New Zealand on conservation by Indigenous and Traditional communities.

In 2012, Alana was awarded a Churchill Fellowship from the Winston Churchill Memorial Trust to explore the conservation of Australia's Indigenous Heritage Places. The Trust provided funding for Alana to undertake a one month fellowship at the International Centre for the Study of the Preservation and Restoration of Cultural Property, in Rome. According to Alana, her fellowship "has been a fantastic opportunity to learn about the conservation of international heritage sites, and to find new approaches to conserve Australia's Indigenous natural and cultural heritage. The Italian coffee is a bonus".

GRADUATE
PROFILE
DR TOM BRIDGE AND DR PIM BONGAERTS

Tom and Pim's research focuses on mesophotic coral ecosystems – deep-water coral reef communities that occur below regular diving depths. Prior to them commencing their PhDs in 2007, virtually nothing was known about corals occurring in deeper waters on the Great Barrier Reef, and many of the reefs they have recently studied were totally unknown. Focusing on complementary research topics, they have forged a successful collaboration that has helped to raise awareness of a vast but previously unexplored habitat in the Great Barrier Reef World Heritage Area. Although Tom is based at JCU and Pim at UQ, the connection between the two universities engendered by the ARC Centre has enabled a long-term collaboration between the two researchers.

Pim's PhD research focussed on the "deep reef refugia hypothesis", using a range of molecular tools to address the connectivity between shallow and mesophotic reef communities, while Tom's PhD looked at the location, extent and biodiversity of mesophotic coral reefs. Their partnership began shortly before Tom embarked on a major research cruise aboard the RV *Southern Surveyor*, Australia's Marine National Facility. One of the major obstacles to successful mesophotic research is that these habitats occur in deep water, often far from shore, making collection of samples difficult. Having previously only worked on deep reefs in the Caribbean, Pim approached Tom and requested genetic samples of any corals he might collect from deep water. The trip was a great success, with corals collected from depths up to 100 metres. Tom and Pim have co-authored two papers from this research cruise, one documenting coral diversity on mesophotic reefs of the Great Barrier Reef, and another describing the *Symbiodinium* associated with these deep-water corals.

Spurred by this fruitful collaboration, Pim and Tom began applying together for several early career grants to support further research trips. In 2009, while still working on their PhDs, they were awarded a grant from Australian Geographic to document mesophotic coral ecosystems in the Coral Sea. This expedition was conducted in October 2010, and utilised both SCUBA diving and Remotely Operated Vehicles to study Holmes Reef to depths of 150 metres. This was followed by another trip the following year to the Far Northern Great Barrier Reef. Data collected on these expeditions are still being analysed, and already these expeditions have uncovered several coral species not previously known from Australia.

Tom and Pim are now post-doctoral fellows at the ARC Centre of Excellence for Coral Reef Studies, continuing their research on deep coral reefs and submerged shoals in tropical Australia and other parts of the Indo-Pacific. Pim is leading the Deep Reef component of the Catlin Seaview Survey, which constitutes one of the most extensive studies ever undertaken on mesophotic reefs. Through a continued collaboration, their results will provide new insights into these vast but little-known deep-water habitats. Pim and Tom's research has already led to increasing awareness of the extensive coral reef habitat that exists beyond shallow waters, and the remarkable biodiversity occurring there. Their research has been featured in national and international popular science magazines and has received national radio and television coverage. It has also been welcomed by management agencies such as the Great Barrier Reef Marine Park Authority and the Department of Sustainability, Environment, Water, Population and Communities.

Both Tom and Pim began researching mesophotic coral reefs because of a desire to explore. "I used to love reading accounts of Victorian-era naturalists like Alfred Wallace, who spent years exploring and documenting the immense biodiversity of the tropics," says Tom, "Exploring mesophotic reefs gives you a similar sense of adventure – of going where no-one has gone before". However, their work is equally important for conservation of the world's coral reefs. Deep reefs may be less susceptible to climate-change related impacts, such as coral bleaching and storms, and may therefore provide vital refuges for corals and other reef species to survive in coming decades. Through their research, they hope to assist marine managers to devise strategies that can mitigate the damaging effects of climate change on coral reefs.

RESEARCH

PROGRAM 1: EVOLUTIONARY AND ENVIRONMENTAL CHANGE

Researchers

Malcolm McCulloch *Program Leader*
David Bellwood
Sean Connolly *Research Fellow*
Juan Pablo D'Olivo Cordero *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
Eugenia Sampayo *Research Fellow*
Robert Steneck
Ruth Thurstan *Research Fellow*
Zhenlin Zhang *Research Fellow*

Knowledge of the past improves our ability to predict future influences of natural environmental variability, human impacts, and climate change on coral reefs. Together with our ecological studies, Program 1 provides the Centre with a unique perspective on community change that ranges from centuries to millennia. This group also applies cutting-edge isotope technologies to use banded coral skeletons as proxies for paleoclimates and human impacts in Australia and overseas. This innovative approach enables understanding of global climate changes, rainfall variability and drought, and long-term trajectories of nutrient and sediment discharge onto coastal reefs. A further focus of Program 1 is revealing the history of human-coral reef interaction using the fossil record, archeology, historical records and modern ecological data.

In a global overview of reef fish evolution published this year in the ***Journal of Biogeography***, PhD student Peter Cowman and David Bellwood reveal the history of the world's global biodiversity hotspot in the Coral Triangle, highlighting its evolution as a location where species accumulate, originate and then disperse. Sean Connolly, John Pandolfi and colleagues, in a paper published in *The American Naturalist*, used fossil reef communities to test a prominent theory of biodiversity that had been proposed as a basis for reef conservation and management. They demonstrated that the theory fails to explain the dynamics of those communities, and they identified critical differences in the functional roles of different coral species, which the theory assumes are unimportant, as key drivers of reef dynamics.

Growing levels of CO_2 are causing a decline in the pH of seawater, and hence the carbonate saturation state of the ocean's surface, a process commonly described as "ocean acidification". This is of major concern because decreasing concentrations of carbonate ion have the potential to cause major disruptions to the process of calcification, key to the survival and functionality of scleractinian corals, as well as to other calcifiers, such as crustose coralline algae, foraminifera and other blue-water calcifiers.

In a major step-forward, Program Leader Malcolm McCulloch and colleagues have shown that it is now possible to predict how ocean temperature and pH, the key components of climate change, control the rates of coral calcification. The key finding of this work, published in *Nature Climate Change*, shows that corals have the ability to regulate the pH of the calcifying fluid from which their coral skeleton is precipitated and therefore control the carbonate saturation state within the coral. As a consequence, the effects of declining carbonate saturation state of seawater are generally smaller than previously expected. This new research also provides a coherent explanation for what had previously been considered as 'anomalous' low sensitivity responses shown by many coral species, to experimental manipulations that mimic ocean acidification. However, this work also shows that pH regulation of the calcifying environment is not ubiquitous among all calcifiers and many remain vulnerable to future levels of acidification.

In a related study, PhD student Neil Chan and Sean Connolly, in a paper in *Global Change Biology*, conducted a "meta-analysis" of published estimates of the effect of acidification on coral calcification. They found that corals are more resilient to ocean acidification than predicted by some recent, high-profile projections of reef futures, suggesting that, if action is taken soon to curb greenhouse gases, there is still the capacity for reefs to remain dominated by corals.

PhD student George Roff, John Pandolfi and their colleagues published a novel study in *Proceedings of the Royal Society* on the longterm history of corals in Queensland before and after European colonisation. They used cores taken through a nearshore reef on the Great Barrier Reef to show that a healthy community of branching ***Acropora*** corals flourished for centuries before European settlement, despite a long history of frequent floods and cyclone events. Then, between 1920 and 1955, the branching ***Acropora*** disappeared. The destruction of branching corals coincided with wide-spread land clearing for grazing and agriculture which took place in the nearby Burdekin River catchment in the late 19th Century, causing an increase in the release of mud and nutrients into the GBR lagoon. Significantly, the study found no similar collapse at any time in the previous 1,700 years. This research underlines the very strong link between what we do on land and what happens to the Great Barrier Reef.

Corals 'could survive a more acidic ocean'

Corals may be better placed to cope with the gradual acidification of the world's oceans than previously thought – giving rise to hopes that coral reefs might escape climatic devastation.

In new research published in the journal Nature Climate Change, an international scientific team has identified a powerful internal mechanism that could enable some corals and their symbiotic algae to counter the adverse impact of a more acidic ocean.

As humans release ever-larger amounts of carbon dioxide into the atmosphere, besides warming the planet, the gas is also turning the world's oceans more acidic – at rates thought to far exceed those seen during past major extinctions of life. This has prompted strong scientific interest in finding out which species are most vulnerable, and which can handle the changed conditions.

In ground breaking research, a team of scientists from Australia's ARC Centre of Excellence for Coral Reef Studies (CoECRS), at the University of Western Australia (UWA) and France's Laboratoire des Sciences du Climat et de l'Environment, has shown that some marine organisms that form calcium carbonate skeletons have an in-built mechanism to cope with ocean acidification – which others appear to lack.

"The good news is that most corals appear to have this internal ability to buffer rising acidity of seawater and still form good, solid skeletons," says Professor Malcolm McCulloch of CoECRS and UWA. "Marine organisms that form calcium carbonate skeletons generally produce it in one of two forms, known as aragonite and calcite."

"Our research broadly suggests that those with skeletons made of aragonite have the coping mechanism – while those that follow the calcite pathway generally do less well under more acidic conditions."

Also of concern is that a large class of plankton, floating in the open oceans and forming a vital component of marine food webs, appears equally vulnerable to acidification. If so, this could be serious not only for marine life that feeds on them – but also for humans, as it could impair the oceans' ability to soak up increased volumes of CO_2 from the atmosphere. This would cause global warming to accelerate.

The researchers conclude "Although our results indicate that up-regulation of pH at the site of calcification provides corals with enhanced resilience to the effects of ocean acidification, the overall health of coral reef systems is still largely dependent on the compounding effects of increasing thermal stress from global warming and local environmental impacts, such as terrestrial runoff, pollution and overfishing."

McCulloch M, Falter J, Trotter J, Montagna P (2012). Coral resilience to ocean acidification and global warming through pH up-regulation. *Nature Climate Change* 2:623-627.

Photo by: Neil Chan

RESEARCH

PROGRAM 2: UNDERSTANDING AND MANAGING CORAL REEF BIODIVERSITY

Researchers

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

Program 2 aims to understand the mechanisms and processes that maintain coral reef biodiversity, using a combination of mathematical modelling, fieldwork, and laboratory studies. This multi-disciplinary Program informs knowledge-based management of biodiversity, resulting in environmental, social, and economic benefits to tropical maritime nations. Coral reef biodiversity underpins the critically important functions and services performed by reef ecosystems, such as sustaining the productivity of fish stocks on which many tropical nations depend for their food security and future development.

Program 2 researchers made several key breakthroughs in 2012 in our understanding of how marine reserves benefit fisheries. In a paper in *Current Biology*, Hugo Harrison and colleagues demonstrated for the first time that no-take areas ("Green Zones") on the Great Barrier Reef provide benefits to fisheries as well as achieving conservation goals. Adult fishes in no-take (green) zones contribute almost half of the juvenile coral trout and stripey snapper that became established in fished areas. Another fishery benefit of reserves was uncovered by PhD student, Fraser Januchowski-Hartley, working with ARC Centre researchers Nick Graham, Garry Russ, and Joshua Cinner. Writing in *Ecology Letters*, they showed that fish inside marine reserves are less fearful of spearfishers, making them easier to catch when they wander into nearby fished zones.

Climate change research is another major focus of Program 2. For example, in a ground-breaking paper in *Nature Climate Change*, Jennifer Donelson, Philip Munday, and Mark McCormick showed that some reef fish have a far greater capacity to adjust to ocean warming than previously thought, via a process called "trans-generational acclimation". In a subsequent paper, Gabrielle Miller and Sue-Ann Watson joined members of the original team to show that similar effects may mitigate the impacts of ocean acidification on juvenile reef fishes. In a paper in the journal ***Coral Reefs***, Andrew Baird and colleagues documented, for the first time that reef-building corals are extending south along the Australian coastline in response to warmer seawater.

2012 also saw some key breakthroughs in our understanding of herbivory and the interaction between seaweeds and corals. In the journal ***Ecology***, PhD student Loic Thibaut and Program Leader Sean Connolly show that high biodiversity of herbivores makes reefs less vulnerable to dips in herbivory associated with environmental fluctuations. In a related study, David Bellwood, Andrew Hoey, and Terry Hughes, in the *Proceedings of the Royal Society*, revealed that the herbivorous role played by parrotfishes is particularly critical yet vulnerable to increasing exploitation. An article in *Trends in Ecology and Evolution* by George Roff and Peter Mumby found that seaweeds bloom four times faster on reefs in the Atlantic Ocean, potentially making these reefs less resilient than reefs in the Pacific and Indian Oceans.

Researchers in Program 2 also made numerous important contributions in 2012 to coral reef policy issues at State, Commonwealth, and international levels. For example, Morgan Pratchett has led capacity-building workshops in Pacific Island nations to develop strategies for fishery and aquaculture industries to adapt to climate change. Glenn Almany's research in Papua New Guinea informed the design of a "Ridges to Reefs" conservation plan and a new Ecosystem Approach to Fisheries Management plan for Manus Province. Nick Graham assessed the US Navy's recreational fishery in the Chagos Archipelago for the British Indian Ocean Territory administration; an assessment currently being used to develop better ways of regulating this fishery. Andrew Baird advised the Acehenese Provincial Government on the design of a reef monitoring program in the Indonesian Province of Aceh. Philip Munday led the tropical fishes chapter for the 2012 Marine Climate Change Impacts and Adaptation Report Card for Australia.

Program 2 researchers received several awards and honours during 2012. Andrew Hoey, Vimoksalehi Lukoschek, and Nick Graham were awarded ARC Discovery Early Career Researcher Awards, and John Pandolfi received a Discovery Outstanding Researcher Award, from the ARC. Joana Figueiredo commenced a Queensland Smart Futures Fellowship, and also received a short-term Fellowship from the Japan Society for the Promotion of Science to work at the University of Ryukyus. Morgan Pratchett undertook an Australian Commonwealth Titular Fellowship to Oxford University, and was elected a Fellow of the Linnean Society of London, and the London Zoological Society. Nick Graham was recognised as The Young Tall Poppy of the year for Queensland.

Coral reef winners and losers in a warmer world

There are winners and losers among corals under the accumulating impacts of climate change, according to a new scientific study.

In the world's first large-scale investigation of how climate affects the composition of coral reefs, an international team of marine scientists concludes that the picture is far more complicated than previously thought – but that total reef losses due to climate change are unlikely.

"Coral reefs are sometimes regarded as canaries in the global climate coal mine – but it is now very clear than not all reef species will be affected equally," explains lead author Professor Terry Hughes, director of the ARC Centre of Excellence for Coral Reef Studies at James Cook University.

The emerging picture, he says, is one of 'winners and losers', with some corals succeeding at the expense of others. Rather than experiencing wholesale destruction, many coral reefs will survive climate change by changing the mix of coral species as the ocean warms and becomes more acidic.

This in turn has implications for humans, who rely on the rich and beautiful coral reefs of today for food, tourism and other livelihoods.

The research team carried out detailed studies of the coral composition of reefs along the entire length of Australia's Great Barrier Reef. They identified and measured a total of 35,428 coral colonies on 33 reefs from north to south. They found that as one species decreases in abundance, another tends to increase, and that species wax and wane largely independently of each other.

"Previous studies around the world have focused on total coral cover as the main indicator of reef health, but we wanted to explore what happens within the coral assemblage itself. The way these individual species are mixed together is extraordinarily flexible," Professor Hughes explains.

The good news from the research, says Professor Hughes, is that complete reef wipe-outs appear unlikely due to temperature and pH alone. "However, in many parts of the world, coral reefs are also threatened by much more local impacts, especially by pollution and over-fishing. We need to address all of the threats, including climate change, to give coral reefs a fighting chance for the future."

Hughes TP, Baird AH, Dinsdale EA, Moltschaniwskyj NA, Pratchett MS, Tanner JE, Willis BL (2012). Assembly rules of reef corals are flexible along a steep climatic gradient. *Current Biology* 22:736-741.

Photo by: Neil Chan

RESEARCH
PROGRAM 4: GENETIC, MOLECULAR AND PHYSIOLOGICAL PROCESSES

Researchers

Ove Hoegh-Guldberg *Program Leader*
Tracy Ainsworth *Research Fellow*
Pim Bongaerts *Research Fellow*
Sophie Dove
Simon Dunn *Research Fellow*
Bill Leggat
David Miller
Philip Munday *Research Fellow*
Mathieu Pernice *Visiting Research Fellow*
Jodie Rummer *Research Fellow*
Linda Tonk *Research Fellow*
Madeleine van Oppen
Bette Willis
David Yellowlees

Coral reefs are a prominent feature of tropical coastal ecosystems and are dominated by reef-building corals that form symbioses with microalgae, sponges, bacteria and a wide range of other organisms. Program 4 focuses on the processes that underpin these intimate interactions at genetic, molecular and physiological levels of analysis, and in particular, how they are influenced by the rapid environmental changes that are now occurring within tropical coastal waters worldwide. Many of the researchers in Program 4 pursue questions associated with the tolerance of these crucial organisms to global changes in ocean temperature, pH and the partial pressure of CO_2. When integrated with the Centre's ecological programs, these studies provide a detailed understanding of how anthropogenic climate change and ocean acidification are likely to impact coral reef ecosystems.

ARC Future Fellow Madeleine van Oppen continues to work on the critical issue of adaptation in reef-building corals and whether or not evolutionary processes can keep pace with the current rapid rate of climate change. Her work was published in several major journals in 2012, with key contributions on how coral thermal tolerance can be shaped by the local adaptation of photosymbionts within the coral's tissue. Madeleine and collaborators also established the first frozen repository for Great Barrier Reef corals as part of a project aimed at exploring their cryopreservation. Sperm cells from two species of *Acropora* were successfully cryopreserved and, after thawing, samples were used to fertilise eggs resulting in functioning larvae.

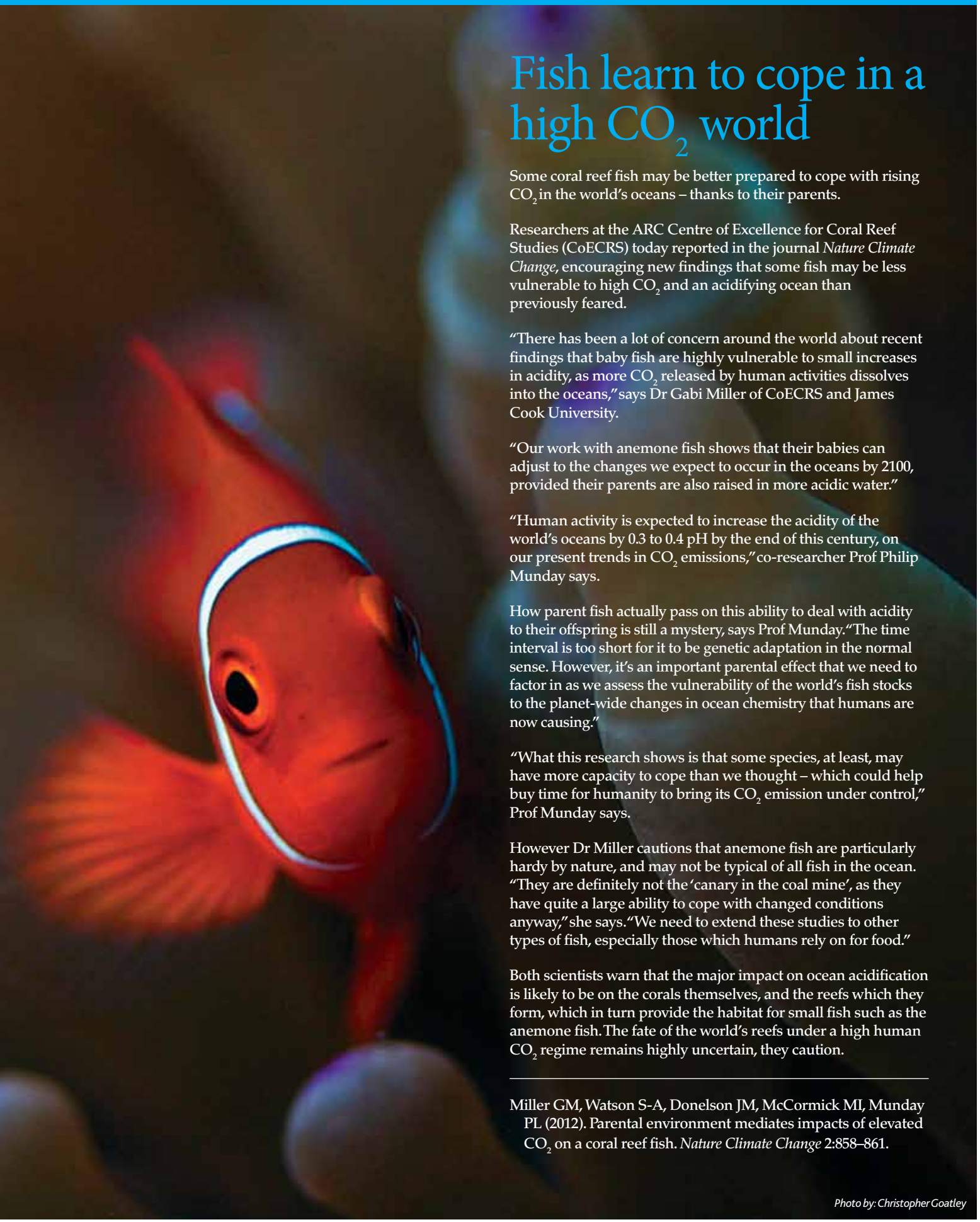
Throughout 2012, Sophie Dove led a research team that has completed a future climate change scenario experiment at Heron Island Research Station. These new facilities are able to establish different ocean warming and acidification scenarios predicted by the IPCC and allow investigation of how these altered conditions affect small replicated patch reef communities. Each mesocosm holds a 'snapshot' of the fore-reef community and the experimental procedure incorporates diurnal and seasonal variability, actively recreated by the computer control system. This novel experimental infrastructure has enabled postdoctoral researchers and students to explore how altered conditions are likely to affect a range of organisms (e.g. corals, algae, bacterial communities) as well as processes such as primary production and calcification.

Understanding the complex interrelationships between corals and microbial associates has also been the focus of Bette Willis and colleagues. Breakdown of these complex relationships appear to underpin outbreaks of coral disease. Bette and her team have continued to focus on responses by coral to rapid changes in sea temperature and water quality. Bette and her colleagues at the Great Barrier Reef Marine Park Authority have published in *Environmental Management* a framework on how these types of studies are important for adaptive management of coral disease outbreaks.

Postdoctoral Fellow Linda Tonk is finalising the database and archive, SymbioGBR, which is a web-based application for host-symbiont associations on the Great Barrier Reef. The web-based database will provide an important resource for both Australian and international research groups interested in understanding the patterns and behaviour of *Symbiodinium* across large reef systems like the Great Barrier Reef.

David Miller and his group made progress in understanding the molecular basis of several fundamental biochemical processes in corals. For instance, they reported in *PLOS One* the discovery of a signaling protein, acrocalcin, which potentially mediates calcium-dependent processes during the development of *Acropora millepora*.

The response of corals to stress has been a cross-nodal focus involving Tracy Ainsworth, Bill Leggat and Simon Dunn. Tracy is focussing largely on bacterial associations with corals. Bill is using a combination of transcriptomics along with parallel analysis using proteomics and metabolomics. Meanwhile, Simon Dunn reported that thermal stress promotes the degradation of the host mitochondria, bringing into question how energy is generated in the coral during bleaching.



Fish learn to cope in a high CO_2 world

Some coral reef fish may be better prepared to cope with rising CO_2 in the world's oceans – thanks to their parents.

Researchers at the ARC Centre of Excellence for Coral Reef Studies (CoECRS) today reported in the journal *Nature Climate Change*, encouraging new findings that some fish may be less vulnerable to high CO_2 and an acidifying ocean than previously feared.

"There has been a lot of concern around the world about recent findings that baby fish are highly vulnerable to small increases in acidity, as more CO_2 released by human activities dissolves into the oceans," says Dr Gabi Miller of CoECRS and James Cook University.

"Our work with anemone fish shows that their babies can adjust to the changes we expect to occur in the oceans by 2100, provided their parents are also raised in more acidic water."

"Human activity is expected to increase the acidity of the world's oceans by 0.3 to 0.4 pH by the end of this century, on our present trends in CO_2 emissions," co-researcher Prof Philip Munday says.

How parent fish actually pass on this ability to deal with acidity to their offspring is still a mystery, says Prof Munday. "The time interval is too short for it to be genetic adaptation in the normal sense. However, it's an important parental effect that we need to factor in as we assess the vulnerability of the world's fish stocks to the planet-wide changes in ocean chemistry that humans are now causing."

"What this research shows is that some species, at least, may have more capacity to cope than we thought – which could help buy time for humanity to bring its CO_2 emission under control," Prof Munday says.

However Dr Miller cautions that anemone fish are particularly hardy by nature, and may not be typical of all fish in the ocean. "They are definitely not the 'canary in the coal mine', as they have quite a large ability to cope with changed conditions anyway," she says. "We need to extend these studies to other types of fish, especially those which humans rely on for food."

Both scientists warn that the major impact on ocean acidification is likely to be on the corals themselves, and the reefs which they form, which in turn provide the habitat for small fish such as the anemone fish. The fate of the world's reefs under a high human CO_2 regime remains highly uncertain, they caution.

Miller GM, Watson S-A, Donelson JM, McCormick MI, Munday PL (2012). Parental environment mediates impacts of elevated CO_2 on a coral reef fish. *Nature Climate Change* 2:858–861.

Photo by: Christopher Goatley

RESEARCH

PROGRAM 5: RESILIENCE OF LINKED SOCIAL-ECOLOGICAL SYSTEMS

Researchers

Terry Hughes *Program Leader*
Natalie Ban *Research Fellow*
Andrew Baird *Research Fellow*
David Bellwood
Joshua Cinner *Research Fellow*
Louisa Evans *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 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, and the social sciences. The Program has three themes: Understanding the dynamics of complex systems, Adapting and responding to environmental change and Managing for resilience. Two new 3-year postdoctoral fellows will be recruited to this Program in early 2013.

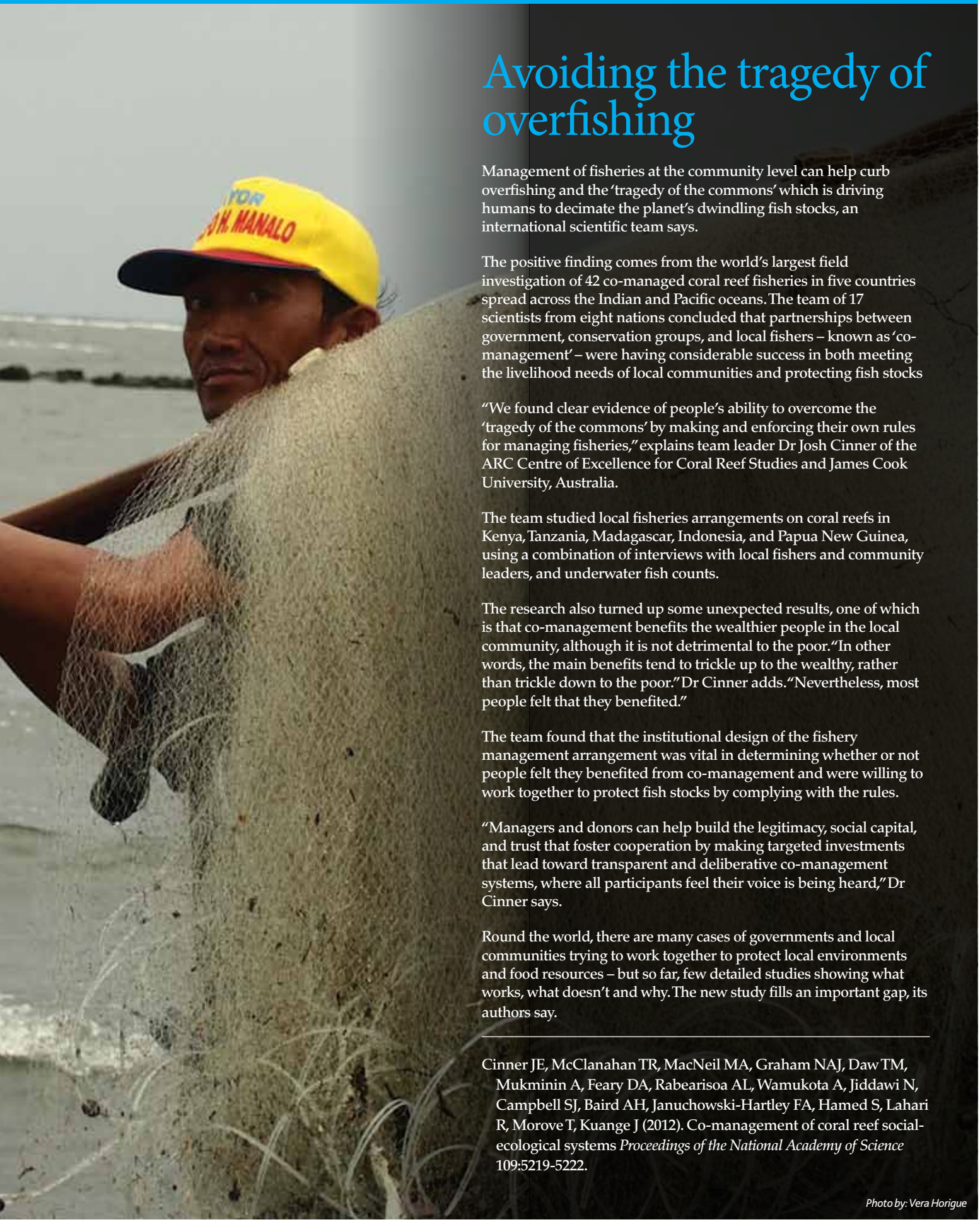
Joshua Cinner began the second year of his 5-year ARC Australian Research Fellowship, based at James Cook University, expanding his work on climate change adaptation. Josh, Nick Graham, Andrew Baird and their colleagues published a new multi-disciplinary study in *PNAS*, on management of coral reefs in Kenya, Madagascar, Tanzania, Indonesia and Papua New Guinea. A related paper published this year in *Marine Policy* examined institutional designs of customary fisheries management arrangements in Indonesia, Papua New Guinea, and Mexico. Josh and his colleagues also published a new study in *Global Environmental Change* on the vulnerability of coastal communities to climate change impacts on coral reef fisheries.

Louisa Evans undertook most of her fieldwork during the year in the Solomon Islands and Kenya. She has also initiated a new 3-year project on ecosystem approaches to fisheries management in Tanzania, as a consultancy with WorldFish. Natalie Ban and Louisa also began an international collaboration with 14 young scholars from around the world, working in resilience and common-pool resource theory. Their collaboration has designed a database to facilitate meta-analysis of governance of large-scale social-ecological systems (SES). From this work, Natalie and Louisa have three papers in review: two analyzing the Great Barrier Reef Marine Park as a large scale SES, and one synthesizing lessons across five cases, ranging from global pollution, to trans-boundaries fisheries, to regional protected area management. Louisa has also been involved in a collaboration with the *Resilience Alliance Young Scholars*, which resulted in a publication in *Annual Review of Environment and Resources* in 2012. This work is now being expanded into an edited book.

Program Leader Terry Hughes and colleagues published a new study in *Current Biology*, on the resilience of coral reefs to climate change (p21). They harnessed the 2,000 kilometre length of the Great Barrier Reef to measure the responses of corals to gradients in temperature, and concluded that the mix of species is surprisingly flexible – as one species becomes less abundant, another tends to take its place. These findings support the concept of "winners and losers" as coral reef ecosystems respond to climate change. This study received widespread media attention in 2012, and was featured in an episode of the ABC's science show, *Catalyst*.

In April, the ARC Centre and the International Union for Conservation of Nature (IUCN) co-funded the first in a series of research workshops, chaired by Professor Jeremy Jackson. The objective is to develop the Global Coral Reef Monitoring Network, and to undertake an ambitious meta-analysis of the status of coral reef ecosystems over time. In December, the group met again in Brisbane to prepare a major synthesis on long-term changes in coral reefs throughout the Caribbean. Sean Connolly, Terry Hughes, Peter Mumby and John Pandolfi comprised the ARC Centre participants at both meetings.

In October, Terry travelled to Jakarta at the request of the Australian Government Department of Sustainability, Environment, Water, Population and Communities, to attend a workshop of officials from the six Coral Triangle countries, supported by the Asian Development Bank, and to review the resulting Regional State of the Coral Triangle Report. Later in October, Terry and the Chairman of our Advisory Board, Brian Walker, convened a mini-symposium at the Australian Academy of Science, focusing on the resilience of the Great Barrier Reef (p62).



Avoiding the tragedy of overfishing

Management of fisheries at the community level can help curb overfishing and the 'tragedy of the commons' which is driving humans to decimate the planet's dwindling fish stocks, an international scientific team says.

The positive finding comes from the world's largest field investigation of 42 co-managed coral reef fisheries in five countries spread across the Indian and Pacific oceans. The team of 17 scientists from eight nations concluded that partnerships between government, conservation groups, and local fishers – known as 'co-management' – were having considerable success in both meeting the livelihood needs of local communities and protecting fish stocks

"We found clear evidence of people's ability to overcome the 'tragedy of the commons' by making and enforcing their own rules for managing fisheries," explains team leader Dr Josh Cinner of the ARC Centre of Excellence for Coral Reef Studies and James Cook University, Australia.

The team studied local fisheries arrangements on coral reefs in Kenya, Tanzania, Madagascar, Indonesia, and Papua New Guinea, using a combination of interviews with local fishers and community leaders, and underwater fish counts.

The research also turned up some unexpected results, one of which is that co-management benefits the wealthier people in the local community, although it is not detrimental to the poor. "In other words, the main benefits tend to trickle up to the wealthy, rather than trickle down to the poor." Dr Cinner adds. "Nevertheless, most people felt that they benefited."

The team found that the institutional design of the fishery management arrangement was vital in determining whether or not people felt they benefited from co-management and were willing to work together to protect fish stocks by complying with the rules.

"Managers and donors can help build the legitimacy, social capital, and trust that foster cooperation by making targeted investments that lead toward transparent and deliberative co-management systems, where all participants feel their voice is being heard," Dr Cinner says.

Round the world, there are many cases of governments and local communities trying to work together to protect local environments and food resources – but so far, few detailed studies showing what works, what doesn't and why. The new study fills an important gap, its authors say.

Cinner JE, McClanahan TR, MacNeil MA, Graham NAJ, Daw TM, Mukminin A, Feary DA, Rabearisoa AL, Wamukota A, Jiddawi N, Campbell SJ, Baird AH, Januchowski-Hartley FA, Hamed S, Lahari R, Morove T, Kuange J (2012). Co-management of coral reef social-ecological systems *Proceedings of the National Academy of Science* 109:5219-5222.

Photo by: Vera Horigue

RESEARCH

PROGRAM 6: CONSERVATION PLANNING FOR A SUSTAINABLE FUTURE

Researchers

Bob Pressey *Program Leader*
Glenn Almany *Research Fellow*
Jorge Álvarez-Romero *Research Fellow*
Amélie Augé *Research Fellow*
Natalie Ban *Research Fellow*
Ian Craigie *Research Fellow*
Rodolphe Devillers *Visiting Research Fellow*
Mariana Fuentes *Research Fellow*
Alana Grech *Research Fellow*
Laurence McCook
Rebecca Weeks *Research Fellow*

Program 6 focuses on spatial solutions to diverse resource management problems, involving the design of conservation areas and application of management actions. The goal is to guide management that promotes the persistence and sustainable use of natural resources, while working with local communities and other stakeholders to ensure that we propose practical solutions to management problems. Systematic conservation planning provides a rigorous approach which increasingly syntheses advances in biology, geography, economics, computing and the social sciences, to minimise the loss of biodiversity and ecosystem services. As well as helping to shape the field's science, Program 6 researchers lead a world-wide shift towards translating concepts and techniques into actual planning decisions on the ground. In designing and conducting the research, high value is placed on engagement with local communities, managers and policy makers, government agencies and non-government organisations.

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

New funding in 2012 included about $2 million for research on biosecurity on islands off the north-west coast of Australia. This project will complement existing research with the Queensland Parks and Wildlife Service to prioritise management actions on islands in the southern Great Barrier Reef.

In 2012, Program 6 received $50,000 from the Australian Centre for Ecological Analysis and Synthesis (ACEAS) to lead three one-week workshops on the theme of "Integrated catchment-to-coast planning: data, decision support, and governance". These ongoing workshops are bringing together experts in modelling and governance with management representatives from four study regions across northern Australia: including parts of the Great Barrier Reef coast, the Fitzroy catchment in the Kimberley, the Daly catchment south of Darwin and the Gilbert catchment flowing into the Gulf of Carpentaria. Part of this study is the subject of a paper in *Biological Conservation* by Vanessa Adams, an adjunct research fellow in Program 6, together with co-authors Bob Pressey and Natalie Stoeckl from JCU's School of Business. Program 6 also received $30,000 in 2012 from the Save our Seas Foundation to develop a systematic framework to help agencies prioritise management of sea turtles in northern Australia.

Across the Coral Triangle, Program 6 researchers continue to develop and strengthen collaborations with government agencies and non-government organisations (NGO), with research projects underway in the Philippines, Indonesia, and Papua New Guinea. In the Philippines, PhD student Vera Horigue has developed the MPA (marine protected area) Network Effectiveness Assessment Tool (MPA NEAT), used to evaluate collaborative partnerships for co-managing MPA networks. The research underpinning MPA NEAT was published this year in *Ocean and Coastal Management*. Rebecca Weeks has been collaborating with the Coastal Conservation and Education Foundation, a Philippine NGO, to assist in the development of MPA networks in Siquijor Province and Danajon Bank. Georgina Gurney has been working closely with the Wildlife Conservation Society in North Sulawesi, Indonesia, to assess the social impact of a network of community-based MPAs, and with ReefCheck to understand participation in community-based MPAs. PhD student Mélanie Hamel began an extensive field project in the Madang Lagoon in Papua New Guinea in 2012 to collect data on coral reef fishes in relation to mapped habitats, and to survey local people about the importance of places for their livelihoods. At the regional level, Program 6 researchers are closely engaged with the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security, providing input to the *Regional Exchange on Designing and Supporting National and Regional MPA Systems,* drafting the Coral Triangle Marine Protected Area System framework, and contributing to the Seascapes Working Group.

During 2012, Johnathan Kool and Vanessa Adams moved to new positions in Canberra and Darwin, while Jorge Álvarez-Romero, Rebecca Weeks and Amélie Augé took up new Fellowships within Program 6.

Climate is changing the Great Barrier Reef

Satellite measurement of sea surface temperatures has yielded clear evidence of major changes taking place in the waters of Australia's Great Barrier Reef (GBR) over the past 25 years, marine scientists have found.

The changes have big implications for the future management of the GBR and its marine protected areas say Dr Natalie Ban and Professor Bob Pressey of the ARC Centre of Excellence for Coral Reef Studies and James Cook University.

"For example, off Rockhampton the water has warmed by about half a degree over the last 25 years."

The changes were also altering the seasonal patterns of water temperature at particular places along the reef, Dr Ban says. "In some areas summer is coming earlier and lasting longer; in others, both summers and winters are warmer than in the past. This all affects the sea life."

The research has revealed temperature conditions are dynamic, with warmer waters moving in both space and time – posing new questions for the management of Green Zones and other protected areas which tend to be fixed.

"Some people think we ought to have the highest levels of protection for areas that are changing the least, so they remain as refugia to recharge the surrounding reef areas," Dr Ban says.

"Others argue the opposite – that the greatest protection should be afforded to the most vulnerable areas."

"Others still argue that Green Zones and other types of restrictions should migrate geographically along with the climate – that their boundaries should change gradually in line with trends in water temperature and reef biology."

"Our aim in publishing this paper on what is actually happening is to stimulate and inform this discussion, so that we can come up with the best and most flexible system for managing the GBR through what will undoubtedly be momentous environmental change."

Australia is recognised as a world leader in managing coral reefs, and was again leading global thinking about how to best manage them as waters warm and conditions change."We hope that our research will also prove valuable to countries of the Coral Triangle who are trying to manage the world's centre of coral diversity through this challenging period," she says.

Ban NC, Pressey RL, Weeks S (2012). Conservation objectives and sea-surface temperature anomalies in the Great Barrier Reef. *Conservation Biology* 26:799-809.

Photo by: Tom Bridge

RESEARCH

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*
Terry Hughes *Research Fellow*
David Mills *Research Fellow*
John Pandolfi

Program 7, launched in mid-2009, addresses the multi-faceted challenges of improving coral reef governance. This multi-disciplinary research program covers cultural, political, historical, and economic aspects of coral reef management at multiple scales. While Program 7's activities include a focus on the Great Barrier Reef, they are global in scope, with emphasis on the rapidly evolving coastal resource management and governance challenges throughout the Indo-Pacific region, particularly in Melanesia and the Coral Triangle. Program 7 addresses drivers of coral reef resource-use from global to local scales, and aims to understand the complex, and often difficult to quantify, cultural, social, political and economic dimensions of resource use and management, both contemporary and historical. Program 7 is already involved in capacity-building activities in many countries, working with NGOs and national governments.

A major highlight this year was the award of a prestigious Branco Weiss 5-year Fellowship to Mike Fabinyi. Mike will use this fellowship to expand his 2012 published work on the seafood trade and consumption in China. Increased consumption of seafood in China will have significant, long-term implications for local livelihoods and environments in source countries, as well as influencing global seafood markets. The insights of an anthropological approach to these issues will allow Mike to contribute to an understanding that can ultimately inform improved governance, providing social and environmental benefits. In 2012, Mike continued his work on informal cross-border trading of natural resources across Southeast Asia, which is a growing issue with economic, security and environmental implications for the region. This collaborative project with Palawan State University in the Philippines focuses on the cross-border trade in live reef fish between southern Philippines and Sabah, Malaysia.

Louisa Evans has completed work on the first year of a 3-year WorldFish-EU Ecosystem Approach to Small-Scale Fisheries Management Project. This is in collaboration with WorldFish and the University of Dar es Salaam. She continues work on various collaborative projects on fishery management and climate change adaptation in the Solomon Islands and East Africa. In 2012, Program 7 continued to facilitate a network of over 20 social and interdisciplinary scholars from JCU's Schools of Anthropology, Marine and Tropical Biology, the ARC Centre of Excellence for Coral Reef Studies, the Centre for Sustainable Tropical Fisheries and Aquaculture, WorldFish and CSIRO. Researchers participate in monthly meetings, which are aimed at providing support to scientists engaging in social science research by sharing ideas, skills and expertise in theories and concepts, research methodologies, and analysis techniques, as well as providing practical support through review of papers, proposals and fieldwork materials. In 2012 topics included; frontiers and challenges in the nexus of conservation and development, lessons from anthropology for interdisciplinary researchers and conservation action, proposal development and dealing with donors, research ethics, values, and Elinor Ostrom's work on common pool resources and governance. This network of scholars continues to provide a valuable forum in which to bounce ideas around or to help address particular challenges faced in interdisciplinary research careers.

Simon Foale and Mike Fabinyi co-convened a well-subscribed and timely session at the 12th International Coral Reef Symposium (ICRS2012) in Cairns in July, on historical, cultural and political dimensions of coral reef fishery management. At the same conference, Simon launched a fisheries education DVD called 'Fish and People' (www.coralcoe.org.au/videos/videos) – an innovative science learning tool with high production values targeted at Melanesian high school audiences and produced by Digital Dimensions and Eco Media Production Group. 'Fish and People' is already proving to be very popular not just in the Solomon Islands and Papua New Guinea, but also as far afield as Kenya and Vietnam. Simon and collaborators from the ARC Centre of Excellence, WorldFish, WWF and Charles Darwin University co-authored a publication titled 'Food security and the Coral Triangle Initiative (CTI)', which was also launched at ICRS2012. This paper provides a constructive critique of the CTI from the perspective of a group of policy-oriented social and natural scientists.

Food security at risk in coral countries

Safeguarding food security in the Coral Triangle, the region embracing six nations and 350 million people to Australia's north, is a key focus at an international meeting in Cairns today.

The meeting of the Coral Triangle Initiative (CTI) countries, hosted by the Asian Development Bank and Australia, reports on the progress of an international effort to protect the world epicenter of marine biodiversity and the food that it supplies to the region.

The six nations of the Coral Triangle – Indonesia, the Philippines, the Solomon Islands, Timor Leste, Papua New Guinea and Malaysia – meet amid warnings that seafood supplies for the region's growing population could become critical if the balance between commercial fishing, conservation and the needs of local fishers is not managed carefully.

Professor Bob Pressey of the ARC Centre of Excellence for Coral Reef Studies (CoECRS) at James Cook University says that marine conservation approaches adopted in developed countries like Australia and the United States will need re-thinking if they are to work in the Coral Triangle, where so many livelihoods depend on the sea.

"Sure, you can show there are benefits to the fish catch if you put in some no-take areas – but the CTI plan also has a focus on issues like resilience to climate change and biodiversity conservation. These additional goals will almost certainly need more areas to be set aside from fishing than needed only to sustain livelihoods. So achieving these higher-level goals will need to be handled with great care to avoid adding to the pressures on the affected people."

Research by Dr Simon Foale of CoECRS and James Cook University, and colleagues, suggests the food security of the region could be at risk due to soaring demand (both local and international), a decline in stocks of wild fisheries, and degradation of coastal and marine ecosystems.

Dr Foale warns that one of the first consequences of this confluence of pressures is that the price of fish will become unaffordable for the majority of local people throughout the CTI region."Urbanisation is increasing, leading to growing demand for fish at a time when marine resources are already overstretched," he says, adding that groups which are economically and politically marginalised will suffer most.

He adds that the CTI is a bold and exciting initiative. Aquaculture of both fish and sea plants could offer a viable alternative source of incomes for many communities affected by closure of fishing areas.

Foale S, Adhuri D, Alino P, Allison EH, Andrew N, Cohen P, Evans L, Fabinyi M, Fidelman P, Gregory C, Stacey N, Tanzer J, Weeratunge N (2012). Food security and the Coral Triangle Initiative. *Marine Policy* 38:174-183.

Photo by: Mathinee Yucharoen

RESEARCH

PROGRAM 8: GENOMICS AND META-GENOMICS OF CORAL REEFS

Researchers

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

Program 8 focuses on the genomics of the coral holobiome – the name given to the association between the metazoan coral and their symbiotic photosynthetic dinoflagellates, and bacterial and viral communities. Its objective is study the structure and function of genomes in order to better understand how the holobiome functions under normal and stressed conditions. Program 8 works closely with the more biochemical and physiological approach taken in Program 4: *Genetic, molecular and physiological processes*.

This year Dr Benjamin Mason joined us, as a recipient of a prestigious USA National Science Foundation International Research Fellowship. Ben will study the sensory biology of coral larvae, focussing particularly on the roles of opsins and related proteins in settlement and metamorphosis. Professor Bruno Lapeyre from the Centre National de la Recherche Scientifique's (Montpellier) macromolecular biochemistry program joined us on sabbatical, and is employing his expertise in RNA biology and nucleic acid modification to study the mechanisms and significance of base modification in coral symbionts.

The year saw the launch of Sea-quence 20/20 project, involving many Program 8 members Susanne Sprungala, Bill Leggat, David Miller, Ove Hoegh-Guldberg, Eldon Ball, Sylvain Forêt and Madeleine van Oppen. Sea-quence 20/20 aims to provide whole genome and transcriptome data for 20 coral species representing the diversity of coral growth forms, as well as data for their dinoflagellate symbionts and associated microbes. This project will provide a platform for understanding the diversity of coral responses to stress and their ability to acclimate or adapt to climate change. Three of the Centre's nodes, James Cook University, the University of Queensland and the Australian National University as well as The Australian Institute for Marine Science, the King Abdullah University of Science and Technology in Saudi Arabia and the Great Barrier Reef Marine Park Authority are involved in this project.

Program members Bill Leggat, Tracy Ainsworth, Bette Willis and others began a new project in 2012 to investigate the roles of microbes in coral health, reef resilience and responses to climate change. Bill Leggat has continued work on the comparative genomics of *Symbiodinium.* In collaboration with PhD student Lynda Boldt and David Yellowlees, they reported in ***PLOS One*** a transcriptomic study showing genes for the light-harvesting complex proteins in *Symbiodinium* are hyperdiverse, with multiple phylogenetic ancestries.

Other notable achievements include the generation of a comprehensive transcriptome assembly for the coral *Acropora millepora* by program member Sylvain Forêt. Researchers in Program 8 and 4 are using this new information to study how gene expression is affected by ocean acidification. This collaboration demonstrates that under high CO_2 conditions corals lose over half their *Symbiodinium* populations, and show lower levels of both photosynthesis and respiration. Whole transcriptome analyses, carried out primarily by Aurélie Moya and visiting PhD student, Lotte Huisman, demonstrate that the most dramatic impact of acute exposure to elevated CO_2 is on expression of genes encoding components of the skeletal organic matrix – the proteins that control the deposition of the skeleton. The results of these analyses have led to a major paper in *Molecular Ecology* (p31). The transcriptome assembly has also been extensively used to investigate the molecular bases of the coral immune response; this work is described in several papers that are currently in review.

During 2012, Program 8 hosted several international visitors immediately following the International Coral Reef Symposium including the eminent Polish paleobiologist Professor Jarowslaw Stolarski, and Dr Chuya Shinzato, a coral genomics researcher at the Okinawa Institute for Science and Technology, Japan. Lisa Holland, a visiting postgraduate from the Ruhr University (Bochum, Germany) also spent October and November working with Susanne Sprungala.

Tracy Ainsworth was awarded a Queensland Smart State International Fellowship, to visit Professor Ruth Gates' lab at the University of Hawai'i from August to December 2012. David Miller, Eldon Ball and Sylvain Forêt were invited participants to the Okazaki Biology Conference "Marne Biology II", held in October at both the National Institute of Basic Biology (Okazaki) and the Okinawa Institute for Science and Technology in Japan.

CO_2 'is messing with coral skeletons'

An international scientific team has carried out the world's first analysis of the impact of ocean acidification on every gene in the coral genome, throwing new light on the likely fate of corals under climate change. This prodigious research undertaking, involving more than 250 million 'reads' of genetic material and their detailed interpretation, was carried out by researchers from Australia, France, Netherlands and South Korea using powerful new genetic analysis tools.

"Every time we release CO_2, it turns the oceans imperceptibly more acidic – and previous research has shown this to have a harmful effect on corals, plankton and other marine organisms which form their skeletons from calcium and carbonate," explains Professor David Miller of the ARC Centre of Excellence for Coral Reef Studies (CoECRS) at James Cook University in Australia.

"We knew a more acidic ocean was bad for corals – but we didn't know exactly how it affected them. Our aim was to go back to basics and explore the effect on every gene in the genome of a young coral, and the job it does. This is an essential first step in gaining an accurate grasp of the impact of increased atmospheric CO_2 on the world's coral reefs and ocean life forms."

Project scientists Dr Aurélie Moya of CoECRS and France's Oceanographic Laboratory and Lotte Huisman of CoECRS and Amsterdam University led the experimental work, which involved raising coral larvae to the point where they settle on the reef, placing them in tanks and then exposing them to air bubbles with levels of CO_2 of 750-1000 parts per million. This is projected to be the world's atmospheric CO_2 content by the end of this century, if humanity fails to cut its carbon emissions.

"Much to our surprise we found the rising acidity had little effect on the production of ion transport proteins that are responsible for circulating and depositing the calcium carbonate within the coral cells to form its skeleton. But equally surprising were the massive changes we observed in the expression of coral genes involved in the creating the framework required for skeleton formation: some were increased and some decreased."

"Overall it means that a more acidic ocean messes with the skeleton formation process in young corals in disturbing, but highly complex, ways. There have been a lot of conflicting reports in the scientific literature about positive and negative effects of ocean acidification on corals – and our research shows why."

"A clearer understanding of the impact of a more acidic ocean on corals, will give us a far better understanding of how best to protect our coral reefs in a world where enormous changes are taking place at great speed."

Moya A, Huisman L, Ball EE, Hayward DC, Grasso LC, Chua CM, Woo HN, Gattuso JP, Foret S, Miller DJ (2012). Whole transcriptome analysis of the coral *Acropora millepora* reveals complex responses to CO_2-driven acidification during the initiation of calcification. *Molecular Ecology* 21:2440-2454.

Photo by: Andrew Baird

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Humanity urged to make best use of 'borrowed time'

Humans may be able to avert major environmental catastrophes that now loom if we learn to make better use of 'borrowed time', according to an eminent Australian marine biologist.

'There is mounting evidence that we have already passed or may soon pass several critical boundaries affecting life on Earth, as well as our own future wellbeing,' says the director of the ARC Centre of Excellence for Coral Reef Studies at James Cook University, Professor Terry Hughes.

Prof. Hughes' comments come as government leaders from around the world gather in Doha for the United Nation's Climate Conference (Nov 26-Dec 7) to try to impart new momentum to stalled efforts to prevent 4-6 degrees of global warming.

He is lead author of a new paper by an international scientific team in the journal Trends in Ecology and Evolution (TREE) which argues that while more and more of the planet's environments are approaching major regime shifts – or points-of-no-return – there may still be time to save them.

The pressure of human activities and demands on the planet's resources is shifting many of its familiar ecosystems to unfamiliar states, often much less productive and less able to support ourselves and other life, Prof. Hughes explains. These are known as 'tipping points' or regime changes.

'For example, there are signs the Arctic will soon shift to an ice-free condition in summer, which is a profound change, occurring just in our lifetime. In the Amazon Basin, clearing of jungle could move the whole region to a much drier state. Both of these changes affect human livelihoods as well as wildlife.

'In coral reefs, too, we see the impact of bleaching and other human pressures causing a shift from a coral-dominated ecosystem to

'In coral reefs, too, we see the impact of bleaching and other human pressures causing a shift from a coral-dominated ecosystem to one dominated by seaweeds, in which the rich diversity of the reef is lost. This in turn directly affects hundreds of millions of humans whose livelihoods depend on coral reefs,' Prof. Hughes says.

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The article appeared in ECOS magazine online **www.ecosmagazine.com/?paper=EC12502** on 3rd December 2012.

However the scientists say the good news is that many of these profound shifts take place over quite long time periods – decades or even centuries – and this gives humanity time to act wisely to prevent irreversible and dangerous damage from occurring.

'In effect we are living dangerously, on borrowed time – and we need to learn how to take early action to prevent ecosystems from approaching a tipping point,' he says.

The researchers say that when the decline in an ecosystem is sudden and dramatic, this often prompts society to take action.

Of greater concern is where the ecosystem degrades steadily over years or even generations before flipping into a new, unproductive state. It is human nature that we often fail to notice this gradual change.

'The human imagination is poorly equipped for dealing with distant future events that contemporary generations unconsciously discount,' the researchers say.

For example, 'it is hard enough to reach a societal consensus that anthropogenic climate change is real today – let alone to convince people of the longer-term threat (from current greenhouse gas emissions) of acidification in the deep ocean in 500–2000 years from now,' they add.

Today it appears 'that human activities are already slowly pushing many ecological and Earth systems closer to regional- and planetary-scale thresholds' – adding that it is possible some of these have already been crossed.

'Nevertheless, delayed responses displayed by slow systems might provide an important window of opportunity to navigate to a safer state,' they conclude.

'The most important slow regime-shift is a social one: convincing enough people to move away from 'business-as-usual' thinking before time runs out,' Professor Hughes says. 'Today this is a challenge for governments, managers, scientists and society alike, all over the world.'

The article 'Living dangerously on borrowed time during slow, unrecognized regime shifts' by Terry P. Hughes, Cristina Linares, Vasilis Dakos, Ingrid A. van de Leemput and Egbert H Van Nes, appears in the online journal Trends in Ecology and Evolution (TREE).

Source: ARC Centre of Excellence for Coral Reef Studies

Melting permafrost in Alaska: one of the signs that the Earth's ecosystem is fast approaching a 'point-of-no-return'?
Credit: Alice Bailey

Photo by: Kydd Pollock

CORAL
REEF
STUDIES

GRADUATE TRAINING

The ARC Centre is the world's largest provider of graduate training in coral reef research. From an initial focus on ecology and natural sciences our program now also trains graduates in social sciences, conservation science and genomics. In 2012, the Centre Chief Investigators and Research Fellows supervised 205 postgraduate students at the four nodes of the Centre. Many of these students have supervisors at more than one node. Centre funds support students through their degree program, covering the costs of their research and providing financial assistance to attend conferences and workshops. In all, the total investment in student activities in 2012 is >25% of the Centre's annual budget.

The Centre's students were major contributors at the *12th International Coral Reef Symposium* in Cairns during July. Ninety-three Centre students presented their research at the Symposium and they were by far the largest postgraduate group contributing to ICRS 2012. In addition, many of our students acted as volunteers before and during the Symposium, giving them invaluable exposure to the leading researchers in their field.

As part of the annual *Celebrating Research @JCU* in September, the Centre held a training session for graduate students who were participating in the Centre's internal elimination round of the 3M competition (My Research in 3 Minutes). In the run up to the event, Liz Tynan, from the Graduate Research School, provided advice to the students on how to communicate their research to a lay audience. Karen Chong-Seng was voted the representative for the Centre in the JCU competition and one of our students, Gergely Torda, also represented the Australian Institute of Marine Science.

The Centre's training program has spread its horizons. The Centre Director, Terry Hughes, was selected by postgraduate students at the University of Hawai'i at Manoa as the Distinguished Speaker and guest for the 37th Annual Albert L. Tester Symposium. The Symposium ran for three days (28th-30th March 2012) during which Terry interacted extensively with graduate students, delivered two lectures to them and acted as judge for the symposium oral presentations.

The ARC Centre's Student Committee has been very active in the past year, with projects including:

- Promoting networking at the 12th International Coral Reef Symposium in Cairns.
- Supporting the Science & Culture Club (S&CC), an informal club organised by Centre students in 2012. S&CC serves as a forum for sharing ideas and promoting science communication in the broader Townsville community. For example, S&CC members have been involved in the Incubator science/art series and the Scientists in Schools program. Through Incubator, funded by the Regional Arts Development Fund, Centre students Kirsty Nash, Karen Chong-Seng and Erika Woolsey collaborated with artists to create public art exhibitions based on their research. Through Scientists in Schools partnerships, Centre students presented science lessons at various Townsville schools.
- Considerable effort was expended in planning a Student Retreat to be held on Magnetic Island at the start of 2013. The retreat will focus on science communication, with Nobel Prize Laureate for Physics, Professor Brian Schmidt, as the keynote speaker.

In 2012, the Centre continued to host networking events for women in science. Recognising that senior research and leadership positions are often dominated by men, this is one important mechanism to ensure that the achievements and progress of female scientists are facilitated and recognised. The Centre hosted several presentations and discussions about careers in academia and women in research. These sessions included an inspiring discussion with Nyawira Muthiga, a scientist who has been involved in the governance, management, and planning of conservation in East Africa for over 20 years. Her work is nationally and internationally recognised through awards including the National Geographic/Buffett Award and the Kenyan Presidential award. Additionally, the group hosted several informal *Wine-ing Women in Science* networking evenings to build rapport between senior staff, postdoctoral research fellows and students.

Awards to ARC Centre students in 2012 include:

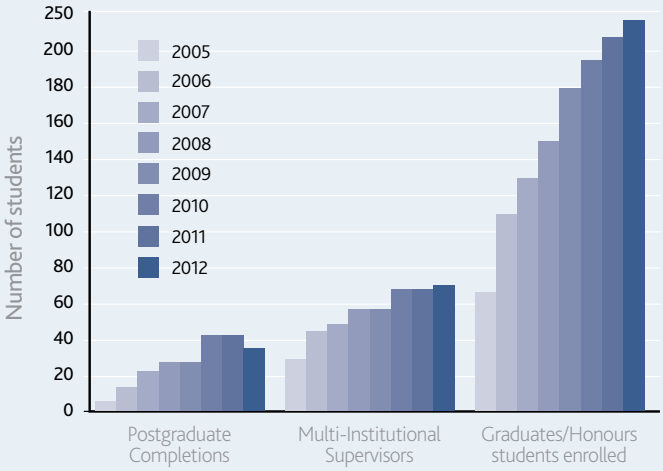
- Eight Centre students received *GBRMPA Science for Management Awards:* Stephen Ban, Sandra Binning, Jordan Casey, Gabrielle Miller, Kirsty Nash, Joseph Pollock, Melanie Trapon and Jeroen Van de Water.
- Peter Waldie, Joseph Pollock and Allison Paley were awarded *ATSE Young Science Ambassador Awards* by the Australian Academy of Technological Sciences and Engineering, to work with school children to build excitement and capacity for science.
- Many of our students were awarded grants to support their research. Successful students included Dominque Roche (Ian Potter Foundation through the Lizard Island Research Foundation, Society for Integrative and Comparative Biology, and Ecological Society of Australia), Vera Horigue (Rare Conservation Inc, and Rufford Small Grants Foundation), Susannah Leahy (Michael Hall Student Innovation Award from Australian Society of Fish Biology), Sandra Binning (Society for Integrative and Comparative Biology), Georgina Gurney (Beryl Henderson Memorial Grant from the Australian Federation of Graduate Women), Gabrielle Miller (Australian Coral Reef Society), and Robert Mason (Wildlife Preservation Society of Australia).
- Travel grants were awarded to Gabrielle Miller (Scientific Committee on Oceanic Research), Christopher Doropoulos, Jeroen Van de Water,

Brigitte Sommer and Erika Woolsey (Australian Coral Reef Society), Sandra Binning and Dominique Roche (International Society for Behavioural Ecology), and Mélanie Hamel (Society for Conservation Biology).

- PhD top-up scholarships were awarded to Brigitte Sommer and Georgina Gurney from CSIRO.
- Kirsty Nash was one of the recipients of a $139,000 grant from the United States Geological Survey to organise two workshops at Fort Collins in Colorado on "Understanding and managing for resilience in the face of global change".
- Peter Waldie made a successful application to participate in the Graduate Network in Tropical Research.
- The Virginia Chadwick Awards are awarded to five ARC Centre of Excellence graduate students for the most outstanding publications in peer-reviewed international journals. The student must be the lead author on the paper which must be published in a high ranking journal. Each attracts a prize of $1,000. The winners for 2012 were Shane Blowes, Tom Brewer, Jenni Donelson, Christopher Doropoulos and Hugo Harrison.

The ARC Centre would like to acknowledge the valuable and critical contribution of the Student Committee during 2012. Along with Olga Bazaka, our graduate student co-ordinator, they make an invaluable contribution to the success of the ARC Centre of Excellence for Coral Reef Studies. Members of the committee during the year were Erika Woolsey (Chair), Sandra Binning and Dominique Roche from ANU, Pip Cohen, Christina Hicks, James Tan and Amelia Wenger from JCU, Renata Ferrari Legorreta, Chico Birrell and Alyssa Marshell from UQ, and Lucy Georgiou and Jessie Short from UWA.

Growth in the ARC Centre's graduate program, 2005-2012.



The ARC Centre's international network of graduate students. In 2012, 152 students came to Australia from 45 countries.

2012 STUDENT MEMBERS

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Novi Susetyo Adi	UQ	Indonesia	Assessment of coral reef productivity using remote sensing data. (PhD)	A/Prof S Dove, 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
Bridie Allan	JCU	New Zealand	The interactive effects of increased water temperatures and elevated dissolved CO_2 on the clutch quantity of two common reef fish: how does this impact on predator-prey interactions? (PhD)	Prof M McCormick, Prof P Munday
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 awarded)	Prof R Pressey, Dr N Ban
Kristen Anderson	JCU	Canada	Effects of changing environmental conditions on the growth rates of branching corals: consequences for habitat. (PhD)	Prof M Pratchett, Dr A Baird
Shelley Anthony	JCU, AIMS	USA	Tissue sloughing and coral disease in a large-scale reef mesocosm. (PhD)	Prof B Willis
Adrian Arias	JCU	Costa Rica	Marine spatial planning for developing countries: overcoming obstacles. (PhD)	Prof R Pressey, Dr J Cinner
Jennifer Atherton	JCU	United Kingdom	Effect of the threat of predation risk on offspring through maternal effects. (PhD)	Prof M McCormick, Dr A Frisch, Prof G Jones
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	The ecology and dynamics of coral reef communities in marginal reef environments. (PhD)	Prof M Pratchett, Dr A Baird
Roger Beeden	JCU	New Zealand	How healthy is the Great Barrier Reef in a warming world? (PhD)	Prof B Willis
Dorothea Bender	UQ, Griffith	Australia	Effects of climate change and ocean acidification on coral reef turf algae. (PhD)	A/Prof S Dove
Brock Bergseth	JCU	USA	Methods of measuring and assessing compliance in marine reserves. (MSc awarded)	Prof G Russ, Dr J Cinner
Sandra Binning	ANU	Canada	Phenotypic plasticity in coral reef fish ecomorphology. (PhD)	Prof D Yellowlees
Chico Birrell	UQ	Australia	Understanding the spatial and temporal variation in macroalgal growth and assemblage development on coral reefs. (PhD)	Prof P Mumby

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Shane Blowes	JCU	Australia	Territoriality, competition, and coexistence of butterflyfishes. (PhD)	Prof S Connolly, Prof M Pratchett
April Boaden	JCU	Australia	Predator/prey interactions and the influence of predators on the abundance demography and growth of prey fishes on the Great Barrier Reef. (PhD)	Prof M Kingsford, Dr D Williamson
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
Melissa Bos	JCU	USA	Marine conservation finance. (PhD)	Prof R Pressey
Lisa Bostrom Einersson	JCU	Sweden	Competitive interactions, habitat degradation and the structure of coral reef fish assemblages. (PhD)	Prof G Jones, Prof P Munday, Dr M Bonin
Madeleine Bottrill	UQ, JCU	United Kingdom	Evaluating the effectiveness of conservation planning: when do plans work. (PhD awarded)	Prof R Pressey
Alyssa Bowden	JCU	USA	Gill remodelling in fishes under climate change scenarios. (MSc)	Dr J Rummer
Dominique Bradbury	JCU	USA	Bleaching susceptibility of corals: a hierarchy of causes and consequences. (PhD)	Prof M Pratchett, Dr A Baird, Prof T Hughes
Simon Brandl	JCU	Germany	Pair formation in herbivorous reef fishes: environmental and ecological implications. (PhD)	Prof D Bellwood
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
Sarah Buckley	UQ	Ireland	A reconstruction of historical baselines of Queensland fisheries since the Anthropocene. (PhD)	Prof J Pandolfi
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
Carolina Castro Sanguino	UQ	Colombia	Effects of reef degradation on the dynamics and function of *Halimeda*. (PhD)	Prof P Mumby
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 coral. (PhD awarded)	Dr A Baird, Dr W Leggat, Prof T Hughes
Pedro Cipresso Pereira	JCU	Brazil	Competition habitat selection and imprinting of coral-dwelling fishes. (PhD)	Prof P Munday, Prof G Jones

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Tara Clark	UQ, AIMS	Australia	Historical mortality in Great Barrier Reef coral communities since European settlement. (PhD awarded)	Prof J Pandolfi
Christophe Cleguer	JCU	France	Distribution, relative abundance and habitat use of the dugong: a basis for marine conservation and management planning in New Caledonia. (PhD)	Dr A Grech, Dr M Fuentes
Philippa Cohen	JCU	Australia	The contribution of locally-managed marine areas to food security of Solomon Islands. (PhD)	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 awarded)	Prof M Pratchett, Dr N Graham, Prof P Munday
Geoffrey Collins	JCU	Australia	Hypoxia tolerance in barramundi fish. (PhD)	Dr J Rummer
Amy Coppock	JCU	United Kingdom	Olfactory discrimination in juvenile coral reef fishes. (MSc)	Prof G Jones, N. Gardiner
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 awarded)	Prof D Bellwood
Alicia Crawley	UTS	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 awarded)	Prof B Willis, Dr V Lukoschek
Vivian Cumbo	JCU, AIMS	Australia	Thermal tolerance in corals: the role of the symbiont. (PhD awarded)	Dr A Baird, Dr M van Oppen, Prof T Hughes
Christopher Cvitanovic	JCU, ANU	Australia	Ecological energetics 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
Blanche D'Anastasi	JCU, UWA	Australia	Population genetics and genomic dietary analyses of Australian sea snakes. (PhD)	Dr V Lukoschek
Sana Dandan	UWA	Denmark	Resilience of coral reef communities and coral metabolism in extreme environmental conditions. (PhD)	Prof M McCulloch
Benjamin Davis	JCU	United Kingdom	Temporal nekton dynamics in tidal floodplain wetlands. (PhD)	Prof G Russ
Martina De Prezeres	UQ, AIMS	Brazil	Foraminifera as tools for analysis of interactions between water quality and climate change effects on the Great Barrier Reef: historical reconstruction and biology at community, individual and cellular scales. (PhD)	Prof J Pandolfi
Anderson de Sevilha	JCU	Brazil	Systematic conservation planning for the Parana River Basin, Brazil. (PhD)	Prof R Pressey
Ayax Diaz-Ruiz	UQ	Mexico	The use of coral associated fauna as indicators of coral health. (PhD)	Prof O Hoegh-Guldberg, Prof J Pandolfi
Juan Pablo D'Olivo Cordero	ANU	Mexico	Cross-shelf variation of coral calcification in the central Great Barrier Reef and its relationship to ocean acidification, temperature and terrestrial run-off. (PhD)	Prof M McCulloch
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, Dr G Diaz-Pulido
Michelle Dyer	JCU	Australia	Knowledge, power and fishery management in the Solomon Islands. (PhD)	Dr S Foale

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Britt Edelman	JCU	USA	Trophodynamics of garfish (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
Norbert Englebert	UQ	Netherlands	Phenotypic and physiological responses of a widespread coral species to changing environmental conditions: functional variability in natural populations of *Stylophora pistillata*. (PhD)	Prof O Hoegh-Guldberg, A/Prof S Dove
Kar-Hei (James) 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 (Sonny) 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
Eric Fisher	JCU, AIMS	Australia	Spawning aggregation sites on tropical reefs. (MSc)	Prof M McCormick
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 awarded)	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
Ashton Gainsford	JCU	Australia	A multi-disciplinary evaluation of the hybrid anemonefish ***Amphiprion leucokranos***: behaviour shaping evolutionary outcomes of hybridisation. (PhD)	Prof G Jones
Lucy Georgiou	UWA	United Kingdom	Boron isotopes and B/Ca in scleractinian corals: evaluating their validity as paleo-pH recorders and assessment of vital effects. (PhD)	Prof M McCulloch
Sarah Gierz	JCU	Australia	Acclimation of *Symbiodinium* to thermal stress. (PhD)	Dr W Leggat
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	The energetics of scleractinian coral larvae and implications for dispersal. (PhD awarded)	Prof B Willis, Prof S Connolly, Dr A Baird
Katie Grenchik	JCU	USA	Developmental thermal acclimation in reef fishes. (MAppSc)	Prof P Munday
Sallyann Gudge	JCU	Australia	Do macro algae mediate the effects of ocean acidification on scleractinian corals? (MSc)	Prof M Pratchett, Dr A Hoey
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

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Jessica Haapkyla	JCU, AIMS	Finland	Dynamics and drivers of coral diseases on Indo-Pacific reefs. (PhD awarded)	Prof B Willis
Catherine Hair	JCU	Australia	Development of community-based sea cucumber culture methodologies in Papua New Guinea. (PhD)	Dr S Foale
Mélanie Hamel	JCU, IRD Noumea	New Caledonia	Costs, effectiveness, and cost-effectiveness of marine habitat-driven conservation planning in the Madang Lagoon, Papua New Guinea. (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
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)	Dr J Cinner, Prof T Hughes, Prof R Pressey
Jennifer Hodge	JCU	USA	Evolution and speciation processes in coral reef fishes. (PhD)	Prof D Bellwood
Jessica Hopf	JCU	Australia	Metapopulation analysis of the role of connectivity in marine protected area design. (PhD)	Prof S Connolly, Prof G Jones
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 awarded)	Prof B Willis, 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
Adriana Humanes Schumann	JCU, AIMS	Venezuela	Interactive effects of water quality and climate change on the early life history stages of hard corals. (PhD)	Prof B Willis
Matthew Ireland	JCU	Australia	Trophic ecology of large predatory fishes on the Great Barrier Reef. (MAppSc awarded)	Dr A Frisch
Matt Jankowski	JCU	United Kingdom	Depth distributions and habitat specialisation of coral reef fish over a depth gradient. (PhD)	Prof G Jones, Dr N Graham
Fraser Januchowski-Hartley	JCU	United Kingdom	Biological mechanisms of customary management of Melanesian coral reefs and their consequences for the coral reef fish community. (PhD)	Dr N Graham, Dr J Cinner, Prof G Russ
Young Koo Jin	JCU, AIMS	South Korea	Nature or nurture? Testing the correlation between stress tolerance and genotypes in *Acropora millepora* on the Great Barrier Reef. (PhD)	Prof B Willis, Dr M van Oppen
Jacob Johansen	JCU	Denmark	Energetics of habitat choice in planktivorous coral reef fishes. (PhD awarded)	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
Julie Jourdan	U. Montpellier, JCU	France	Effectiveness of different management strategies to mitigate the impacts of projected increases in temperature on sea turtle reproductive output. (MSc)	Dr M Fuentes
Jung Ok Kang	ANU	Korea	Anthropogenic increase of atmospheric carbon dioxide and ocean acidifying and global warming: implications for long-term changes in the classification rate of coral reefs. (PhD)	Prof M McCulloch

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Lisa Kelly	JCU	Canada	Characterisation of skeletal and histological structures for a novel coral growth anomaly and the immune response elicited in the coral host. (MAppSc)	Prof B Willis, Dr T Ainsworth
James Kerry	JCU, AIMS	United Kingdom	Structural complexity and the ecology of large reef fish. (PhD)	Prof D Bellwood
Maurice Knight	JCU	USA	Modelling governance – a case study of the coral triangle initiative on corals, fisheries and food security. (PhD)	Prof R Pressey
Michael Kramer	JCU	New Zealand	The functional importance of benthic carnivory on coral reefs. (PhD)	Prof D Bellwood, Prof S Connolly
Antony Kuret	UWA	Australia	Reconstructing the seasonal variability of sea surface temperature in the Leeuwin Current System from coral geochemistry. (MSc)	Prof M McCulloch
Joleah Lamb	JCU, AIMS	USA	Influence of reef-based industries on coral health and disease. (PhD)	Prof B Willis, Prof G Russ
Rebecca Lawton	JCU, AIMS, KAUST	New Zealand	Geographic variation in the ecology of butterflyfishes and resilience to large scale disturbances. (PhD awarded)	Prof M Pratchett, Prof T Hughes
Angela Lawton	UQ	USA	The effects of micro-scale variation on the photosynthetic productivity of the symbiotic algae of reef building corals. (PhD awarded)	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
Anne Leitch	JCU, CSIRO	Australia	Social resilience to climate change: the adaptive capacity of local government. (PhD)	Prof T Hughes
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
Govinda Liénart	JCU	Austria	Temperature effects of chemically mediated predator-prey interactions. (PhD)	Prof M McCormick
Mei-Fang Lin	JCU, ANU	Taiwan	Transcriptomics of Corallimorpharian *Rhodactis indosinensis* (Cnidaria: Anthozoa) and its usefulness to understanding coral bleaching. (PhD)	Prof D Miller, Dr S Forêt
Oona Lonnstedt	JCU	Sweden	Omnious odour - the role of olfactory cues in predator-prey interactions. (PhD)	Prof M Kingsford, 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 awarded)	Prof J Pandolfi
Katalin Magnenat	JCU	Switzerland	Distribution and abundance of reef sharks on the Great Barrier Reef. (MAppSc awarded)	Dr A Frisch

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Rafael Magris	JCU	Brazil	Applying biodiversity conservation planning tools into the design of a long term conservation strategy for Abrolhos Bank. (PhD)	Prof R Pressey, Dr N Ban
Rachel Manassa	JCU, U. Saskatchewan	Australia	Importance of social systems and information transfer in coral reef fish. (PhD)	Prof M McCormick, Prof P Munday
Hannah Markham	UQ	United Kingdom	Long-term ecological dynamics along a gradient of anthropogenic activity on the inshore Great Barrier Reef. (PhD)	Prof J Pandolfi
Alyssa 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 awarded)	A/Prof S Dove, Prof O Hoegh-Guldberg
Morana Mihaljević	UQ	Croatia	Indo-Pacific coral evolution: Neogene reefs from the South China Sea. (PhD)	Prof J Pandolfi
Gabrielle Miller	JCU	Australia	Influence of climate change on early development in coral reef fishes. (PhD)	Prof PL Munday, Prof M McCormick
Matthew Mitchell	JCU	United Kingdom	Antipredator defence through chemical alarm cues: how common amongst tropical marine fishes? (PhD awarded)	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
Amin Mohamed Esmail	JCU	Egypt	Coral reef conservation through monitoring of coral diseases and the use of ecological genomic tools. (PhD)	Prof D Miller, Prof B Willis
Christopher Mooney	JCU	Australia	Statoliths of Cubozoan jellyfishes: their utility to discriminate taxa and elucidate population ecology. (PhD)	Prof M Kingsford
Jessica Morris	JCU	Australia	Towards an understanding of the global effort to understand the impacts of climate change on sea turtles. (MSc awarded)	Dr M Fuentes
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	Coral disease on the Great Barrier Reef: Corallivorous species as potential vectors of brown band disease. (MAppSc)	Prof B Willis, Prof M Pratchett
Jessica Nowicki	JCU	USA	The roles of nonapeptides in modulating animal personality and reproductive behaviour in coral reef fish. (PhD)	Prof M Pratchett, Dr S Walker
Colleen O'Brien	JCU	USA	Reef restoration – culture of corals for the restoration of degraded reefs. (MAppSc)	Dr J Figueiredo
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

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Christine Pam	JCU	Australia	The global discourse of climate change and small island states. (PhD)	Dr S Foale
Pedro Pereira	JCU	Brazil	Competition, habitat selection and imprinting of coral dwelling gobies. (PhD)	Prof P Munday, Prof G Jones
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. (PhD)	Prof M Pratchett
F. Joseph Pollock	JCU, AIMS, College of Charleston (SC, USA)	USA	Understanding the drivers of the coral disease white syndrome on the Great Barrier Reef. (PhD)	Prof B Willis
Davina Poulos	JCU	Australia	Prior residency effects and the dynamics of fish communities in a changing environment. (PhD)	Prof M McCormick
Kate Quigley	JCU, AIMS	USA	Comparing the efficacy of DGGE, qPCR and Next Generation Sequencing molecular techniques to detect and quantify background abundances of *Symbiodinium* types in coral symbioses. (MAppSc awarded)	Prof B Willis
Paola G. Rachello-Dolmen	UQ, Australian Museum	Italy	Historical changes in marine molluscan assemblages from subtropical Moreton Bay Marine Park, Queensland (Australia). (PhD)	Prof J Pandolfi
Jean-Baptiste Raina	JCU, AIMS	France	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
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 awarded)	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, Dr A Hoey
Jan Robinson	JCU	United Kingdom	Are socio-economic drivers strengthening the relationship between the spatial behaviour of fish and fishers? (PhD)	Dr N Graham, Dr J Cinner, Dr G Almany
Dominique Roche	ANU, JCU	Canada	Bio-physical interactions and predator-prey relationships in coral reef fishes. (PhD)	Prof D Yellowlees
Melissa Rocker	JCU, AIMS	USA	Effects of local and global stressors on the energy budgets and fitness of inshore reef-building corals. (PhD)	Prof B Willis
Giverny Rodgers	JCU	Australia	Impacts of temperature on adaptability of a coral reef fish population close to its thermal limit. (PhD)	Prof M McCormick, Prof P Munday
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
Liza Roger	UWA	United Kingdom	Boron isotopic systematics in pteropod shell & links to seawater pH. (PhD)	Prof M McCulloch
Theresa Rueger	JCU	Germany	Reproduction and habitat use in reef fishes. (PhD)	Prof G Jones

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Jimena Samper-Villarreal	UQ	Costa Rica	Carbon sequestration by seagrasses in Moreton Bay. (PhD)	Prof P Mumby
Yui Sato	JCU, AIMS	Japan	Ecology and microbiology of black band disease: new insights into the etiology of an old coral disease. (PhD awarded *cum laude*)	Prof B Willis
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
Travis Shute	JCU	USA	Predatory fish ecology of Kimbe Bay, Papua New Guinea. (MAppSc awarded)	Prof G Jones, Prof M McCormick
Tiffany Sih	JCU	USA	Evidence for near-reef chemical signatures in the otoliths of pre-settlement damselfishes. (MSc)	Prof M Kingsford
Jennifer Smith	JCU	Canada	Influence of patch dynamics on coral reef fishes on the southern Great Barrier Reef. (PhD)	Prof G Jones, Prof M McCormick
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
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 awarded)	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	Genetic assessment of population structure and the origin of recruits in brooding corals: understanding population connectivity on the Great Barrier Reef on various timescales. (PhD awarded)	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, Dr A Hoey
Svetlana Ukolova	JCU	Russia	Characterisation of the Wnt signalling system in *Acropora*. (PhD awarded)	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
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 P Munday, Dr B Leggat
Jennifer Vick	JCU	USA	Spatial and temporal patterns in the foraging of carnivorous fishes on coral reefs. (MAppSc)	Prof G Jones

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisors
Francisco Vidal Ramirez	UQ	Chile	Effect of possible future seawater environments on sea cucumbers and the sediments they process. (PhD)	A/Prof S Dove
Estefania Maldonado Villacis	JCU	Ecuador	Biological conservation planning for multiple species habitat restoration in Ecuador. (PhD)	Prof R Pressey
Peter Waldie	JCU, UQ	Australia	Toward the ecosystem-based co-management of exploited brown-marbled grouper spawning aggregations. (PhD)	Dr G Almany, Dr J Cinner
Patricia Warner	JCU, AIMS	USA	Evolutionary and ecological connectivity at hierarchical scales from sperm to species in the reef-building coral genus *Seriatopora.* (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
Megan Welch	JCU	USA	Transgeneration effects of CO_2 on personality traits. (MSc)	Prof P Munday, Prof M McCormick
Justin Welsh	JCU	Canada	Evaluating the spatial scale of ecosystem functions on coral reefs. (PhD)	Prof D Bellwood, Prof S Connolly
Colin Wen	JCU	Taiwan	Recruitment hotspots and their role in the ecology and management of large exploited predatory fishes. (PhD awarded)	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
Wiebke Wessels	JCU, ANU	Germany	Genetic and molecular basis of coral embryonic development. (PhD)	Prof D Miller, Dr S Foale
James White	JCU, AIMS	USA	Personality and predation risk in fishes. (MSc)	Prof M McCormick, Dr M Meekan
Paul Whittock	JCU	United Kingdom	Understanding risk to marine turtles from expanding industrial development in northern Western Australia. (PhD)	Dr A Grech
Kumara Anura Wickrama Arachchige	JCU	Sri Lanka	Coral disease in Kimbe Bay, Papua New Guinea. (MAppSc)	Prof B Willis
Jessica Williams	JCU	Australia	Searching for practical solutions to sea turtles poaching in Mozambique. (PhD)	Dr M Fuentes
Laura Woodings	JCU, AIMS	Australia	Variation in gene expression, growth, and lipid content between colour morphs of *Acropora millepora.* (MAppSc)	Prof B Willis
Erika Woolsey	JCU, U. Sydney	USA	Reefs on the edge: coral biogeography and larval ecology in a warming ocean. (PhD)	Dr A Baird, Dr S Keith
Shreya Yadav	JCU	India	Vertical migration, swimming and orientation: behavioural studies on *Copula sivickisi* (*cubozoa*). (MAppSc awarded)	Prof M Kingsford
Matthew Young	JCU	Australia	Reef fishing: a social ecological perspective. (PhD)	Prof D Bellwood, Dr S Foale
Dan Zeh	JCU, AIMS	USA	The potential of using data-logging acoustic receivers to study the movements and residency patterns of dugongs in port environments: a comparison with satellite tracking. (PhD)	Dr A Grech

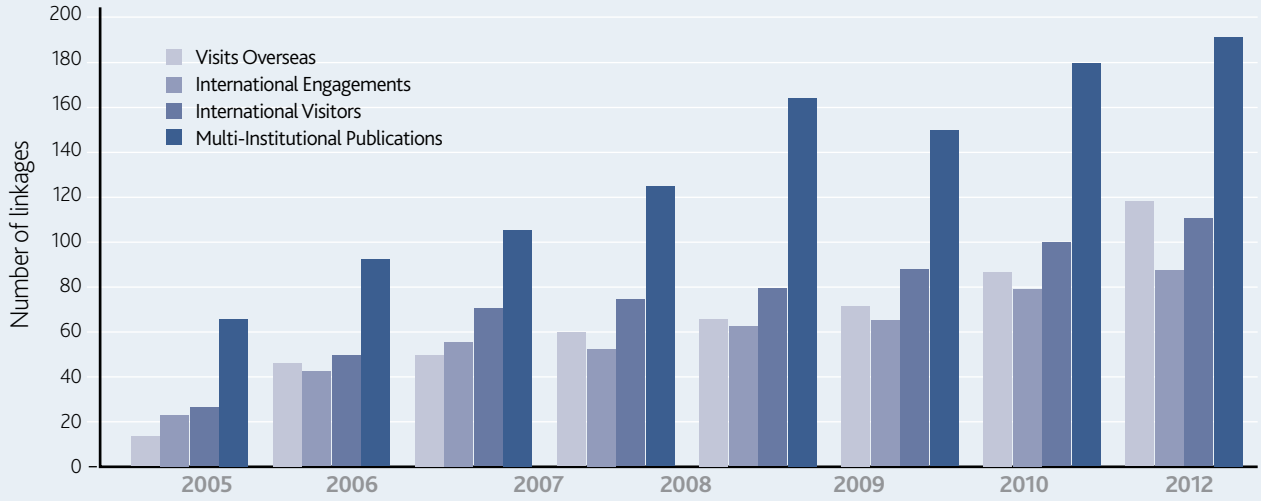
“Your support meant that I could not only attend ICRS 2012, probably the single most exciting event I’ve ever been to, but present my PhD research to the coral community on modelling reef futures.”

– Emma Kennedy, PhD student, University of Exeter, UK

Photo by: Gergely Torda

NATIONAL AND INTERNATIONAL LINKAGES

The Centre's international linkages in 2005 to 2012
All four metrics have shown strong growth



The ARC Centre is a global hub for coral reef science collaboration. The Centre's linkages are illustrated by multi-institutional publications, visits to overseas institutions and by the number of visiting researchers we host at all four nodes of the ARC Centre. Our research profile and reputation have attracted hundreds of overseas postgraduate students to Australia, and in 2012 they have come from 45 countries (p35). Centre personnel are also actively involved in many international research consortia and in activities such as field work, consultancies, editorial boards and end-user engagement in many countries. A major boost to the Centre's profile was achieved by our decision to convene the *12th International Coral Reef Symposium* in July 2012, when we hosted a very large cross-section of the international research community (p52). Over 2,100 delegates from 80 countries attended the Symposium.

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 ARC Centre's Program Leaders (Terry Hughes, Malcolm McCulloch and Bob Pressey) are Fellows of the *Australian Academy of Science*. In 2012, the ARC Centre produced 195 publications with cross-institutional co-authorship (compared to 88 in 2006), involving researchers from 334 institutions in 56 countries. The ARC Centre participated in or convened 41 international working groups during 2012. During the year, we hosted 104 international visitors from 32 countries, and ARC Centre personnel travelled to 36 countries.

The ARC Centre's major international collaborations in 2012 include:

International Programme on Ecosystem Change and Society (PECS)

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. 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* projects such as Analysis, Integration and Modeling of the Earth System

- International Human Dimensions Programme (*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, have collaborations in several countries. TNC depends on sound scientific knowledge to accomplish its mission, and works closely with the Centre on many fronts. For example, throughout 2012, Future Fellow Glenn Almany was seconded from the Centre's JCU node to TNC's Brisbane office, to work with researcher Alison Green, senior marine scientist for the TNC's Asia-Pacific Program. This collaboration focusses on reef connectivity and the design of networks of coral reef marine protected areas in the Coral Triangle region. TNC and Program 6 Leader, Bob Pressey, also undertook ongoing collaborations in 2012, focusing on conservation planning and seascape approaches to coastal management in the Coral Triangle.

The Stockholm Resilience Centre

The ARC Centre of Excellence for Coral Reef Studies and the Stockholm Resilience Centre (SRC) collaborate in several areas of mutual interest. Both Centres undertake trans-disciplinary research that underpins adaptive governance of interlinked social-ecological systems. 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 recent Board member of the Beijer Institute. As part of this ongoing collaboration, more than a dozen postdoctoral fellows and PhD students have travelled between Australia and Sweden to work on joint projects, including Örjan Bodin, Albert Norström, Magnus Nyström, Per Olsen, Terry Hughes, Natalie Ban, Joshua Cinner, Louisa Evans, Nick Graham and Christina Hicks.

WorldFish

WorldFish is an international non-profit scientific agency working in Africa, Asia and the Pacific to *'reduce poverty and hunger through improving fisheries and aquaculture'*. WorldFish has a global staff of about 330, permanent offices in seven countries and ongoing projects in 25 countries. In 2009, James Cook University and WorldFish established a Memorandum of Understanding to build new collaborative links. In 2011, WorldFish researcher David Mills moved from Penang to Australia, to take up a 3-year secondment in the ARC Centre at JCU. Neil Andrew from WorldFish joined the Centre's Advisory Board in 2011. Several of the ARC Centre's researchers, notably Louisa Evans, Bob Pressey, Simon Foale and PhD student Pip Cohen, have substantial collaborative projects with WorldFish in the Solomon Islands, elsewhere in the Coral Triangle region, and in east Africa.

The ARC Centre is continuously expanding its international linkages to equivalent and complementary research organisations. For instance, in 2012, we have been developing new interactions with the Center for Ocean Solutions at Stanford University and a French Centre of Excellence for Coral Reefs based in Perpignan. These initial collaborations are already resulting in multiple publications and research projects, exchange of researchers and recruitment of co-funded postdoctoral fellows.

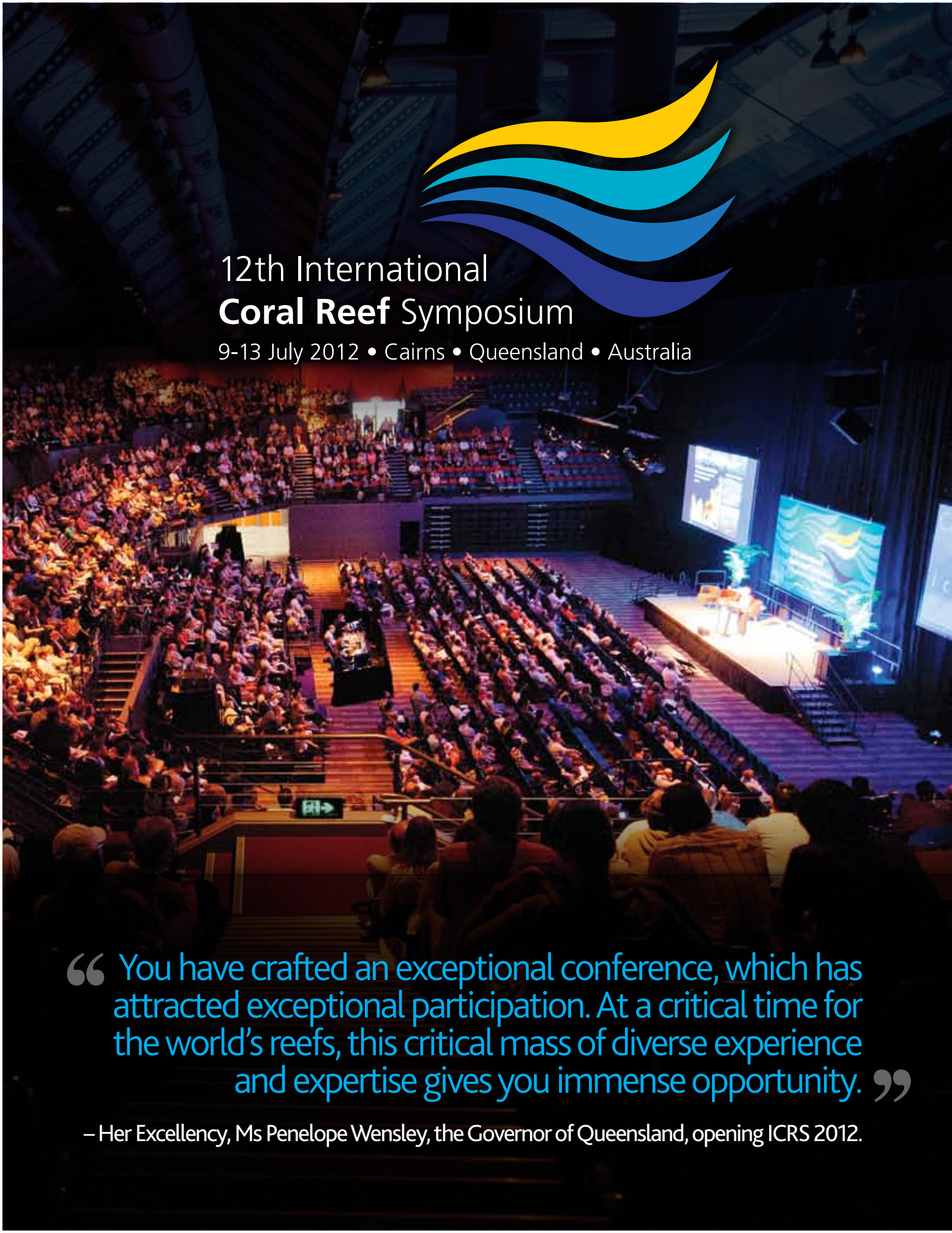
Overseas visiting researchers and end-users

In 2012, 104 international visitors were hosted by one or more nodes of the ARC Centre, or attended working group meetings organised by the Centre.

International visitors to the ARC Centre of Excellence for Coral Reef Studies in 2012

Visitor	Organisation	Country
Dr Rene Abesamis	Silliman University	Philippines
Renerio Acosta	United States Agency for International Development	Thailand
Dr Maja Adamska	Sars International Centre for Marine Molecular Biology	Norway
Anna-Maria Addamo	National Museum of Natural Sciences	Spain
Dr Greta Aeby	Hawai'i Institute of Marine Biology	USA
Soifa Ahamed	Association d'Intervention pour le développement et l'Environnement	Comoros
Prof Denis Allemand	University of Nice-Sophia Antipolis	France
Vincent Amelie	Ministry of Environment, Natural Resources and Transport	Seychelles
Chantal Andrianarivo	Madagascar National Parks	Madagascar
Hafifa Assoumani	Institut National de Recherche pour l'Agriculture la Peche et l'Environnement	Comoros
Dr Chris Barnes	University of Victoria	Canada
Anthony Bellantuono	University of Louisiana	USA
Randriamanantsoa Bemahafaly	Wildlife Conservation Society	Madagascar
Dr Noam Ben-Moshe	Interuniversity Institute for Marine Studies in Eilat (Red Sea) and Ben-Gurion University	Israel
Dr Michael Berumen	Red Sea Research Center, King Abdullah University of Science and Technology	Saudi Arabia
Sean Bignami	University of Miami	USA
Dr Orjan Bodin	Stockholm University	Sweden
Prof Andrew Brierely	University of St Andrews	United Kingdom
Margaux Carmichael	University Pierre et Marie Curie	France
Dr Russell Chalmers	South African Institute for Aquatic Biodiversity	South Africa
Akilananda Chellapermal	Centre de Documentation, de Recherches, et de Formation Indianocéaniques	Mauritius
Prof Doug Chivers	University of Saskatchewan	Canada
Prof Mary Alice Coffroth	State University of New York	USA
Emily Darling	Simon Fraser University	Canada
David Derand	The Centre for Environment & Education	Seychelles
Dr Rodolphe Devillers	Memorial University of Newfoundland	Canada
Dr Paolo Domenici	Istituto per l'Ambiente Marino Costiero	Italy
Jay Dunbar	Columbia University, New York	USA
Prof Jonathan Erez	The Hebrew University of Jerusalem	Israel
Dr Maud Ferrari	University of Saskatchewan	Canada
Soren Franzenburg	University of Kiel	Germany
Dr Jörg Frommlet	Universidade de Averiro	Portugal
Prof Gabi Gerlach	Oldenburg University	Germany
Amelia Grant-Mahony	Department of Fisheries and Oceans	Canada
Dr David Greenwood	Brandon University	Canada
Dr Craig Grove	Royal Netherlands Institute for Sea Research	The Netherlands
Alawi Haji Hija	Department of Environment	Zanzibar
Dr Benjamin Halpern	National Center for Ecological Analysis and Synthesis	USA
Shannon Hanson	Newcastle University	United Kingdom
Ralison Harifidy	WWF Madagascar & Western Indian Ocean Programme Office	Madagascar
Lisa Holland	Ruhr University	Germany
Dr Nicole Hondow	University of Leeds	United Kingdom
Fathima Iftikar	University of Auckland	New Zealand
Prof Xabier Irigoyen	Red Sea Research Center - King Abdullah University of Science and Technology	Saudi Arabia
Prof Jeremy Jackson	International Union for Conservation of Nature	USA
Prof Jamaluddin Jompa	Hasanuddin University	Indonesia
Dr Peter Kareiva	The Nature Conservancy	USA
Dr Shaun Killen	University of Glasgow	United Kingdom
Maurice Knight	US Coral Triangle Support Partnership	USA
Meera Koonjul	Ministry of Fisheries and Rodrigues	Mauritius
Dr Roland Kröger	University of York	United Kingdom
Prof Bruno Lapeyre	Centre de Recherche de Biochimie Macromoleculaire du CNRS	France

Visitor	Organisation	Country
Prof Howie Lasker	State University of New York	USA
Christophe Legrand	Indian Ocean Commission	Mauritius
Prof Jane Lubchenco	National Oceanic and Atmospheric Administration	USA
Daniel Luck	Hawaii Pacific University	USA
Dr Aaron MacNeil	Australian Institute of Marine Science	Canada
Pauline Malterre	PARETO Ecoconsult SARL	France
Dr Stefanie Manel	University of Montpelier	France
Prof Mikhail Matz	University of Texas	USA
Dr Jeff Maynard	Maynard Consulting	USA
Prof Tim McClanahan	Wildlife Conservation Society	Kenya
Laura McMonagle	British Museum	United Kingdom
Dr Malte Meinhausen	Potsdam Institute for Climate Impact Research	Germany
Dr David Mills	WorldFish	Malaysia
Dr Nicholas Mitchell	University of Hohenheim and University of Applied Sciences	Germany
Dr Paolo Montagna	Istituto di Scienze Marine (ISMAR)	Italy
Keereejee Moorooven	Indian Ocean Commission	Mauritius
Dr Andrea Morash	Cambridge University	United Kingdom
Prof David Mouillot	University of Montpelier	France
Dr Aurélie Moya	Centre National de la Recherche Scientifique	France
Dr Nyawira Muthiga	Wildlife Conservation Society	Kenya
Prof Goran Nilsson	University of Oslo	Norway
Mahen Nuvin Khedah	Indian Ocean Commission	Mauritius
Hamza Makame Omar	Community Development and Environmental Conservation	Zanzibar
Prof Robert Pontius	Clark University	USA
Tyler Poppenweimer	College of Wooster	USA
Karine Pothin	GIP Reserve Marine Naturelle de la Réunion	La Reunion
Jean Pascal Quod	PARETO Ecoconsult SARL	La Reunion
Prof David J. Randall	City University of Hong Kong	Hong Kong
Jean Maurice Ravina	Mauritius Research Council de Rodrigues	Rodrigues
Prof Robert Richmond	International Society for Reef Studies	USA
Jan Robinson	Seychelles Fishing Authority	Seychelles
Jennifer Selgrath	University of British Columbia	Canada
Dr Joao Serodio	Universidade de Averiro	Portugal
Dr Philip Shearman	University of Papua New Guinea	Papua New Guinea
Dr Chuya Shinzato	Okinawa Institute of Science and Technology	Japan
Dr Kotaro Shirai	University of Tokyo	Japan
Dr Umesh Srinivasan	National Centre for Biological Sciences	India
Dr Jonathan Stecyk	University of Alaska	USA
Prof Robert Steneck	University of Maine	USA
Prof Jaroslaw Stolarski	Polish Academy of Sciences	Poland
John Tanzer	WWF	Switzerland
Dr Lydia Teh	University of British Columbia	Canada
Dr Louise Teh	University of British Columbia	Canada
Dr Maria Thorell	Calluna Consultancy & International Advisory Committee on Biosphere Reserves (UNESCO)	Sweden
Renee van der Locht	University of York	United Kingdom
Dr Piero Visconti	Microsoft Research – Computational Ecology	United Kingdom
Dr Petra Visser	University of Amsterdam	Netherlands
Prof Robert Warner	University of California	USA
Dr Tsuyoshi Watanabe	Hokkaido University	Japan
Dr Jorge Wiedenmann	Southampton University	United Kingdom
Dr Joanne Wilson	The Nature Conservancy	Indonesia
Mr James Wise	Ambassador to Thailand	Thailand



12th International **Coral Reef** Symposium

9-13 July 2012 • Cairns • Queensland • Australia

> “You have crafted an exceptional conference, which has attracted exceptional participation. At a critical time for the world’s reefs, this critical mass of diverse experience and expertise gives you immense opportunity.”

– Her Excellency, Ms Penelope Wensley, the Governor of Queensland, opening ICRS 2012.

CORAL
REEF
STUDIES

12th International **Coral Reef** Symposium
9-13 July 2012 • Cairns • Queensland • Australia

OUTCOMES REPORT

The 12th International Coral Reef Symposium (ICRS 2012), held in Cairns from 9th to 13th July 2012, was hosted by the Australian Research Council Centre of Excellence for Coral Reef Studies and James Cook University. This major event attracted more than 2,000 delegates from 80 countries. The delegates included more early career researchers than in any previous meeting, securing the future of coral reef research. Generous support from sponsors also provided an unparalleled number of grants to assist attendance. Delegates presented the largest and most comprehensive scientific program in the history of ICRS, including nine outstanding plenary talks and over 1,500 presentations in 12 concurrent sessions. The focus on coral reef science and management was highlighted by the unveiling of the *Consensus Statement on Climate Change and Coral Reefs*, endorsed by >3,000 scientists. Media coverage of this Statement and the Symposium in general was unprecedented, with over 2,500 stories reported across the world.

ICRS 2012 illustrated the growing evolution of coral reef science and provided a timely opportunity for the global research community to present the cutting edge findings necessary for the conservation and management of reefs around the world. Climate change and ocean acidification along with chronic anthropogenic factors and their impacts on bleaching, diseases and Crown of Thorns starfish were major topics of discussion. Conservation planning, coral reef management and the social and economic dimensions of coral reefs were also major themes, with more talks on these topics than any previous ICRS. These issues featured heavily in the eight plenary talks and in the Darwin Medal lecture, the Press Briefings and stories emanating from ICRS 2012.

Delegates

Two thousand and eighty one delegates from 80 countries around the world attended the quadrennial meeting of coral reef scientists, which is sanctioned by the International Society for Reef Studies. The geographical location of each meeting is a major factor affecting the mix of delegates. Consequently, although the largest attendance at ICRS 2012 continued to be from the USA (457 delegates) and Australia (622), we saw a marked increase in representation from the six Coral Triangle countries (129) and South-East Asia (204) compared to the delegates attending ICRS 2008 in Florida. Of particular note was the number of early career researchers, including 531 student delegates.

Opening Ceremony

The week began with a welcome from the Convenor of the Symposium, Terry Hughes, followed by an inspirational introduction from the Governor of Queensland, Her Excellency Ms Penelope Wensley AC, about her concern for the environment and sustainable development, and more specifically her interest in coral reefs through her involvement as an Australian diplomat with the International Coral Reef Initiative. The Queensland Premier was represented by Michael Trout MP who spoke of the benefits that hosting the Symposium brought to the region and the importance of protecting the Great Barrier Reef. Bob Richmond, the President of the International Society for Reef Studies, then launched the *Consensus Statement on Climate Change and Coral Reefs*.

Consensus Statement on Climate Change and Coral Reefs

The *Consensus Statement* was drafted by a working group of eminent scientists, brought together under the auspices of The Center for Ocean Solutions, to address the topic of climate change impacts on coral reefs. The invitation to endorse the statement was issued by three of the authors, Steve Palumbi, Bob Richmond and Terry Hughes. As of 1st August 2012 there were 3,150 endorsees. The *Consensus Statement* drew attention from around the world and formed the basis of a well reported Press Briefing on the first morning of ICRS 2012 in Cairns that resulted in over 600 media stories.

Plenary Talks

The eight plenary talks and Darwin Medal lecture highlighted many of the major research themes and challenges faced by coral reef scientists and managers in today's environment. All of these high profile talks injected unique perspectives, documented significant

advances in coral reef science, and were challenging, thought provoking, and entertaining.

The Plenary speakers, in order of appearance, were Jane Lubchenco, Jamaluddin Jompa, Denis Allemand, Geoffrey Jones, Peter Kareiva, Helene Marsh, Madeleine van Oppen and Ove Hoegh-Guldberg. Jeremy Jackson *(pictured)* delivered the Darwin Medal lecture.

Scientific Sessions

There were 72 *Mini-Symposia* aggregated into 22 Symposia Themes. They provided the framework for 1,300 talks and 225 posters presented by the delegates at ICRS 2012. The program had 12 concurrent sessions across two adjoining venues, the Cairns Convention Centre and the Sebel Hotel. The program was designed to maximise the number of delegates who were afforded the opportunity to speak, resulting in a 25% increase in the size of the oral program compared to ICRS 2008. The speed talks were a new innovation and proved to be a successful and stimulating addition.

Traditional coral reef science featured prominently in the scientific sessions, interspersed with new technologies: the growing influence of genomics, an increase in the use of remote sensing, robots and sensor networks. Many research areas have expanded since 2008, and the program reflected the increased interest in ocean acidification, climate change, coral bleaching, and in modeling the dynamics of reefs into the future. However, the major expansion was in the areas of conservation planning, management and social sciences. One specialised theme in this vein was The Coral Triangle Initiative, which attracted 61 presentations.

The Coral Triangle Initiative

The Coral Triangle Initiative theme attracted great interest in the 2012 Symposium. Two and a half days were specifically devoted to the Coral Triangle (CT) during which speakers from the six CT countries spoke along with others who are actively contributing to research in the region. These sessions followed on from a highly successful meeting held on the Saturday preceding ICRS 2012, which unveiled the State of the Coral Triangle Report. This satellite meeting was attended by 130 delegates - most also attended ICRS 2012 – of whom a number were senior representatives of each of the six Coral Triangle countries.

ICRS 2012 Photographic competition's Best in Show, taken by Kemit-Amon Lewis in the Bahamas

Media Uptake

As in previous years, the media outreach from ICRS 2012 was ably managed by *SeaWeb* under the guidance of Kristian Teleki and Scott Radway. They recruited eleven journalists from developing countries; co-ordinated the media workroom for journalists, the daily Press Briefings, managed social media exposure and distributed media releases around the world. They were helped by Melissa Lyne who expertly dealt with the Australian media. This effort resulted in an extremely high media profile for ICRS 2012, with over 2,500 stories and interviews logged during the week long Symposium. The *Media Portal* including the streaming of the Press Briefings is accessible from the ICRS 2012 web site.

Future Forum

Associated with ICRS 2012, the Australian Broadcasting Corporation, in collaboration with James Cook University, recorded a one-hour "Future Forum" television program at the Cairns Cruise Liner Terminal entitled *Can coral reefs survive the 21st century?* A diverse panel with expertise in the science, management, and goods and services provided by coral reefs discussed the topic and answered questions from an interested and informed audience.

Web site

The ICRS 2012 web site (www.icrs2012.com) has been a major communication and outreach tool, with 8.9 million hits since February 2010. It has been used not only for those attending the Symposium, but also for anyone interested in coral reefs. Indeed, many scientists and reef managers who did not come to Cairns nonetheless experienced the Symposium through the web site, accessing the daily editions of *Coral News* and viewing the Plenary talks which were available online on the same day as the live presentations. The web site will remain as a permanent resource into the future, providing access to the Symposium Proceedings, the 1,500 abstracts, plenary talks, uploaded posters, photographs, and Press Briefings.

Innovations at ICRS 2012

A number of new features were introduced at ICRS 2012. The feedback from delegates suggests that they were a success and added to the value of the Symposium. The major innovations were:

- The Welcome Reception was held on the evening prior to the opening of ICRS. This provided a focus for delegates to meet and greet before talks commenced, and was enjoyed by >1,500 delegates;
- Art by North Queensland primary school students featured in all delegate name badges;
- A comprehensive daily newspaper, *Coral News,* was published onsite and online each day. It featured the previous day's science and events and the highlights for the coming day;
- Memory sticks were distributed at registration containing the scientific program, abstracts, a list of delegates, and notably, the Proceedings. All these functions were searchable, providing access to the content and outcomes of ICRS 2012;
- All Plenary talks were loaded onto the ICRS 2012 web site within a couple of hours of presentation and are freely available for viewing;
- Speed talks were included in the program to offer as many delegates as possible an opportunity to talk, which is often a requirement for attendance by delegates; and
- All Press Briefings were streamed on the Media Portal by *SeaWeb*.

Proceedings of the 12th ICRS

The ICRS Proceedings have in the past taken a protracted period to complete, long after the Symposium. The Executive decided for ICRS 2012 that the Proceedings would be available electronically, for distribution to delegates at registration on the first day of the Symposium. The *Proceedings* are on the ICRS 2012 website, and are also available from *ReefBase*.

Financial Support for Delegates

Funding was obtained by the ICRS 2012 Fundraising Committee from a number of sources, to support the costs of delegates to attend ICRS 2012. The funds were targeted at postgraduate students and early career scientists and in particular, those from developing nations, the Coral Triangle countries and the south west Pacific. We sincerely thank the sponsors for their generosity which enabled 120 people from 40 countries to offset their costs of registration, accommodation and/or travel, more than any previous ICRS meeting.

Symposium Committees

International *Committees* were established to organise the scientific program, the field trips, and to raise $1 million in sponsorship funds. The hosts would like to thank all the members on these Committees for their time and expertise. A listing of all Committees can be accessed at www.icrs2012.com.

Sponsors

The generous support of sponsors is crucial to the success of ICRS. Thank you to those sponsors who repeatedly back ICRS and to those sponsors who supported for the first time in 2012. A listing of sponsors can be viewed at www.icrs2012.com. We applaud your commitment to supporting coral reef science.

In Conclusion

ICRS 2012 was an extremely successful quadrennial meeting of the coral reef science community. The scientific program showcased the latest in coral reef research and demonstrated how scientific knowledge contributes to the sustainable use of coral reefs. The next ICRS, to be held in 2016, will be in Hawai`i and will be convened by Bob Richmond and his team at the University of Hawai`i.

Terry Hughes
ICRS 2012 Convenor

Consensus Statement on Climate Change and Coral Reefs

In May 2012, scientists from around the world were invited to endorse a Consensus Statement urging governments to take action for the preservation of coral reefs for the benefit of present and future generations. The Consensus Statement was drafted by a working group of eminent scientists, brought together under the auspices of The Center for Ocean Solutions at Stanford University, to address the topic of climate change and coral reefs. The working group, chaired by Steven Palumbi, includes three senior members of the ARC Centre of Excellence – Terry Hughes, Ove Hoegh-Guldberg and John Pandolfi. To build a large base of support, the Consensus Statement was launched by Bob Richmond, President of the International Society for Reef Studies, during the opening ceremony of the 12th International Coral Reef Symposium, on July 9th, in Cairns, Australia. The Consensus Statement received global media coverage during the Symposium. So far, an unprecedented 3,200 scientists have endorsed the statement.

Consensus Statement on Climate Change and Coral Reefs

The international Coral Reef Science Community calls on all governments to ensure the future of coral reefs, through global action to reduce the emissions of carbon dioxide and other greenhouse gases, and via improved local protection of coral reefs.

Coral reefs are important ecosystems of ecological, economic and cultural value yet they are in decline worldwide due to human activities. Land-based sources of pollution, sedimentation, overfishing and climate change are the major threats, and all of them are expected to increase in severity.

Changes already observed over the last century:

- Approximately 25-30% of the world's coral reefs are already severely degraded by local impacts from land and by over-harvesting.
- The surface of the world's oceans has warmed by 0.7°C, resulting in unprecedented coral bleaching and mortality events.
- The acidity of the ocean's surface has increased due to increased atmospheric CO_2.
- Sea-level has risen on average by 18cm.

By the end of this century:

- CO_2 emissions at the current rate will warm sea surface temperatures by at least 2-3°C, raise sea-level by as much as 1.7 meters, reduce ocean pH from 8.1 to less than 7.9, and increase storm frequency and/or intensity. This combined change in temperature and ocean chemistry has not occurred since the last reef crisis 55 million years ago.

Other stresses faced by corals and reefs:

- Coral reef death also occurs because of a set of local problems including excess sedimentation, pollution, habitat destruction, and overfishing.
- These problems reduce coral growth and vitality, making it more difficult for corals to survive climate changes.

Future impacts on coral reefs:

- Most corals will face water temperatures above their current tolerance.
- Most reefs will experience higher acidification, impairing calcification of corals and reef growth.
- Rising sea levels will be accompanied by disruption of human communities, increased sedimentation impacts and increased levels of wave damage.
- Together, this combination of climate-related stressors represents an unprecedented challenge for the future of coral reefs and to the services they provide to people.

Across the globe, these problems cause a loss of reef resources of enormous economic and cultural value. A concerted effort to preserve reefs for the future demands action at global levels, but also will benefit hugely from continued local protection.

ABC TV FUTURE FORUM: CAN CORAL REEFS SURVIVE THE 21ST CENTURY?

How can we ensure the continued survival of the remaining coral reefs? Are marine parks the only solution? And how can we juggle the food and energy needs of the world's growing population while sustaining coral reefs for future generations? To debate these issues the ARC Centre worked closely with ABC 24, who produced a one hour televised forum, hosted by Robyn Williams, well-known science journalist and ABC broadcaster. Robyn was joined by a panel of leading experts and practitioners comprising:

- Meg Caldwell, Executive Director, Centre for Ocean Solutions and Stanford Law School
- Daniel Gschwind, CEO, Queensland Tourism Industry Council
- Terry Hughes, Director, ARC Centre of Excellence Coral Reef Studies, James Cook University
- Jeremy Jackson, Darwin Medallist, Scripps Institution of Oceanography
- Helene Marsh, Professor of Environmental Science, James Cook University
- Agnetha Vave-Karamui, Chief Conservation Officer, Coral Triangle Initiative, Solomon Islands

The Program, filmed before an informed live audience, is available online at *www.abc.net.au/news/2011-08-01/can-coral-reefs-survive-the-21st-century/4121444*

MEDIA AND PUBLIC OUTREACH

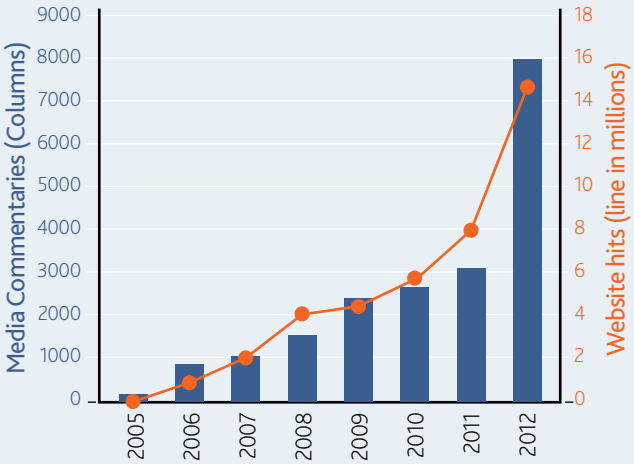
The ARC Centre of Excellence engages with the wider community through the media and through a variety of other outreach activities to exchange knowledge, transfer technologies and research outcomes and to promote understanding, awareness and co-operation in the management of coral reefs.

Our communications strategy is multi-stranded and targeted at the local, national and international levels. We promote our research outcomes through media releases, an engaging website, presenting public lectures, hosting community workshops, convening annual conferences, participating in international symposia, providing government and industry briefings, and by generating reports and brochures on our activities.

Media uptake in 2012 was >7,500 stories, some of which are highlighted below. Media uptake was more than 2.5 times that of 2011. The Centre's media profile has risen hugely in diversity and breadth since 2005 when we reported media uptake of 109 stories.

The Centre's website was redesigned during 2012 to improve access to the Centre's research programs and resources. It caters for multiple audiences, providing information, access to resources, research services, and downloads of research, teaching and educational materials and tools. The Centre's highly popular webinars are now prominently featured and the video series has been expanded so that users can readily select from a range of short, highly topical presentations on issues of interest, as well as longer videos showcasing the latest, leading-edge coral reef science. Social media tools will be further developed during 2013 to amplify the reach of the Centre's research. The website attracted 14.3 million web hits in 2012, almost twice as many as 2011, representing a 24-fold increase since the Centre's original website was launched in 2006.

Media commentaries and web hits of the ARC Centre of Excellence from 2005 to 2012



In 2012, researchers from the ARC Centre participated in 64 public outreach events and programs, reaching audiences locally, nationally and internationally. Examples of our outreach activities include:

- Media coverage of the 12th International Coral Reef Symposium included more than 2,500 stories worldwide across print, radio, television, and online. Strong story angles led to a rich, informative and engaging week of coral reef science. Coverage of the event included articles by the Associated Press, Reuters, Inter Press Service, Agence France-Presse, United Press International, Bloomberg and Australian Associated Press. Stories were also run by wide-reaching and highly influential outlets, such as The New York Times, The Guardian (UK), The Washington Post, USA Today, The Independent, National Public Radio (US), Australian Broadcasting Corporation, Al Jazeera, and the British Broadcasting Corporation.
- Increasingly, we are delivering public lectures by ARC Centre researchers on the Internet, attracting large online audiences. The most far-reaching of these were the nine keynote lectures from the 12th International Coral Reef Symposium, *www.icrs2012.com*. In addition, David Bellwood presented online "Lessons from Coral Reefs" as part of the Pop-Tech video series that brings experts together to work on new approaches to some of the world's toughest challenges. Centre members were also involved in the 60 minute ABC News 24 Forum "Can corals survive the 21st century?" which is also accessible online *www.abc.net.au/news/2011-08-01/can-coral-reefs-survive-the-21st-century/4121444*. On 13 November, David Williamson participated in The Royal Institute of Australia's Science Behind the Headlines panel discussion, "Marine Parks and 'No-Take' Zones" which was live-streamed and is accessible online *http://riaus.org.au/events/science-behind-the-headlines-november/*. In a project led by Ove Hoegh-Guldberg, millions of people worldwide will have access to the undersea world through Google's project to provide 360 degree underwater views of the Great Barrier Reef. Talks by Centre members at the Second Earth System Outlook conference at the Shine Dome (p61X) can be viewed online at *http://science.org.au/events/conferences-and-workshops/earth-system-outlook2/index.html*
- Ove Hoegh-Guldberg's work on the Intergovernmental Panel on Climate Change (IPCC), as coordinating lead author on "Oceans", aims to help communities around the world understand and manage the challenging issue of climate change.
- At local government level, Glenn Almany made a presentation to local government and the public on fisheries management and conservation in the Solomon Islands. At grass roots level, in the Philippines, Mike Fabinyi presented at the Palawan State University and the University of the Philippines on livelihoods and the live reef fish for food trade. In Chagos, Nick Graham spoke on "Fish and coral connectivity across the Indian Ocean" to British fishery officers and

crew on a British Indian Ocean Territory fishery patrol vessel. Bob Pressey spoke on marine coastal planning and management to the general public at the Hasanuddin University, Indonesia.

- Members of the ARC Centre are increasingly being invited to showcase Australia's leadership in coral reef research. At the invitation of the Australian Embassy in the Philippines, Terry Hughes participated in Manila's World Environment Day activities to highlight Australia's leadership and expertise in marine conservation and management and the importance of regional and global cooperation. During his 5-day visit in June 2012, Terry was the keynote speaker at the "Forum on the Coral Triangle Initiative" and presented lectures at the Philippines-Marine Science Institute in Manila and at the Silliman University in the provincial city of Dumaguete. Joining Terry was ARC Centre PhD student Vera Horigue from the Philippines, who shared her experiences as a marine scientist now training in Australia. Terry also made a presentation to students at the Philippines State High School and participated in the launching of the planetarium film "Coral Rekindling Venus film" by the internationally acclaimed Australian artist Lynette Wallworth. Both city and provincial activities attracted large audiences and were well covered by the Philippines media.
- With the aim of improving science communication, Centre of Excellence graduate students have been involved in a series of collaborations with artists in Townsville. Their public art exhibition Artspace presents Incubator involved a three channel video installation entitled "Reefs on the Edge" showcasing coral reef science and art.
- Centre researchers are actively engaged in scientific outreach with school children (p60).

MEDIA STORIES – A FEW EXAMPLES

In 2012, the ARC Centre media releases generated 7,856 media stories that reached local, national and international audiences. Some highlights and the researchers involved include:

International Business Times, *China's Coral Reefs Deteriorates At Expense of Booming Economy* – Study, 28 December 2012, T Hughes

BBC Vietnam, *Biển Đông đang mất gà`n hê´t san hô (Shrinking coral reefs)*, 27 December 2012, T Hughes

Cosmos magazine, *Most read opinion pieces of 2012 – Securing the future of the Great Barrier Reef*, 21 December 2012, T Hughes

Australian Geographic, *Aussies unfit to care for Great Barrier Reef?* 19 December 2012, T Hughes

Solomon Times, *Prioritising Climate Change Adaptations for Fisheries and Aquaculture in Fiji*, 18 December 2012, M Pratchett

Asian Scientist, *Corals Are Retreating From Equator*, Study, 17 December 2012, J Pandolfi

Spiegel Online, *Meeresforschung: Klimaschwankungen verschieben Korallenriffe (Marine research: climate change alters coral reefs)*, 11 December 2012, J Pandolfi

PhysOrg, *Marine reserves 'must adapt to climate change'*, 27 November, B Pressey

Science News, *Naïve Fish: Easy Targets for Spear Fishers*, 13 November 2012, F Januchowski-Hartley

Fox News, Study: *Humans Caused Historic Great Barrier Reef Collapse*, 8 November 2012, J Pandolfi

Discovery Channel Denmark, *Humans Caused Historic Great Barrier Reef Collapse*, 8 November 2012, J Pandolfi

NBC News, *Humans Caused Historic Great Barrier Reef Collapse*: study, 6 November 2012, J Pandolfi

Asia - ABC Radio Australia, *Crown of thorns starfish controller*, 22 October 2012, J Posada-Rivera

Science Codex, *Coral reefs and food security: Study shows nations at risk*, 18 October, J Cinner

LabSpaces.net, *Fisheries benefit from 400-year-old tradition*, 13 October 2012, A Baird, J Cinner M Pratchett

Australian Geographic, *New hope to stop crown of thorns destroying reefs*, 12 October, M Pratchett

Elites TV, *Calcification, Storm Damage and Population Resilience of Tabular Corals under Climate Change*, 5 October 2012, S Connolly

ABC Radio Australia News, *Great Barrier Reef Virtual Tour*, 4 October 2012, O Hoegh-Guldberg

Asian Correspondent, *New research shows Great Barrier Reef in trouble*, 3 October, N Ban

The Conversation, *Crown of Thorns is a symptom of reef decline: let's address the cause*, 3 October 2012, T Hughes

Inter Press Service, *Ocean Acidification Leaves Mollusks Naked and Confused*, 3 October 2012, P Munday

The Telegraph UK, *Great Barrier Reef loses half its coral in 27 years*, 2 October 2012, O Hoegh-Guldberg

Scientific American, *Ocean Acidification Can Mess with a Fish's Mind*, 27 September 2012, P Munday

CTV News, *Google unveils underwater 'street view' of Great Barrier Reef*, 26 September 2012, O Hoegh-Guldberg

The Huffington Post, *Great Barrier Reef Threatened By Warming Waters*, Study Shows, 26 September 2012, N Ban

Independent Media Centre, *Coral reefs being pushed to extinction by global warming*, 23 September 2012, N Ban, S Connolly, O Hoegh-Guldberg, T Hughes, L McCook, P Mumby

The National, *Concern over future of UAE's coral reefs*, 21 September 2012, M Pratchett

Express.co.uk, *Emissions could destroy coral reefs*, 16 September 2012, O Hoegh-Guldberg

Pacific Island News Association, *Ciguatera fish poisoning a significant public health concern in Pacific*, 12 September 2012, T Brewer

Noodls, *Researchers tabulate disturbing changes and disappearance in biodiversity in southern Taiwan coral reefs over last 26 years*, 11 September 2012, A Baird

SeaWeb, *Study Looks at the Increasing Influence of Luxury Seafood Demand On Coastal Communities*, 11 September 2012, M Fabinyi

The Times Eureka's Oceans issue (radio segment and magazine article), *Into the Deep*, 7 September 2012, N Graham

Catalyst ABC TV Science, *Coral Winners*, 30 August 2012, T Hughes

Radio National The Science Show, *Forum on The Great Barrier Reef: Can coral reefs survive the 21st century*, 8 September 2012, T Hughes

The Guardian and The Observer, UK, *Fatal attacks prompt call to lift ban on killing great white sharks*, 25 August 2012, J Pandolfi

Science News online, In Fiji, *Marine Protection Gets Local Boost*, 22 August 2012, V Adams, N Ban, M Mills, B Pressey

UPI, *Scientists warn of marine life extinctions*, 21 August 2012, J Pandolfi

Pacific Beat ABC Radio Australia, *Local strategies might help save coral from warming*, 21 August 2012, O Hoegh-Guldberg

Pacific Island News Association, *New children's book aims to help save endangered dugongs*, 17 August 2012, M Fuentes

Asia - ABC Radio Australia, *Expert says UN Compact will regenerate interest in saving oceans*, 17 August 2012, M McCulloch

I-Newswire, *Coral Reefs Need Immediate Protection, Scientists Said*, 11 August 2012, T Hughes

Science Network WA, *Genetic tracing fish offspring outside Kimberley no-take sanctuaries proposed*, 10 August 2012, G Jones

Science Daily, *Scientists Predict Impact of Ocean Acidification on Shellfish*, 5 August 2012, P Munday

Al Jazeera, *Local control revives depleted fisheries*, 20 July 2012, G Jones

Earth Times, *Fish Competition within Degraded Coral Reef Ecosystems*, 20 July 2012, M McCormick

Inter Press Service News Agency, *Great Barrier Reef at a crossroads*, 18 July 2012, A Grech, L McCook, T Hughes

ECOS magazine, *More reserves, less seaweed for coral reef health*, 16 July 2012, G Jones

The New York Times, *When Coral Reefs Recover*, 16 July 2012

Neues Deutschland, *Die große Korallenkrise (The large coral crisis)*, 16 July 2012

Radio New Zealand International, *Small Pacific marine reserves good for fish and fishermen alike*, 16 July 2012, G Jones

GMA News, *Live fish trade declining in Palawan due to unregulated fishing*, 15 July 2012, M Fabinyi

Press Trust, *Our coral reefs: In trouble - but tougher than we thought*, 15 July 2012, P Mumby, G Roff

National Times, *Coral wonderland at tipping point*, 14 July 2012, J Lough, P Munday

News.com.au, *Nemo faces an acid test in real-life movie sequel*, 14 July 2012, O Hoegh-Guldberg, P Munday

The New York Times, *A World Without Coral Reefs*, 13 July 2012

USA Today, *Ocean acidity major threat to reefs*, 10 July 2012

Science Insider, *Coral Reef Scientists Issue Call for Action*, 10 July 2012

ScienceNewsline, *'We Can Still Save Our Reefs:' Coral Scientist*, 10 July 2012, J Pandolfi

News - Nine MSN and current affairs, *New Qld ports put dugongs 'at risk'*, 10 July 2012, A Grech

Inter Press Service, *Coral Triangle Fights to Save Reefs from Extinction*, 10 July 2012, T Hughes

The Guardian (UK), *Rising ocean acid levels are 'the biggest threat to coral reefs'*. 9 July 2012,

Environmental Research Web, *Fish learn to cope in a high CO_2 world*, 9 July 2012, G Miller, P Munday

Environmental News Service, *Coral Reef Emergency: 2,600 Scientists Call For Worldwide Rescue*, 9 July 2012

BBC News, *Scientists urge action for coral reef protection*, 9 July 2012

The Huffington Post, *Ocean Acidification Is Climate Change's 'Equally Evil Twin,' NOAA Chief Says*, 9 July 2012

Sky News Australia, *More reef protection urged*, 9 July 2012

Big Pond, *Scientists call for action to save reefs*, 9 July 2012

Campus Daily, *Price to save coral reefs is "one year of GDP growth"*, 9 July 2012

Taipei Times, *Coral reefs in rapid decline worldwide, scientists say*, 9 July 2012

ABC 1 Sydney and Melbourne, *Scientists from more than eighty countries gather in Qld for international coral symposium*, 8 July 2012

Newspower Europe, *Time to 'step up' on Great Barrier Reef protection*, 8 July 2012

Asia News Network, *Coral Triangle leaders vow to manage seas together*, 8 July 2012, T Hughes

Science magazine, *Australia Creates World's Largest Network of Marine Reserves*, 22 June 2012, T Hughes

Philippine Information Agency, *Australian environmentalist fears global decline of coral reefs*, 15 June 2012, T Hughes

The Conversation, *New marine reserves won't address UNESCO's Reef concerns*, 14 June 2012, T Hughes

Ocean News & Technology, *Marine Reserves Provide Baby Bonus to Fisheries*, 13 June 2012, H Harrison, G Russ, D Williamson

Scientific American, *Giant Reef Fish Head-Butt Rivals for Sex*, 9 June 2012, D Bellwood

Red Orbit, *Australian Great White Shark Populations Separated by Genetics*, 6 June 2012, J Pandolfi

New Scientist, *DNA suggests marine reserves boost commercial fishing*, 30 May 2012, H Harrison, G Russ

Science Daily, *Weed-Eating Fish 'Help Protect Jobs, Livelihoods'*, 8 May 2012, S Connolly

Campus Daily, *Australia's disappearing sea snakes*, 4 May 2012, V Lukoschek

Nature magazine, *Can coral cope with climate change?* 18 April 2012, T Hughes

Public Radio International, *New research points to big changes, not necessarily disappearance, for coral reefs as climate changes*, 18 April 2012, T Hughes

Phys.Org, *Ocean acidification changes the behaviour of baby coral,* 16 April 2012, P Mumby

Asian Scientist, *Corals with Aragonite Skeletons Could Survive a More Acidic Ocean*, 5 April 2012, J Falter, M McCulloch

Australian Geographic, *Jawless creature had world's sharpest teeth*, 8 March 2012, D Bellwood

Innovations Report, *1 solution to global overfishing found*, 21 March 2012, J Cinner, N Graham, A Baird, F Januchowski-Hartley

Australasian Science, *Parenting comes at a price for male fish*, 18 March 2012, D Bellwood

The Epoch Times (International), *Climate Change May Threaten Mouthbrooding Cardinalfish*, 15 March 2012, D Bellwood, A Hoey

Wild Singapore, *Australia: disappearing underwater world*, 10 March 2012, D Miller, J Pandolfi

Discovery News, *Google Street View Goes Under The Sea*, 25 February 2012, O Hoegh-Guldberg

Australasian Science, *Carbon dioxide 'is driving fish crazy'*, 23 February 2012, P Munday

ABC Radio Australia Pacific Beat, *Scientists want more protection for Australia's Coral Sea*, 16 February 2012, T Hughes

United Press International, *Importance of corals to fish studied*, 13 February 2012, J Kerry, D Bellwood

Mail and Guardian online, *Carbon dioxide 'driving fish mad',* 13 February 2012, P Munday

BBC News - Science & Environment, *Overfishing 'costs EU £2.7bn each year'*, 13 February 2012, J Cinner.

CENTRE RESEARCHERS BOOST SCIENCE IN SCHOOLS

The ARC Centre of Excellence is showcasing Australia's research expertise to the next generation, by actively engaging in novel and diverse ways with school children, both in Australia and abroad. The Centre builds Australia's human capacity in coral reef research by attracting, from within Australia and abroad, researchers of high international standing as well as the most promising research students. The Centre provides a high-quality postgraduate and postdoctoral training environment for the next generation of coral reef researchers, and it serves as a hotspot of engagement between higher education institutions and the broader community, including schools.

"A logical part of our ARC Centre's activities is to promote cutting-edge science in primary and secondary schools, both in Australia and abroad," says Professor Terry Hughes, Director of the ARC Centre of Excellence for Coral Reef Studies.

"Our outreach activities with children and their teachers involve face-to-face activities in dozens of schools across Australia, the production of children's books, videos and webinars, our website materials, as well as providing advice to governments on curriculum content and delivery."

In Western Australia, for example, Centre researchers contribute to SPICE *http://spice.wa.edu.au*, a secondary teachers' enrichment program that provides science teachers with access to professional development, and opportunities for interaction with leading scientists.

In New South Wales, ARC Centre researchers are working with members of the Marine Teachers Association of NSW, to educate high school students in years 8-12, in rural and regional areas (including schools in Eden, Bega, Moruya, Nowra, and Ulladulla). Issues discussed include how scientific research helps us to design and monitor marine protected areas, and what the work of a marine scientist can involve.

In Queensland, the ARC Centre's PhD students participate as Young Science Ambassadors in a science education promotional scheme of the Australian Academy of Technological Sciences and Engineering. This encourages school-aged students to pursue a career in science. In 2012, graduate students contributed to a new program, The Wonder of Science Challenge, which connects students and their teachers at rural, remote and indigenous schools with young scientists and industry ambassadors, and encourages them to complete small research projects. The schools involved range from Cairns to Mt. Isa to Townsville (and everywhere in-between).

Centre researchers also play rewarding roles as Scientists in Schools, building partnerships with primary school teachers and students. Peak activities this year occurred during Science Week, when for example, Professor Morgan Pratchett set up a series of fish tanks and taught Grade 2 students how to measure salinity and temperature conditions that are suitable for raising fishes.

In addition to the school program, the coral reef ARC Centre also contributes to Nova: Science in the News, run by the Australian Academy of Science, through its *Science for Sustainable Reefs* topic *www.science.org.au/nova/117/117key.html*. The goal of Nova is to provide reliable and up-to-date information for science teachers, students, journalists and anyone who is interested in learning more about the science that is behind topical issues. The Centre's own website which attracted 14 million hits in 2012, also provides a large selection of material for children and school teachers.

Learning to rescue endangered species

Thanks to a new book, Australia's children are being enlisted in the fight to save dugongs from the multiple risks of habitat loss, climate change, and environmental pollution. 'Dhyum the Dugong' *https://www.coralcoe.org.au/wp-content/uploads/2012/10/dhyum-the-dugong.pdf*, published this year and authored by ARC Super Science Fellow, Dr Mariana Fuentes, takes the reader on a charming journey through the dugong's life, from how they are born to how we can protect them. Apart from being distributed to schools across the Torres Strait, the book will also be used by the Torres Strait Regional Authority as part of their environmental education program.

"Dugongs have great cultural and social importance to Australia's Indigenous peoples living near the Great Barrier Reef and in Torres Strait," says Dr Fuentes. "One of the main reasons I wrote the book was to help children and the general public appreciate how we can use science to look after endangered animals".

"The story includes information on how dugongs move from Torres Strait to Papua New Guinea, so now communities in both countries are working together to help protect them".

Art meets science

The Centre of Excellence engaged with the local community at many levels in hosting the International Coral Reef Symposium held in Cairns in July 2012, and enlisted the artistic skills of more than 2,000 local primary school-aged children from North Queensland. The children contributed to the Symposium by decorating a card, inspired by the Great Barrier Reef, which were displayed on each delegate's name badge. These delightful images not only charmed the scientific delegates from 80 countries, but they also increased awareness amongst school children of the beauty and importance of coral reefs to their environment.

A global demand for coral reef education

The ARC Centre of Excellence for Coral Reef Studies undertakes research in 25 countries, providing an opportunity to meet and work with many communities around the tropics. For example, in the Solomon Islands, the ARC Centre's social science researchers are engaging with youth groups in five communities, to build future scenarios on community development, environmental change, and youth aspirations for their future. Another major project in the Solomon Islands was an exciting collaborative venture with the multi-award winning media production company, Digital Dimensions, and with Telekom Television. This project is developing and testing a DVD-based fishery biology learning tool *www.ecomedia.com.au/fishandpeople.html* for Pacific secondary school students. Other projects in the Coral Triangle and South West Pacific (Papua New Guinea, the Philippines and Fiji) involve ARC Centre researchers actively engaging with many rural communities, to establish locally-managed marine parks.

SECOND AUSTRALIAN EARTH SYSTEM OUTLOOK CONFERENCE

THE SHINE DOME, AUSTRALIAN ACADEMY OF SCIENCE, CANBERRA 26TH – 27TH NOVEMBER 2012

This 2-day event was organised by the Academy's National Committee for Earth System Science, and featured a major contribution by the ARC Centre of Excellence for Coral Reef Studies. The theme of the Conference was *Ticking time bombs in the human-earth system*. The meeting was held in conjunction with the 25th Officers Meeting of the International Geosphere Biosphere Programme (IGBP), supported by the Commonwealth Department of Climate Change and Energy Efficiency.

The Conference focussed on how human activities since the industrial revolution are affecting the functioning of the entire planet - changing the composition of the atmosphere, waters and soils, modifying the energy balance at the Earth's surface and, consequently, climatic patterns; acidifying land and sea; reducing the diversity of the biosphere and raising sea level. Continuing major human impacts on global systems are now unavoidable, meaning that well-informed, integrated management of the Earth system is a great challenge for global governance of the 21st century. Earth System Science is an emerging, highly inter-disciplinary, quantitative and rigorous research area that aims to (i) understand how the Earth system works, including the role of humans as an integral part of the system; and (ii) provide the knowledge required for humanity to thrive in the 21st century and beyond, by maintaining a well-functioning and resilient Earth system. This theme is closely aligned with the ARC Centre's Program 5, *Resilience of linked social-ecological systems.*

This Second Australian Earth System Outlook Conference explored a selection of four globally significant systems that are at risk of unmanageable and undesirable change unless anticipatory actions are taken soon: (1) over-investment in fossil fuel infrastructure in the face of climate change, (2) polar deglaciation and sea level, (3) global food security, and (4) the Great Barrier Reef.

The Great Barrier Reef session was co-convened by ARC Centre Director, Terry Hughes *FAA*, and the Chair of the ARC Centre's Advisory Board, Brian Walker. The invited speakers also included Bob Pressey FAA and Geoff Jones (ARC Centre), Helene Marsh and Jon Brodie (James Cook University), Ian Poiner and Peter Doherty (Australian Institute of Marine Science), Daniel Gschwind (Queensland Tourism Industry Council) and Jon Day (Great Barrier Reef Marine Park Authority). Many of the speakers argued that business as usual is not an option for the Great Barrier Reef. Transformational, rather than piecemeal, changes are required to address the escalating impacts of coastal developments, climate change and pollution. The talks can be viewed online at *http://science.org.au/events/conferences-and-workshops/earth-system-outlook2/index.html*

Photo by: William Goodwin

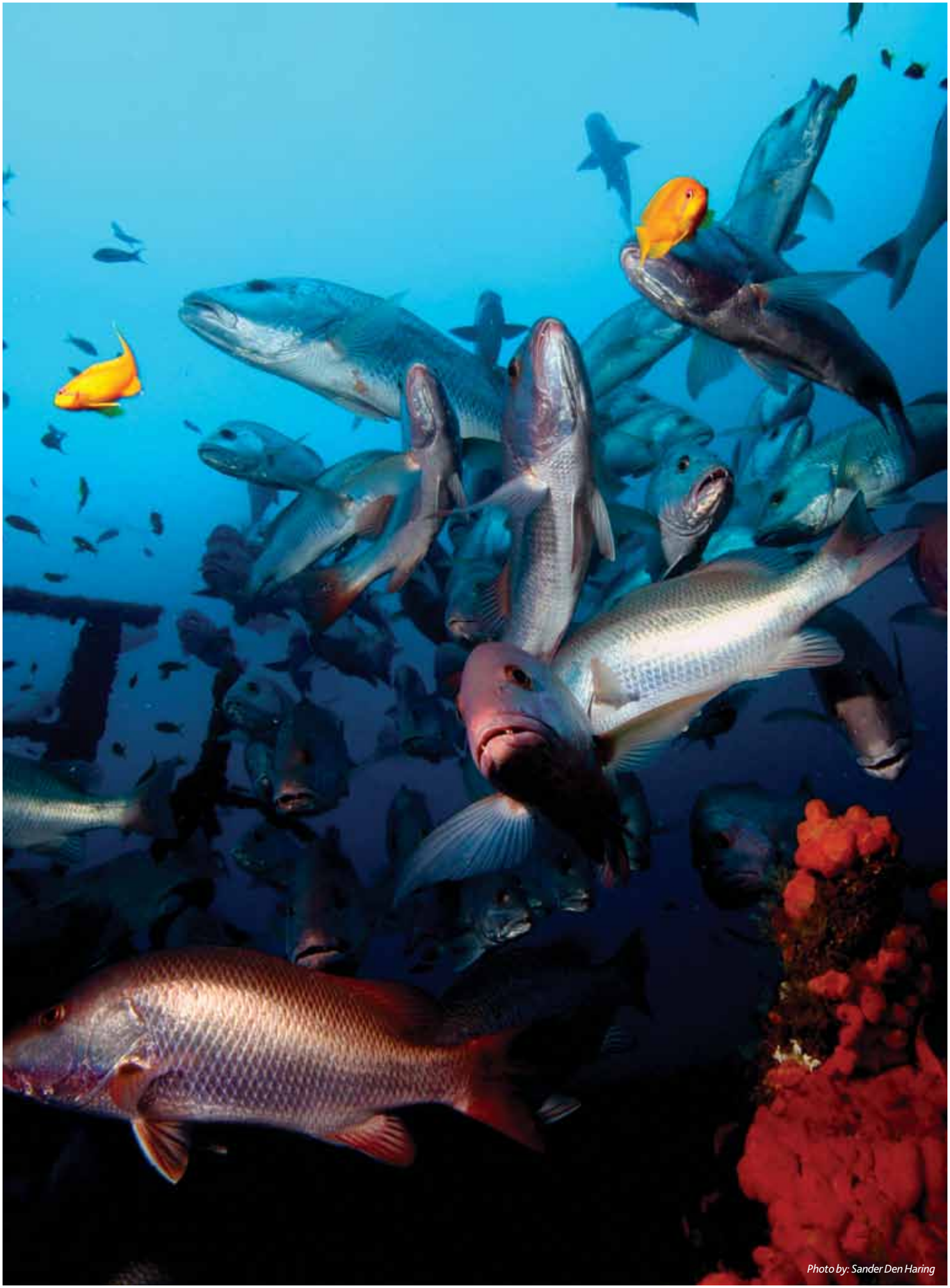


Photo by: Sander Den Haring

NATIONAL BENEFIT CASE STUDY 1

SUSTAINABLE FISHERIES

Coastal economies and communities depend heavily on fisheries and aquaculture, especially in developing countries and small island states. Sustaining the benefits of aquatic resources in the face of the many local and global drivers (e.g. overfishing, pollution, globalisation and climate change) is a difficult challenge. The ARC Centre of Excellence for Coral Reef Studies undertakes multidisciplinary research and outreach to end-users to directly address these issues, and to help secure the future of fisheries and aquaculture in northern Australia, across the tropical Pacific, and elsewhere. Examples of the ARC Centre's many ongoing activities in this sector include:

- The ARC Centre is a major contributor to the coastal fisheries chapters in the Secretariat for the Pacific Community's latest book on *Pacific Fisheries and Climate Change: A Vulnerability Assessment*. More than a dozen of the Centre's researchers provided comprehensive data and analyses, delivering critical information to managers and policy makers in Australia and throughout the Pacific region. According to their assessment, there will be future winners and losers – tuna are expected to be more abundant in the east, while coastal fisheries associated with coral reefs could decrease by 20% by 2050.
- ARC QEII Fellow, Philip Munday, contributed to the *IPCC 2011 Climate Change Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems*. In 2012, he was the invited scientific expert on the impacts of climate change and ocean acidification on fish for the *Coral Triangle Initiative Effects of Climate Change and Ocean Acidification on Fish and Fisheries* workshop run by NOAA and USAID in Bohol, Philippines. Philip also led the tropical coastal fishes section of the *Marine Climate Change Impacts and Adaptation Report Card for Australia* in 2012. Both of these reports are designed to inform policy making at governmental and inter-governmental levels.
- Program Leader, Simon Foale, has developed *Fish and People,* an innovative 5-module video education series with accompanying lesson plans and teaching resources, designed for the Solomon Islands' and PNG's education systems *(www.coralcoe.org.au/videos/videos*). The videos include state of the art animation to visualise fish biology and fishery management concepts. This educational tool is being used by a broad range of audiences in Melanesia and across the Indo-Pacific.
- Centre Director, Terry Hughes, and Program Leader, Bob Pressey, engaged in many activities in Jakarta and Manila associated with the *Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security*. This developing partnership of six countries is aimed at securing sustainable development and improving stewardship of coastal and marine resources in the world's richest biodiversity hotspot.

These undertakings exemplify the Centre's diverse research activities that focus on economic development and food security, which bolster Australia's international reputation as a leader in sustainability research and natural resource management.

Sample publications

Bell JD, Andrew NL, Batty MJ, Chapman LB, Dambacher JM, Dawson BD, Gehrke PC, Hampton J, Hobday AJ, Hoegh-Guldberg O, Johnson JE, Kinch JP, Le Borgne R, Lehodey P, Lough JM, Pickering TD, Pratchett MS, Vunisea A and Waycott M (2011). Adapting fisheries and aquaculture in the Pacific community to the changing climate: Management measures, policies and investments. Pages 803-876 in Bell JD, Johnson JE, Hobday AJ (Eds) *Vulnerability of tropical Pacific Fisheries and Aquaculture to Climate Change*. Secretariat for the Pacific Community, Noumea, New Caledonia.

Bellwood, DR; Hoey, AS and Hughes, TP (2012) Human activity selectively impacts the ecosystem roles of parrotfishes on coral reefs. *Proceedings of the Royal Society B: Biological Sciences.* 270(1733):1621-1629.

Cinner, JE; Basurto, X; Fidelman, P; Kuange, J; Lahari, R and Mukminin, A (2012) Institutional designs of customary fisheries management arrangements in Indonesia, Papua New Guinea, and Mexico. *Marine Policy*. 36(1):278-285.

Pratchett, MS, Munday, PL, Graham, NAJ, Kronen, M, Pinica, S, Friedman, K, Brewer, T, 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. Pages ***493-576*** in Bell JD, Johnson JE, Hobday AJ (Eds) *Vulnerability of tropical Pacific Fisheries and Aquaculture to Climate Change*. Secretariat for the Pacific Community, Noumea, New Caledonia.

Harrison, HB, Williamson, DH, Evans, RD, Almany, GR, Thorrold, SR, Russ, GR, Feldheim, KA, van Herwerden, L, Planes, S, Srinivasan, M, Berumen, ML and Jones, GP (2012). Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Current Biology* 22(11): 1023-1028.

Marine reserves provide baby bonus to fisheries

An international team of scientists has gathered the first conclusive evidence that marine reserves can help restock exploited fish populations on neighbouring reefs which are open to both commercial and recreational fishing.

The ground breaking study was carried out in the Keppel Island group on Australia's Great Barrier Reef by researchers from the ARC Centre of Excellence for Coral Reef Studies (CoECRS), in conjunction with other leading research institutions, and is reported in the latest issue of the journal *Current Biology*.

Its findings help to resolve a long-running debate in Australia and worldwide about whether marine reserves, areas closed to all forms of fishing, can help to replenish fish numbers in areas left open to fishing.

Using DNA fingerprinting technology, the team of scientists tracked the dispersal pathways of baby coral trout and stripey snappers from the marine reserves in the Keppel Island group where they were spawned. They found that a very large proportion of baby fish settled on reefs in areas that are open to fishing, up to 30 kilometres from the place they were spawned.

"We found that the marine reserves, which cover about 28 percent of the 700 hectare reef area of the Keppels, had in fact generated half the baby fish, both inside and outside of the reserves," says lead author Hugo Harrison, of CoECRS and James Cook University. "The study provides conclusive evidence that fish populations in areas open to fishing can be replenished from populations within marine reserves."

The research establishes proof-of-concept for the idea that setting aside networks of marine reserves within a larger managed ecosystem like the Great Barrier Reef Marine Park, can simultaneously provide significant fishery and conservation benefits. Local recreational fishers worked with the research team to sample adult fish populations within the reserves.

Co-author Professor Garry Russ adds "Networks of marine reserves on coral reefs are a central strategy for ensuring food security for millions of people in the Coral Triangle region, just to the north of Australia. This study in the Keppel Islands, for the first time, demonstrates that reserve networks can contribute substantially to the long-term sustainability of coral reef fisheries, and thus to food security and livelihoods in the region."

The researchers conclude "The fact that local fishing communities can directly benefit from a source of recruitment from their local reserves is the strongest support yet that reserve networks can be an effective tool for sustaining future generations of both fish and fishers."

Harrison HB, Williamson DH, Evans RD, Almany GR, Thorrold SR, Russ GR, Feldheim KA, van Herwerden L, Planes S, Srinivasan M, Berumen ML, Jones GP (2012) Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Current Biology*. 22:1023-1028

Photo by: Bastien Preuss

NATIONAL BENEFIT CASE STUDY 2

RESPONDING TO THE THREAT OF CROWN-OF-THORNS STARFISH

2012 saw greatly renewed interest in the crown-of-thorns starfish (*Acanthaster planci*) coinciding with the start of the fourth recorded outbreak on the Great Barrier Reef (GBR). These coral-eating starfishes are a major contributor to declines in coral cover. Reducing the incidence of outbreaks would greatly enhance the resilience of coral communities and reef ecosystems in this region, and would have a major impact on the provision of ecosystem goods and services, particularly in the tourism and fishing industries. The current outbreaks are not only on the GBR, with recent reports detailing outbreaks in the Coral Triangle (e.g. Philippines and Indonesia).

The ARC Centre was a recipient of the National Environmental Research Program (NERP) 2011 Emerging Priorities research funding, directed at understanding and preventing further outbreaks of crown-of-thorns starfish (CoTs). Centre Researcher Morgan Pratchett has also been advising the Commonwealth Government on critical gaps in the understanding of crown-of-thorns starfish, which underlie many important initiatives such as *Reef Rescue,* which is designed to reduce runoff from land onto the Great Barrier Reef.

While there remain significant uncertainties surrounding the fundamental causes of crown-of-thorns outbreaks, research undertaken in the ARC Centre has focused attention on the potential for direct control of starfish populations. Attempting to understand the role of pathogens in naturally ending outbreaks of crown-of-thorns starfish, ARC Centre PhD student Jairo Rivera Posada discovered that CoTs are particularly vulnerable to bacterial infections. After inducing disease with injections of a standard media culture (TCBS) the starfish not only die very quickly, but also infect other nearby starfishes. If shown to have no impact on other coral reef organisms, this research breakthrough could greatly improve the ability to control outbreak populations, even if only to protect small reef areas of high ecological or economic value.

Control programs so far have been ineffective at stopping outbreaks or preventing coral loss over reef scales. In Australia, the Association of Marine Park Tourism Operators has a large control program supported by both State and Commonwealth governments, but their effort is largely concentrated on key tourism locations. The current best practice for killing crown-of-thorns is to inject individual starfish with carefully administered doses of sodium bisulfate. Improvements in the efficiency and effectiveness of these control programs could be achieved by a better understanding of the natural immunological and allergenic responses of these starfish.

Ongoing research within the ARC Centre, in collaboration with the Australian Institute of Marine Science, is focused on two distinct objectives. The first is to improve efficiency and effectiveness of current hand controls, without introducing any pathogens that might spread or infect other reef organisms. Jairo suggests that the best method involves injecting starfish with a solution made from Oxbile. He says, "this simple protein causes a severe allergic reaction that quickly kills starfish, but only those starfish that are actually injected". Research will also continue on the range of pathogens and diseases that affect crown-of-thorns starfish, with the goal of identifying a species-specific pathogen that might be used to prevent future outbreaks.

Sample publications

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

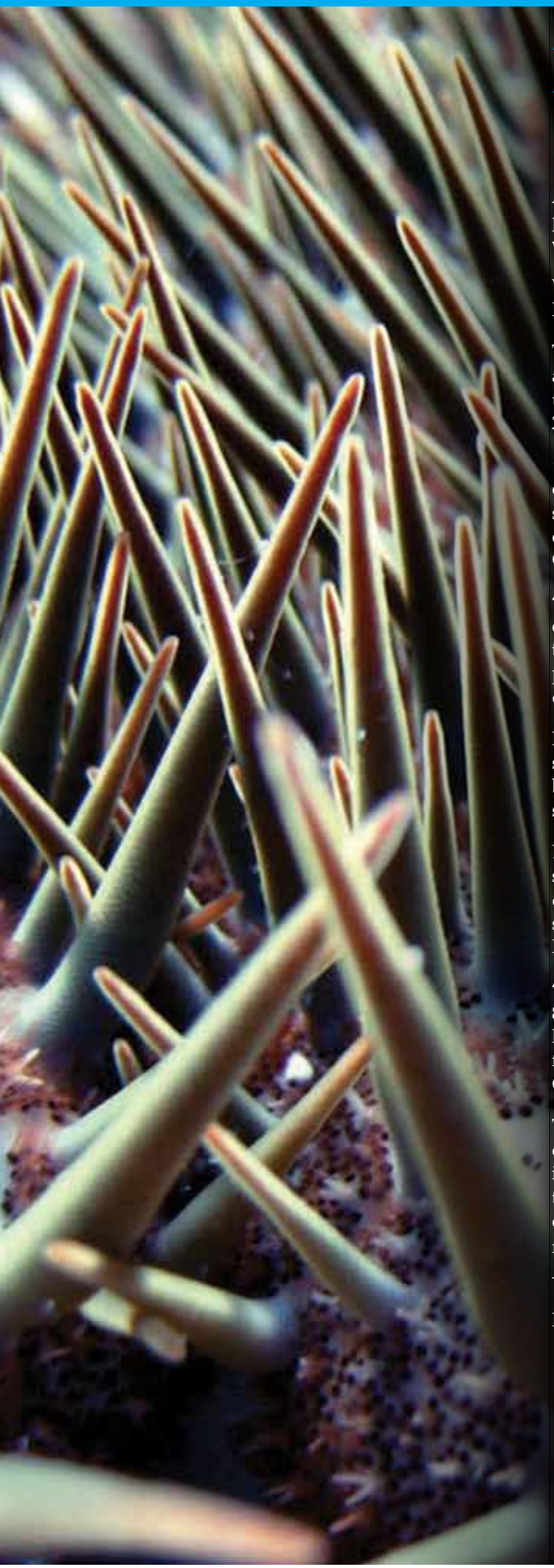
Caballes, CF, Schupp, PJ, Pratchett, MS and Rivera-Posada, JA (2012). Interspecific transmission and recovery of TCBS-induced disease between *Acanthasther planci and Linckia guildingi. Diseases of Aquatic Organisms* 100: 263-267.

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.

Rivera-Posada, J, Owens, L, Caballes, CF and Pratchett, MS (2012). The role of protein extracts in the induction of disease in *Acanthaster planci*. *Journal of Experimental Marine Biology and Ecology*. 429: 1-6.

Rivera-Posada, J and Pratchett, M (2012). *Acanthaster planci controls: A review.* Report to the Department of Sustainability, Environment, Water, Population & Communities, 30 pp.

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.



Researchers find 'killer solution' for a reef killer

An Australia-based team of marine scientists has developed what may prove an effective control for the dreaded Crown of Thorns starfish (CoTs), which periodically ravages coral reefs across the Pacific and Indian Oceans.

With signs that the starfish is building up for another huge attack in the Pacific and Australian region, their solution could come in the nick of time.

The researchers, from the ARC Centre of Excellence for Coral Reef Studies at James Cook University have discovered that a harmless protein mixture used to grow bacteria in the laboratory can destroy the starfish in as little as 24 hours.

"A Crown of Thorns outbreak can destroy from 40-90 per cent of the corals on a reef. Over the past 50 years it has caused more damage than bleaching," says Dr Jairo Rivera Posada. "There were massive outbreaks in many countries in the 1960s and 1980s – and a new one is well underway on the Great Barrier Reef."

"In developing a biological control you have to be very careful to target only the species you are aiming at, and be certain that it can cause no harm to other species or to the wider environment. This compound looks very promising from that standpoint – though there is a lot of tank testing still to do before we would ever consider trialling it in the sea."

Professor Pratchett says starfish outbreaks in the vicinity of specific tourist sites are currently controlled using a poison injection delivered by a diver – but we need to find more effective and efficient control methods if we are to scale-up control programs.

Dr Rivera adds that the protein solution needs only a single jab into a starfish, enabling a diver to kill as many as 500 Crown of Thorns in a single dive – compared with 40 or so using the poison injection. Nevertheless, stopping an established outbreak of millions of starfish will not be feasible. It is already too late to stop the current outbreak, they say.

"In the current CoTs outbreak in the Philippines they removed as many as 87,000 starfish from a single beach. This gives you an idea of the numbers we have to deal with," he adds. Other fresh CoTs outbreaks have been reported from Guam, French Polynesia, Papua New Guinea, and the central Indian Ocean.

The ARC researchers are also exploring other natural parasites and disease-causing organisms for controlling Crown of Thorns, as well as simple protein injections which trigger a fatal allergic reaction. However, any attempts to control these outbreaks will be futile without also addressing the root cause of outbreaks, including loss of starfish predators as well as increased nutrients that provide food for larval starfishes.

Rivera-Posada J, Owens L, Caballes CF, Pratchett MS (2012). The role of protein extracts in the induction of disease in *Acanthaster planci*. *Journal of Experimental Marine Biology and Ecology* 429:1-6.

Photo by: Jennifer Smith

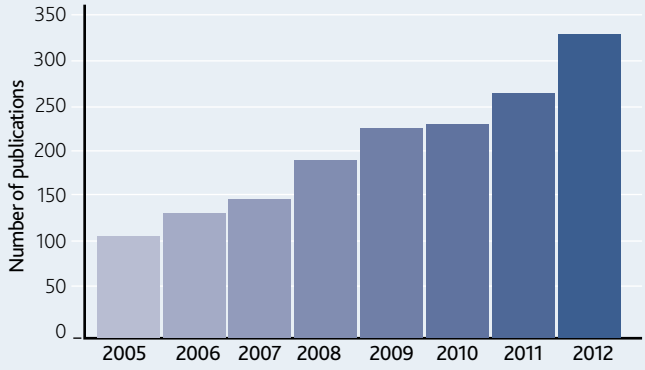
PUBLICATIONS

In 2012, the ARC Centre of Excellence for Coral Reef Studies produced 325 publications, continuing the rapid growth in output exhibited since the Centre began in 2005. The Centre's research outputs were published in a total of 77 journals, spanning many fields of research, including archaeology, biochemistry, biogeography, botany, conservation biology, ecology, evolution, fisheries, immunology, modelling, oceanography, paleobiology, photobiology, physiology, population biology, genomics, geochemistry, social science, and systematics.

This year's output brings the total number of publications since 2005 by the Centre to 1,611. 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.

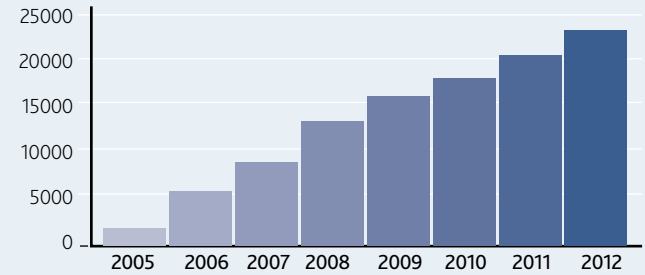
In 2012, 94 of the Centre's publications are in journals with Impact Factors greater than four, including top-tier journals such as *Science*, the *Nature* journals, *PNAS* and *Current Biology*. The average Impact Factor for all 272 journal articles published in 2012 was 3.9.

Number of publications by members of the ARC Centre of Excellence each year for 2005-2012.



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 2012, sixteen of the Centre members had >500 citations, and five had >1,000 citations during the past 12-month reporting period.

Summed citations to members of the ARC Centre of Excellence each year for 2005-2012.



League table achievements in 2012 include:

- *The Faculty of 1000 Biology* highlighted 11 of the ARC Centre's publications for review in 2012:
  1. Arnold, SN and Steneck, RS (2011). Settling into an increasingly hostile world: the rapidly closing "recruitment window" for corals. *PLoS ONE* 6(12):e28681.
  2. Kiessling, W, Simpson, C, Beck, B, Mewis, H and Pandolfi, JM (2012). Equatorial decline of reef corals during the Pleistocene interglacial. *Proceedings of the National Academy of Sciences* 109:21378-83.
  3. Harrison, HB, Williamson, DH, Evans, RD, Almany, GR, Planes, S, Srinivasan, M, Berumen, ML and Jones, GP (2012). Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Current Biology* 22:1023-8.
  4. Cowman, PF and Bellwood, DR (2012). The historical biogeography of coral reef fishes: global patterns of origination and dispersal. *Journal of Biogeography* 40:209-224.
  5. Miller, GM, Watson, SA, Donelson, JM, McCormick, MI and Munday, PL (2012). Parental environment mediates impacts of increased carbon dioxide on a coral reef fish. *Nature Climate Change* 2:858-861.
  6. Andutta, F, Kingsford, M and Wolanski, E (2012). 'Sticky water' enables the retention of larvae in a reef mosaic. *Estuarine, Coastal and Shelf Science* 101:54-63.
  7. Sprenger, D, Dingemanse, NJ, Dochtermann, NA, Theobald, J and Walker, SP (2012). Aggressive females become aggressive males in a sex-changing reef fish. *Ecology Letters* 15:986-92.
  8. Roff, G and Mumby, PJ (2012). Global disparity in the resilience of coral reefs. *Trends in Ecology and Evolution* 27:404-13.
  9. Pandolfi, JM, Connolly, SR, Marshall, DJ and Cohen AL (2011). Projecting coral reef futures under global warming and ocean acidification. *Science* 333:418-22.
  10. 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* 334:652-5.
  11. Gagliano, M, McCormick, MI, Moore, JA and Depczynski M (2010). The basics of acidification: baseline variability of pH on Australian coral reefs. *Marine Biology* 157:1849-56.
- *ISI Essential Science Indicators* identified seven *Research Fronts* during 2012 that highlight the Centre's research. A research front is a group of recent highly cited papers, referred to as *Core Papers*, in

an emerging topic defined by a bibliometrical cluster analysis. The *Research Fronts* are:

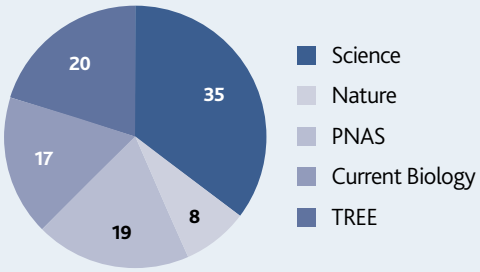
1. Climate change and coral reefs
2. Marine protected areas and connectivity
3. Coral disease
4. Global marine ecosystems
5. The Great Barrier Reef
6. Ocean acidification
7. Marine spatial planning and management.

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

HIGH PROFILE PUBLICATIONS

Since 2005, the ARC Centre has published more than one hundred high-profile papers in five of the world's most prestigious multi-disciplinary journals (*Current Biology, Nature, Proceedings of the National Academy of Science, Science,* and *Trends in Ecology & Evolution*). A few examples of these high profile papers illustrate their novelty and significance:

Number of papers in top journals published in 2005-2012 by members of the ARC Centre of Excellence for Coral Reef Studies.



1. **Almany, GR et al. (2007). Local replenishment of coral reef fish populations in a marine reserve. *Science* 316:742-744.**

   A team of Australian, American and French coral reef scientists achieved a world breakthrough in tracking larval fish, showing that many reefs are self-seeded. These findings will revolutionise the design of marine parks, assist with the sustainable management of coral reefs and help to restore threatened fisheries. The team consists of ARC Future Fellow Glenn Almany and Geoff Jones from the ARC Centre of Excellence, Michael Berumen of the University of Arkansas, Simon Thorrold of the Woods Hole Oceanographic Institute, and Serge Planes from the University of Perpignan, France.

2. **Rockstrom, J et al. (2009). A safe operating space for humanity. *Nature* 461:472-475.**

   Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years. This period of stability — known to geologists as the Holocene — has seen human civilizations arise, develop and thrive. Such stability may now be under threat. This innovative study proposes ten planetary boundaries which should not be exceeded to avoid crossing dangerous tipping points that hinder human development. This landmark study is a global collaboration involving the ARC Centre Director, Terry Hughes and leading researchers from 24 other institutions in Australia, Belgium, Denmark, USA, UK, Germany, the Netherlands and Sweden.

3. **McCook, LJ et al. (2010). Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. *Proceedings of the National Academy of Sciences* 107:18278-18285.**

   This important paper demonstrates that the establishment of a large-scale network of marine reserves on the Great Barrier Reef is proving to be an excellent investment - in social, economic and environmental terms. Given the major challenge posed by climate change, the expanded network of marine reserves provides a critical and cost-effective contribution to enhancing the resilience of the Great Barrier Reef. The 21 authors are affiliated with the ARC Centre of Excellence, the Australian Institute of Marine Science, the Commonwealth Scientific and Industrial Research Organisation, and the Great Barrier Reef Marine Park Authority. Lead author, Laurence McCook is a Partner Investigator in the ARC Centre.

4. **Pandolfi, JM et al. (2011). Projecting coral reef futures under global warming and ocean acidification. *Science* 333:418-422.**

   Coral reefs are naturally highly diverse and resilient, and are likely to respond to changing environmental conditions in different ways and at varying rates. This multidisciplinary paper, by an international team led by the ARC Centre, illustrates that 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 vary in different regions, so managing the response of reefs to climate change will require improved understanding of the capacity of reef species to acclimate and adapt to change.

5. **Hughes, TP et al. (2012). Assembly rules of reef corals are flexible along a steep climatic gradient. *Current Biology* 22:736-741.**

   This study is the world's first investigation of how climate affects the composition of coral reefs at very large scales, using the entire length of the Great Barrier Reef as a natural laboratory. The surprisingly large flexibility in community composition that was measured along latitudinal environmental gradients indicates that climate change is likely to result in a reassortment of coral reef taxa rather than wholesale loss of entire reef ecosystems.

PUBLICATIONS LIST

Book (2)

1. Fabinyi, M (2012). Fishing for fairness: Poverty, morality and marine resource management in the Philippines. Asia-Pacific Environment Monograph 7 ANU E-Press, Canberra, 227 pp.
2. Salas, E, Ross-Salazar, E and Arias, A (2012). Diagnosis of marine protected areas and responsible fishing areas in the Costa Rican Pacific Fundación Mar Viva, San José, Costa Rica, 174 pp.

Book Section (9)

1. Fuentes, M, Hamann, M and Lukoschek, V (2012). Marine Reptiles, In *A Marine Climate Change Impacts and Adaptation Report Card for Australia* 2012. Poloczanska, ES, Hobday, AJ and Richardson, AJ. (Eds.). National Climate Change Adaptation Research Facility, 379-400 pp.
2. Hoegh-Guldberg, O (2012). Coral reefs, climate change, and mass extinction, saving a million species, In *Saving a million species: Extinction risk from climate change*. Hannah, L. (Ed.). Island Press, Washington, DC, United States, 389-394 pp.
3. Holbrook, N, Brown, J, Davidson, J, Feng, M, Hobday, A, Lough, J, McGregor, S, Power, S and Risbey, J (2012). El Niño-Southern Oscillation, In *A Marine Climate Change Impacts and Adaptation Report Card for Australia* 2012. Poloczanska, ES, Hobday, AJ and Richardson, AJ. (Eds.). National Climate Change Adaptation Research Facility, 82-111 pp.
4. Howard, WR, Nash, M, Anthony, K, Schmutter, K, Bostock, H, Bromhead, D, Byrne, M, Currie, K, Diaz-Pulido, G, Eggins, S, Ellwood, M, Eyre, B, Haese, R, Hallegraeff, G, Hill, K, Hurd, C, Law, C, Lenton, A, Matear, R, McNeil, B, McCulloch, M, Müller, MN, Munday, P, Opdyke, B, Pandolfi, JM, Richards, R, Roberts, D, Russell, BD, Smith, AM, Tilbrook, B, Waite, A and Williamson, J (2012). Ocean acidification, In *A Marine Climate Change Impacts and Adaptation Report Card for Australia* 2012. Poloczanska, ES, Hobday, AJ and Richardson, AJ. (Eds.). National Climate Change Adaptation Research Facility, 114-149 pp.
5. Leitch, A and Robinson, C (2012). Shifting Sands: Uncertainty and a local community response to sea levels and policy in Australia, In *Risk and Social Theory in Environmental Management*. Measham, T and Lockie, S. (Eds.). CSIRO Publishing, Collingwood, Vic, Australia, 117-131 pp.
6. Lough, J, Sen Gupta, A and Hobday, A (2012). Temperature, In *A Marine Climate Change Impacts and Adaptation Report Card for Australia* 2012. Poloczanska, ES, Hobday, AJ and Richardson, AJ. (Eds.). National Climate Change Adaptation Research Facility, 1-25 pp.
7. Marsh, H, Weiss, K and Grech, A (2012). Dugong, In *Queensland's Threatened Animals*. Curtis, L, Dennis, A, McDonald, K, Kyne, P and Debus, S. (Eds.). CSIRO Publishing, Melbourne, Australia, 410-411 pp.
8. Munday, PL, Cheal, AJ, Graham, NAJ, Meekan, M, Pratchett, MS, Sheaves, M, Sweatman, H and Wilson, SK (2012). Tropical Coastal Fishes and Climate Change, In *A Marine Climate Change Impacts and Adaptation Report Card for Australia* 2012. Poloczanska, ES, Hobday, AJ and Richardson, AJ. (Eds.). National Climate Change Adaptation Research Facility, 281-306 pp.
9. Pratchett, M, Bay, L, Coker, D, Cole, A and Lawton, R (2012). Effects of climate change on reef-building corals and associated fishes, In *Wildlife and climate change: towards robust conservation strategies for Australian fauna*. Lunney, D and Hutchings, P. (Eds.). Royal Zoological Society New South Wales, Sydney 59-67 pp.

Journal Article (272)

1. Abrego, D, Willis, B and van Oppen, M (2012). Impact of light and temperature on the uptake of algal symbionts by coral juveniles. *PLOS ONE* 7(11): e50311.
2. Adams, VM, Pressey, RL and Stoeckl, N (2012). Estimating land and conservation management costs: the first step in designing a stewardship program for the Northern Territory. *Biological Conservation* 148(1): 44-53.
3. Albouy, C, Guilhaumon, F, Araujo, MB, Mouillot, D and Leprieur, F (2012). Combining projected changes in species richness and composition reveals climate change impacts on coastal Mediterranean fish assemblages. *Global Change Biology* 18(10): 2995-3003.
4. Andréfouët, S and Hamel, MA (2012). Habitat mapping for conservation planning in Baa Atoll, Republic of Maldives. *Atoll Research Bulletin* 590: 207-222.
5. Andréfouët, S, Hamel, MA and Dalleau, M (2012). Distinction between effective pattern-based and selection-based biodiversity surrogates is essential: caveats for managers. *Marine Ecology Progress Series* 452: 287-295.
6. Andutta, F, Kingsford, M and Wolanski, E (2012). 'Sticky water' enables the retention of larvae in a reef mosaic. *Estuarine Coastal and Shelf Science* 101: 54-63.
7. Attenborough, R, Hayward, D, Kitahara, M, Miller, D and Ball, E (2012). A "neural" enzyme in non-bilateral animals and algae: pre-neural origins for peptidylglycine α-amidating monooxygenase (PAM). *Molecular Biology and Evolution* 29(10): 3095-3104.
8. Augé, AA, Moore, AB and Chilvers, BL (2012). Predicting interactions between recolonising marine mammals and fisheries: defining precautionary management. *Fisheries Management and Ecology* 19(5): 426-433.
9. Bainbridge, Z, Wolanski, E, Alvarez-Romero, JG, Lewis, S and Brodie, J (2012). Fine sediment and nutrient dynamics related to particle size and floc formation in a Burdekin River flood plume, Australia. *Marine Pollution Bulletin* 65: 236–248.
10. Baird, AH, Campbell, SJ, Fadli, N, Hoey, AS and Rudi, E (2012). The shallow water hard corals of Pulau Weh, Aceh Province, Indonesia. *Aquaculture, Aquarium, Conservation and Legislation* 5(1): 23-28.
11. Ban, NC, Cinner, JE, Adams, VM, Mills, M, Almany, GR, Ban, SS, McCook, LJ and White, A (2012). Recasting shortfalls of marine protected areas as opportunities through adaptive management. *Aquatic Conservation-Marine and Freshwater Ecosystems* 22(2): 262-271.
12. Ban, NC, Pressey, RL and Weeks, S (2012). Conservation objectives and sea-surface temperature anomalies in the Great Barrier Reef. *Conservation Biology* 26(5): 799-809.
13. Barbosa, M, Connolly, SR, Hisano, M, Dornelas, M and Magurran, AE (2012). Fitness consequences of female multiple mating: a direct test of indirect benefits. *BMC Evolutionary Biology* 12(185): 1-11.

14. Barnes, L, Bellwood, D, Sheaves, M and Tanner, J (2012). The use of clear-water non-estuarine mangroves by reef fishes on the Great Barrier Reef. *Marine Biology* 159(1): 211-220.

15. Beeden, R, Maynard, JA, Marshall, PA, Heron, SF and Willis, BL (2012). A framework for responding to coral disease outbreaks that facilitates adaptive management. *Environmental Management* 49(1): 1-13.

16. Beldade, R, Holbrook, SJ, Schmitt, RJ, Planes, S, Malone, D and Bernardi, G (2012). Larger female fish contribute disproportionately more to self-replenishment. *Proceedings of the Royal Society B-Biological Sciences* 279(1736): 2116-2121.

17. Bellantuono, A, Granados-Cifuentes, C, Miller, D, Hoegh-Guldberg, O and Rodriguez-Lanetty, M (2012). Coral thermal tolerance: tuning gene expression to resist thermal stress. *PLOS ONE* 7(11): e50685.

18. Bellantuono, AJ, Hoegh-Guldberg, O and Rodriguez-Lanetty, M (2012). Resistance to thermal stress in corals without changes in symbiont composition. *Proceedings of the Royal Society B-Biological Sciences* 279(1731): 1100-1107.

19. Bellwood, DR, Baird, AH, Depczynski, M, González-Cabello, A, Hoey, AS, Lefevre, CD and Tanner, JK (2012). Coral recovery may not herald the return of fishes on damaged coral reefs. *Oecologia* 170(2): 567-573.

20. Bellwood, DR, Hoey, AS and Hughes, TP (2012). Human activity selectively impacts the ecosystem roles of parrotfishes on coral reefs. *Proceedings of the Royal Society B-Biological Sciences* 270(1733): 1621-1629.

21. Bender, D, Diaz-Pulido, G and Dove, S (2012). Effects of macroalgae on corals recovering from disturbance. *Journal of Experimental Marine Biology and Ecology* 429: 15–19.

22. Berkstrom, C, Jones, GP, McCormick, MI and Srinivasan, M (2012). Ecological versatility and its importance for the distribution and abundance of coral reef wrasses. *Marine Ecology Progress Series* 461: 151-163.

23. Berumen, M, Trip, E, Pratchett, M and Choat, J (2012). Differences in demographic traits of four butterflyfish species between two reefs of the Great Barrier Reef separated by 1,200 km. *Coral Reefs* 31(1): 169-177.

24. Berumen, ML, Almany, GR, Planes, S, Jones, GP, Saenz-Agudelo, P and Thorrold, SR (2012). Persistence of self-recruitment and patterns of larval connectivity in a marine protected area network. *Ecology and Evolution* 2(2): 444-452.

25. Biggs, D, Ban, N and Hall, C (2012). Lifestyle values, resilience, and nature-based tourism's contribution to conservation on Australia's Great Barrier Reef. *Environmental Conservation* 39: 370-379.

26. Biggs, D, Hall, CM and Stoeckl, N (2012). The resilience of formal and informal tourism enterprises to disasters: reef tourism in Phuket, Thailand. *Journal of Sustainable Tourism* 20(5): 645-665.

27. Biggs, R, Schluter, M, Biggs, D, Bohensky, EL, BurnSilver, S, Cundill, G, Dakos, V, Daw, TM, Evans, LS, Kotschy, K, Leitch, AM, Meek, C, Quinlan, A, Raudsepp-Hearne, C, Robards, MD, Schoon, ML, Schultz, L and West, PC (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources* 37: 421-448.

28. Blackwood, JC, Hastings, A and Mumby, PJ (2012). The effect of fishing on hysteresis in Caribbean coral reefs. *Theoretical Ecology* 5(1): 105-114.

29. Blower, D, Pandolfi, J, Bruce, B, Gomez-Cabrera, M and Ovenden, J (2012). Population genetics of Australian white sharks reveals fine-scale spatial structure, transoceanic dispersal events and low effective population sizes. *Marine Ecology Progress Series* 455: 229-244.

30. Blowes, SA and Connolly, SR (2012). Risk spreading, connectivity, and optimal reserve spacing. *Ecological Applications* 22(1): 311-321.

31. Boaden, E and Kingsford, MJ (2012). Diel behaviour and trophic ecology of *Scolopsis bilineatus* (Nemipteridae). *Coral Reefs* 31(3): 871-883.

32. Bode, M, Connolly, S and Pandolfi, JM (2012). Species differences drive nonneutral structure in Pleistocene coral communities. *American Naturalist* 180: 577–588.

33. Boldt, L, Yellowlees, D and Leggat, W (2012). Hyperdiversity of genes encoding integral light-harvesting proteins in the dinoflagellate *Symbiodinium* sp. *PLOS ONE* 7(10): e47456.

34. Bonaldo, R, Welsh, J and Bellwood, D (2012). Spatial and temporal variation in coral predation by parrotfishes on the Great Barrier Reef: evidence from an inshore reef. *Coral Reefs* 31(1): 263-272.

35. Bonin, M (2012). Specializing on vulnerable habitat: *Acropora* selectivity among damselfish recruits and the risk of bleaching-induced habitat loss. *Coral Reefs* 31(1): 287-297.

36. Bosiger, YJ, Lonnstedt, OM, McCormick, MI and Ferrari, MCO (2012). Learning temporal patterns of risk in a predator-diverse environment. *PLOS ONE* 7(4): e34535.

37. Bottrill, MC and Pressey, RL (2012). The effectiveness and evaluation of conservation planning. *Conservation Letters* 5: 407-420.

38. Brewer, TD, Cinner, J, Fisher, R, Green, A and Wilson, S (2012). Market access, population density, and socioeconomic development explain diversity and functional group biomass of coral reef fish assemblages. *Global Environmental Change* 22: 399-406.

39. Bridge, T, Beaman, R, Done, T and Webster, J (2012). Predicting the location and spatial extent of submerged coral reef habitat in the Great Barrier Reef World Heritage Area, Australia. *PLOS ONE* 7(10): e48203.

40. Bridge, T, Scott, A and Steinberg, D (2012). Abundance and diversity of anemonefishes and their host sea anemones at two mesophotic sites on the Great Barrier Reef, Australia. *Coral Reefs* 31: 1057–1062.

41. Briffa, M, de la Haye, K and Munday, PL (2012). High CO_2 and marine animal behaviour: potential mechanisms and ecological consequences. *Marine Pollution Bulletin* 64(8): 1519-1528.

42. Bromfield, K and Pandolfi, J (2012). Regional patterns of evolutionary turnover in Neogene coral reefs from the central Indo-West Pacific Ocean. *Evolutionary Ecology* 26(2): 375-391.

43. Bruggemann, JH, Rodier, M, Guillaume, MMM, Andréfouët, S, Arfi, R, Cinner, JE, Pichon, M, Ramahatratra, F, Rasoamanendrika, F, Zinke, J and McClanahan, TR (2012). Wicked social–ecological problems forcing unprecedented change on the latitudinal margins of coral reefs: the case of southwest Madagascar. *Ecology and Society* 17(4): 47.

44. Budd, AF, Nunes, FLD, Weil, E and Pandolfi, JM (2012). Polymorphism in a common Atlantic

reef coral (*Montastrea cavernosa*) and its long-term evolutionary implications. *Evolutionary Ecology* 26(2): 265-290.

45. Burrows, MT, Schoeman, DS, Duarte, CM, O'Connor, MI, Buckley, LB, Kappel, CV, Parmesan, C, Halpern, BS, Brown, C, Brander, KM, Bruno, JF, Pandolfi, JM, Sydeman, WJ, Moore, P, Kiessling, W, Richardson, AJ and Poloczanska, ES (2012). Invasive species unchecked by climate response. *Science* 335(6068): 538-539.

46. Busilacchi, S, Williams, AJ, Russ, GR and Begg, GA (2012). Complexity of applying minimum legal sizes (MLS) of retention in an indigenous coral reef fishery. *Fisheries Management and Ecology* 19(3): 233-244.

47. Buston, PM, Jones, GP, Planes, S and Thorrold, SR (2012). Probability of successful larval dispersal declines fivefold over 1 km in a coral reef fish. *Proceedings of the Royal Society B-Biological Sciences* 279(1735): 1883-1888.

48. Caballes, CF, Schupp, PJ, Pratchett, MS and Rivera-Posada, JA (2012). Interspecific transmission and recovery of TCBS-induced disease between *Acanthaster planci* and *Linckia guildingi*. *Diseases of Aquatic Organisms* 100(3): 263-7.

49. Campbell, S, Cinner, J, Ardiwijaya, R, Pardede, ST, Kartawijaya, T, Mukminin, A, Herdiana, Y, Hoey, A, Pratchett, M and Baird, A (2012). Avoiding conflicts and protecting coral reefs: customary management of fishing gear protects habitat and fish biomass in Aceh, Indonesia. *Oryx* 46: 486-494.

50. Campbell, S, Hoey, A, Maynard, J, Kartawijaya, T, Cinner, J, Graham, N and Baird, A (2012). Weak compliance undermines the success of no-take zones in a large government-controlled marine protected area. *PLOS ONE* 7(11): e50074.

51. Carpenter, SR, Arrow, KJ, Barrett, S, Biggs, R, Brock, WA, Crépin, A-S, Engström, G, Folke, C, Hughes, TP, Kautsky, N, Li, C-Z, McCarney, G, Meng, K, Mäler, K-G, Polasky, S, Scheffer, M, Shogren, J, Sterner, T, Vincent, JR, Walker, B, Xepapadeas, A and Zeeuw, AD (2012). General resilience to cope with extreme events. *Sustainability Science* 4(12): 3248-3259.

52. Carpenter, SR, Folke, C, Norström, A, Olsson, O, Schultz, L, Agarwal, B, Balvanera, P, Campbell, B, Castilla, JC, Cramer, W, DeFries, R, Eyzaguirre, P, Hughes, TP, Polasky, S, Sanusi, Z, Scholes, R and Spierenburg, M (2012). Program on ecosystem change and society: an international research strategy for integrated social–ecological systems. *Current Opinion in Environmental Sustainability* 4(1): 134-138.

53. Cerutti-Pereyra, F, Meekan, MG, Wei, N-WV, O' Shea, O, Bradshaw, CJA and Austin, CM (2012). Identification of rays through DNA barcoding: an application for ecologists. *PLOS ONE* 7(6): e36479.

54. Chan, NCS, Connolly, SR and Mapstone, BD (2012). Effects of sex change on the implications of marine reserves for fisheries. *Ecological Applications* 22(3): 778-791.

55. Chong-Seng, KM, Mannering, TD, Pratchett, MS, Bellwood, DR and Graham, NA (2012). The influence of coral reef benthic condition on associated fish assemblages. *PLOS ONE* 7(8): e42167.

56. Cinner, JE, Basurto, X, Fidelman, P, Kuange, J, Lahari, R and Mukminin, A (2012). Institutional designs of customary fisheries management arrangements in Indonesia, Papua New Guinea, and Mexico. *Marine Policy* 36(1): 278-285.

57. Cinner, JE, Daw, TM, McClanahan, TR, Muthiga, N, Abunge, C, Hamed, S, Mwaka, B, Rabearisoa, A, Wamukota, A, Fisher, E and Jiddawi, N (2012). Transitions toward co-management: the process of marine resource management devolution in three east African countries. *Global Environmental Change-Human and Policy Dimensions* 22(3): 651-658.

58. Cinner, JE, McClanahan, TR, Graham, NAJ, Daw, TM, Maina, J, Stead, SM, Wamukota, A, Brown, K and Bodin, Ö (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change* 22(1): 12-20.

59. Cinner, JE, McClanahan, TR, MacNeil, MA, Graham, NAJ, Daw, TM, Mukminin, A, Feary, DA, Rabearisoa, AL, Wamukota, A, Jiddawi, N, Campbell, SJ, Baird, AH, Januchowski-Hartley, FA, Hamed, S, Lahari, R, Morove, T and Kuange, J (2012). Co-management of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences* 109(14): 5219–5222

60. Clark, NJ and Russ, GR (2012). Ontogenetic shifts in the habitat associations of butterflyfishes (F. Chaetodontidae). *Environmental Biology of Fishes* 94(4): 579-590.

61. Clark, TR, Zhao, JX, Feng, YX, Done, TJ, Jupiter, S, Lough, J and Pandolfi, JM (2012). Spatial variability of initial $^{230}Th/^{232}Th$ in modern *Porites* from the inshore region of the Great Barrier Reef. *Geochimica et Cosmochimica Acta* 78: 99-118.

62. Claydon, J, McCormick, M and Jones, G (2012). Patterns of migration between feeding and spawning sites in a coral reef surgeonfish. *Coral Reefs* 31(1): 77-87.

63. Cohen, PJ, Evans, LS and Mills, M (2012). Social networks supporting governance of coastal ecosystems in Solomon Islands. *Conservation Letters* 5: 376-386.

64. Coker, D, Graham, N and Pratchett, M (2012). Interactive effects of live coral and structural complexity on the recruitment of reef fishes. *Coral Reefs* 31: 919–927.

65. Coker, DJ, Pratchett, MS and Munday, PL (2012). Influence of coral bleaching, coral mortality and conspecific aggression on movement and distribution of coral-dwelling fish. *Journal of Experimental Marine Biology and Ecology* 414: 62-68.

66. Cole, AJ, Lawton, RJ, Wilson, SK and Pratchett, MS (2012). Consumption of tabular acroporid corals by reef fishes: a comparison with plant-herbivore interactions. *Functional Ecology* 26(2): 307-316.

67. Connolly, SR, Lopez-Yglesias, MA and Anthony, KRN (2012). Food availability promotes rapid recovery from thermal stress in a scleractinian coral. *Coral Reefs* 31: 951–960.

68. Connolly, SR and Thibaut, LM (2012). A comparative analysis of alternative approaches to fitting species-abundance models. *Journal of Plant Ecology* 5(1): 32-45.

69. Cooper, TF, O'Leary, RA and Lough, JM (2012). Growth of Western Australian corals in the Anthropocene. *Science* 335(6068): 593-596.

70. Cundill, G, Cumming, GS, Biggs, D and Fabricius, C (2012). Soft systems thinking and social learning for adaptive management. *Conservation Biology* 26(1): 13-20.

71. Daw, TM, Cinner, JE, McClanahan, TR, Brown, K, Stead, SM, Graham, NA and Maina, J (2012). To fish or not to fish: factors at multiple scales affecting artisanal fishers' readiness to exit a declining fishery. *PLOS ONE* 7(2): e31460.

72. Devine, B, Munday, P and Jones, G (2012). Rising CO_2 concentrations affect settlement behaviour of larval damselfishes. *Coral Reefs* 31(1): 229-238.

73. Devine, BM, Munday, PL and Jones, GP (2012). Homing ability of adult cardinalfish is affected by elevated carbon dioxide. *Oecologia* 168(1): 269-276.

74. Devlin, M, McKinna, LI, Alvarez-Romero, JG, Petus, C, Abbot, B, Harkness, P and Brodie, J (2012). Mapping the pollutants in surface riverine flood plume waters in the Great Barrier Reef, Australia. *Marine Pollution Bulletin* 65: 224–235.

75. Diaz-Pulido, G, Anthony, KRN, Kline, DI, Dove, S and Hoegh-Guldberg, O (2012). Interactions between ocean acidification and warming on the mortality and dissolution of coralline algae. *Journal of Phycology* 48(1): 32-39.

76. Dissard, D, Douville, E, Reynaud, S, Juillet-Leclerc, A, Montagna, P, Louvat, P and McCulloch, M (2012). Light and temperature effect on $\delta^{11}B$ and B/Ca ratios of the zooxanthellate coral *Acropora* sp: results from culturing experiments. *Biogeosciences 9*: 4589–4605.

77. Dixson, D (2012). Predation risk assessment by larval reef fishes during settlement-site selection. *Coral Reefs* 31(1): 255-261.

78. Dixson, DL, Pratchett, MS and Munday, PL (2012). Reef fishes innately distinguish predators based on olfactory cues associated with recent prey items rather than individual species. *Animal Behaviour* 84(1): 45-51.

79. Domenici, P, Allan, B, McCormick, MI and Munday, PL (2012). Elevated carbon dioxide affects behavioural lateralization in a coral reef fish. *Biology Letters* 8(1): 78-81.

80. Donelson, JM and Munday, PL (2012). Thermal sensitivity does not determine acclimation capacity for a tropical reef fish. *Journal of Animal Ecology* 81(5): 1126-1131.

81. Donelson, JM, Munday, PL and McCormick, MI (2012). Climate change may affect fish through an interaction of parental and juvenile environments. *Coral Reefs* 31(3): 753-762.

82. Donelson, JM, Munday, PL, McCormick, MI and Pitcher, CR (2012). Rapid transgenerational acclimation of a tropical reef fish to climate change. *Nature Climate Change* 2(1): 30-32.

83. Doropoulos, C, Ward, S, Diaz-Pulido, G, Hoegh-Guldberg, O and Mumby, PJ (2012). Ocean acidification reduces coral recruitment by disrupting intimate larval-algal settlement interactions. *Ecology Letters* 15(4): 338-346.

84. Dunn, SR, Pernice, M, Green, K, Hoegh-Guldberg, O and Dove, SG (2012). Thermal stress promotes host mitochondrial degradation in symbiotic cnidarians: are the batteries of the reef going to run out? *PLOS ONE* 7(7): e39024.

85. Eagle, J, Baird, A, Jones, G and Kingsford, M (2012). Recruitment hotspots: consistent spatial patterns in the relative abundance of coral recruits at One Tree Island, Australia. *Galaxea* 14: 1-8.

86. Emblem, A, Karlsen, B, Evertsen, J, Miller, D, Moum, T and Johansen, S (2012). Mitogenome polymorphism in a single branch sample revealed by SOLiD deep sequencing of the *Lophelia pertusa* coral genome. *Gene* 506: 344-349.

87. Emslie, M, Logan, M, Ceccarelli, D, Cheal, A, Hoey, A, Miller, I and Sweatman, H (2012). Regional-scale variation in the distribution and abundance of farming damselfishes on Australia's Great Barrier Reef. *Marine Biology* 159(6): 1293-1304.

88. Fabinyi, M (2012). Historical, cultural and social perspectives on luxury seafood consumption in China. *Environmental Conservation* 39(1): 83-92.

89. Fabinyi, M, Pido, M, Harani, B, Caceres, J, Uyami-Bitara, A, De las Alas, A, Buenconsejo, J and de Leon, EMP (2012). Luxury seafood consumption in China and the intensification of coastal livelihoods in Southeast Asia: the live reef fish for food trade in Balabac, Philippines. *Asia Pacific Viewpoint* 53(2): 118-132.

90. Fadli, N, Campbell, S, Ferguson, K, Keyse, J, Rudi, E, Riedel, A and Baird, A (2012). The role of habitat creation in coral reef conservation: a case study from Aceh, Indonesia. *Oryx* 46: 501-507.

91. Falter, JL, Lowe, RJ, Atkinson, MJ and Cuet, P (2012). Seasonal coupling and de-coupling of net calcification rates from coral reef metabolism and carbonate chemistry at Ningaloo Reef, Western Australia. *Journal of Geophysical Research-Oceans* 117(C5): C05003.

92. Feeney, WE, Lonnstedt, OM, Bosiger, Y, Martin, J, Jones, GP, Rowe, RJ and McCormick, MI (2012). High rate of prey consumption in a small predatory fish on coral reefs. *Coral Reefs* 31(3): 909-918.

93. Fenberg, P, Caselle, J, Claudet, J, Clemence, M, Gaines, S, Garcia-Charton, J, Goncalves, E, Grorud-Colvert, K, Guidetti, P, Jenkins, S, Jones, P, Lester, S, McAllen, R, Moland, E, Planes, S and Sorensen, T (2012). The science of European marine reserves: status, efficacy, and future needs. *Marine Policy* 36(5): 1012-1021.

94. Ferrari, MCO, Manassa, RP, Dixson, DL, Munday, PL, McCormick, MI, Meekan, MG, Sih, A and Chivers, DP (2012). Effects of ocean acidification on learning in coral reef fishes. *PLOS ONE* 7(2): e31478.

95. Ferrari, MCO, McCormick, MI, Munday, PL, Meekan, MG, Dixson, DL, Loennstedt, O and Chivers, DP (2012). Effects of ocean acidification on visual risk assessment in coral reef fishes. *Functional Ecology* 26(3): 553-558.

96. Fidelman, P and Ekstrom, JA (2012). Mapping seascapes of international environmental arrangements in the Coral Triangle. *Marine Policy* 36(5): 993-1004.

97. Fidelman, P, Evans, L, Fabinyi, M, Foale, S, Cinner, J and Rosen, F (2012). Governing large-scale marine commons: contextual challenges in the Coral Triangle. *Marine Policy* 36(1): 42-53.

98. Field, IC, Buckworth, RC, Yang, G-J, Meekan, MG, Johnson, G, Stevens, JD, Pillans, RD, McMahon, CR and Bradshaw, CJA (2012). Changes in size distributions of commercially exploited sharks over 25 years in northern Australia using a Bayesian approach. *Fisheries Research* 125: 262-271.

99. Figueiredo, J, Baird, A, Cohen, M, Flot, JF, Kamiki, T, Meziane, T, Tsuchiya, M and Yamasaki, H (2012). Ontogenetic change in the lipid and fatty acid composition of scleractinian coral larvae. *Coral Reefs* 31(2): 613-619.

100. Figueiredo, J and Connolly, SR (2012). Dispersal-mediated coexistence under recruitment limitation and displacement competition. *Ecological Modelling* 243: 133-142.

101. Figueiredo, J, Lin, J, Anto, J and Narciso, L (2012). The consumption of DHA during embryogenesis as an indicative of the need to supply DHA during early larval development:

a review. *Journal of Aquaculture Research and Development* 3(5): 1-7.

102. Fisher, P, Malme, M and Dove, S (2012). The effect of temperature stress on coral – *Symbiodinium* associations containing distinct symbiont types. *Coral Reefs* 31(2): 473-485.

103. Flores, F, Hoogenboom, MO, Smith, LD, Cooper, T, Abrego, D and Negri, A (2012). Chronic exposure of corals to fine sediments: lethal and sub-lethal impacts. *PLOS ONE* 7(5): e37795

104. Foster, NL, Paris, CB, Kool, JT, Baums, IB, Stevens, JR, Sanchez, JA, Bastidas, C, Agudelo, C, Bush, P, Day, O, Ferrari, R, Gonzalez, P, Gore, S, Guppy, R, McCartney, MA, McCoy, C, Mendes, J, Srinivasan, A, Steiner, S, Vermeij, MJA, Weil, E and Mumby, PJ (2012). Connectivity of Caribbean coral populations: complementary insights from empirical and modelled gene flow. *Molecular Ecology* 21(5): 1143-1157.

105. Foster, R, Bridge, T and Bongaerts, P (2012). The first record of *Hippocampus denise* (Syngnathidae) from Australia. *Aqua: International Journal of Ichthyology* 18(1): 55-57.

106. Frisch, AJ, Cole, AJ, Hobbs, J-PA, Rizzari, JR and Munkres, KP (2012). Effects of spearfishing on reef fish populations in a multi-use conservation area. *PLOS ONE* 7(12): e51938.

107. Frisch, AJ and Hobbs, J-PA (2012). Demography, fishery yield and potential management strategies of painted spiny lobster (*Panulirus versicolor*) at Northwest Island, Great Barrier Reef, Australia. *Marine and Freshwater Research* 63(5): 387-396.

108. Fuentes, M, Fish, MR and Maynard, JA (2012). Management strategies to mitigate the impacts of climate change on sea turtle's terrestrial reproductive phase. *Mitigation and Adaptation Strategies for Global Change* 17(1): 51-63.

109. Gillanders, B, Black, B, Meekan, M and Morrison, M (2012). Climatic effects on the growth of a temperate reef fish from the Southern Hemisphere: a biochronological approach. *Marine Biology* 159(6): 1327-1333.

110. Glas, MS, Sato, Y, Ulstrup, KE and Bourne, DG (2012). Biogeochemical conditions determine virulence of black band disease in corals. *ISME Journal* 6(8): 1526-1534.

111. Goatley, C, Hoey, A and Bellwood, D (2012). The role of turtles as coral reef macroherbivores. *PLOS ONE* 7(6): e39979.

112. Gonzalez-Rivero, M, Ferrari, R, Schonberg, C and Mumby, P (2012). Impacts of macroalgal competition and parrotfish predation on the growth of a common bioeroding sponge. *Marine Ecology Progress Series* 444: 133-142.

113. Grech, A, Chartrand-Miller, K, Erftemeijer, P, Fonseca, M, McKenzie, L, Rasheed, M, Taylor, H and Coles, R (2012). A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. *Environmental Research Letters* 7(2): 024006.

114. Guest, J, Baird, A, Maynard, J, Muttaqin, E, Edwards, A, Campbell, S, Yewdall, K, Affendi, YA and Chou, LM (2012). Contrasting patterns of coral bleaching susceptibility in 2010 suggest an adaptive response to thermal stress. *PLOS ONE* 7: e33353.

115. Guest, JR, Baird, AH, Goh, BPL and Chou, LM (2012). Sexual systems in scleractinian corals: an unusual pattern in the reef-building species *Diploastrea heliopora*. *Coral Reefs* 31(3): 705-713.

116. Hagedorn, M, van Oppen, M, Carter, V, Henley, M, Abrego, D, Puill-Stephan, E, Negri, A, Heyward, A, MacFarlane, D and Spindler, R (2012). First frozen repository for the Great Barrier Reef coral created. *Cryobiology* 65(2): 157-158.

117. Halpern, B, Diamond, J, Gaines, S, Gelcich, S, Gleason, M, Jennings, S, Lester, S, Mace, A, McCook, L, McLeod, K, Napoli, N, Rawson, K, Rice, J, Rosenberg, A, Ruckelshaus, M, Saier, B, Sandifer, P, Scholz, A and Zivian, A (2012). Near-term priorities for the science, policy and practice of Coastal and Marine Spatial Planning (CMSP). *Marine Policy* 36(1): 198-205.

118. Hamel, MA and Andréfouët, S (2012). Biodiversity-based propositions of conservation areas in Baa Atoll, Republic of Maldives. *Atoll Research Bulletin* 590: 223-235.

119. Harborne, AR, Jelks, HL, Smith-Vaniz, WF and Rocha, LA (2012). Abiotic and biotic controls of cryptobenthic fish assemblages across a Caribbean seascape. *Coral Reefs* 31: 977–990.

120. Harnik, PG, Lotze, HK, Anderson, SC, Finkel, ZV, Finnegan, S, Lindberg, DR, Liow, LH, Lockwood, R, McClain, CR, McGuire, JL, O'Dea, A, Pandolfi, JM, Simpson, C and Tittensor, DP (2012). Extinctions in ancient and modern seas. *Trends in Ecology & Evolution* 27(11): 608-17.

121. Harrison, HB, Williamson, DH, Evans, RD, Almany, GR, Thorrold, SR, Russ, GR, Feldheim, KA, van Herwerden, L, Planes, S, Srinivasan, M, Berumen, ML and Jones, GP (2012). Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Current Biology* 22(11): 1023-1028.

122. Hastings, J, Thomas, S, Burgener, V, Gjerde, K, Laffoley, D, Salm, R, McCook, L, Pet-Soede, L, Eichbaum, WM, Bottema, M, Hemley, G, Tanzer, J, Roberts, CM, Govan, H and Fox, HE (2012). Safeguarding the Blue Planet: six strategies for accelerating ocean protection. *The International Journal of Protected Areas and Conservation* 18(1): 1-13.

123. Heatwole, H, Grech, A, Monahan, JF, King, S and Marsh, H (2012). Thermal biology of sea snakes and sea kraits. *Integrative and Comparative Biology* 52(2): 257-273.

124. Hendy, EJ, Tomiak, PJ, Collins, MJ, Hellstrom, J, Tudhope, AW, Lough, JM and Penkman, KEH (2012). Assessing amino acid racemization variability in coral intra-crystalline protein for geochronological applications. *Geochimica et Cosmochimica Acta* 86: 338-353.

125. Hicks, CC and McClanahan, TR (2012). Assessing gear modifications needed to optimize yields in a heavily exploited, multi-species, seagrass and coral reef fishery. *PLOS ONE* 7(5): e36022.

126. Hobbs, J-PA, Jones, GP, Munday, PL, Connolly, SR and Srinivasan, M (2012). Biogeography and the structure of coral reef fish communities on isolated islands. *Journal of Biogeography* 39(1): 130-139.

127. Hodge, JR, Read, CI, van Herwerden, L and Bellwood, DR (2012). The role of peripheral endemism in species diversification: evidence from the coral reef fish genus *Anampses* (Family: Labridae). *Molecular Phylogenetics and Evolution* 62(2): 653-663.

128. Hoegh-Guldberg, O (2012). Coral reefs and adaptation to climate change: is the Red Queen being outpaced? *Scientia Marina* 76(2): 403-408.

129. Hoey, AS, Bellwood, DR and Barnett, A (2012). To feed or to breed: morphological constraints of mouthbrooding in coral reef cardinalfishes. *Proceedings of the Royal Society B-Biological Sciences* 279(1737): 2426-2432.

130. Hoogenboom, MO, Campbell, DA, Beraud, E, DeZeeuw, K and Ferrier-Pages, C (2012). Effects of light, food availability and temperature stress on the function of photosystem II and photosystem I of coral symbionts. *PLOS ONE* 7(1): e30167.

131. Horigue, V, Alino, PM, White, AT and Pressey, RL (2012). Marine protected area networks in the Philippines: trends and challenges for establishment and governance. *Ocean & Coastal Management* 64: 15-26.

132. Howells, EJ, Beltran, VH, Larsen, NW, Bay, LK, Willis, BL and van Oppen, MJH (2012). Coral thermal tolerance shaped by local adaptation of photosymbionts. *Nature Climate Change* 2: 116-120.

133. Hubert, N, Meyer, CP, Bruggemann, HJ, Guerin, F, Komeno, RJL, Espiau, B, Causse, R, Williams, JT and Planes, S (2012). Cryptic diversity in Indo-Pacific coral-reef fishes revealed by DNA-barcoding provides new support to the centre-of-overlap hypothesis. *PLOS ONE* 7(3): e28987.

134. Hughes, S, Yaua, A, Max, L, Petrovicc, N, Davenport, F, Marshall, M, McClanahan, T, Allison, E and Cinner, J (2012). A framework to assess national level vulnerability from the perspective of food security: the case of coral reef fisheries. *Environmental Science & Policy* 23: 95-108.

135. Hughes, TP, Baird, AH, Dinsdale, EA, Moltschaniwskyj, NA, Pratchett, MS, Tanner, JE and Willis, BL (2012). Assembly rules of reef corals are flexible along a steep climatic gradient. *Current Biology* 22(8): 736-741.

136. Hyndes, GA, Lavery, PS and Doropoulos, C (2012). Dual processes for cross-boundary subsidies: incorporation of nutrients from reef-derived kelp into a seagrass ecosystem. *Marine Ecology Progress Series* 445: 97-107.

137. Januchowski-Hartley, F, Nash, K and Lawton, R (2012). Influence of spear guns, dive gear and observers on estimating fish flight initiation distance on coral reefs. *Marine Ecology Progress Series* 469: 113-119.

138. Januchowski-Hartley, SR, Moon, K, Stoeckl, N and Gray, S (2012). Social factors and private benefits influence landholders' riverine restoration priorities in tropical Australia. *Journal of Environmental Management* 110: 20-6.

139. Jimenez, H, Bigot, L, Bourmaud, C, Chabanet, P, Gravier-Bonnet, N, Hamel, M, Payri, C, Mattio, L, Menou, JL, Naeem, S, Rilwan, Y, Sattar, S, Scott, L, Shiham, A, Vigliola, L and Andréfouët, S (2012). Multi-taxa coral reef community structure in relation to habitats in the Baa Atoll Man and Biosphere UNESCO Reserve (Maldives), and implications for its conservation. *Journal of Sea Research* 72: 77-86.

140. Johansson, CL, Bellwood, DR and Depczynski, M (2012). The importance of live coral for small-sized herbivorous reef fishes in physically challenging environments. *Marine and Freshwater Research* 63(8): 672-679.

141. Jupiter, S, Weeks, R, Jenkins, A, Egli, D and Cakacaka, A (2012). Effects of a single intensive harvest event on fish populations inside a customary marine closure. *Coral Reefs* 31(2): 321-334.

142. Kaniewska, P, Campbell, P, Kline, D, Rodriguez-Lanetty, M, Miller, D, Dove, S and Hoegh-Guldberg, O (2012). Major cellular impacts of ocean acidification on a reef-building coral. *PLOS ONE* 7: e34659.

143. Kayal, M, Vercelloni, J, Lison de Loma, T, Bosserelle, P, Chancerelle, Y, Geoffroy, S, Stievenart, C, Michonneau, F, Penin, L, Planes, S and Adjeroud, M (2012). Predator Crown-of-Thorns Starfish (*Acanthaster planci*) outbreak, mass mortality of corals, and cascading effects on reef fish and benthic communities. *PLOS ONE* 7(10): e47363.

144. Keith, SA, Webb, TJ, Böhning-Gaese, K, Connolly, SR, Dulvy, NK, Eigenbrod, F, Jones, KE, Price, T, Redding, DW, Owens, IPF and Isaac, NJB (2012). What is macroecology? *Biology Letters* 8(6): 904-906.

145. Kerry, J and Bellwood, D (2012). The effect of coral morphology on shelter selection by coral reef fishes. *Coral Reefs* 31(2): 415-424.

146. Kiessling, W, Simpson, C, Beck, B, Mewis, H and Pandolfi, JM (2012). Equatorial decline of reef corals during the last Pleistocene interglacial. *Proceedings of the National Academy of Sciences* 109(52): 21378-21383.

147. Kingsford, MJ, Seymour, JE and O'Callaghan, MD (2012). Abundance patterns of cubozoans on and near the Great Barrier Reef. *Hydrobiologia* 690(1): 257-268.

148. Kitahara, M, Stolarski, J, Cairns, S, Benzoni, F, Stake, J and Miller, D (2012). The first modern solitary Agariciidae (Anthozoa, Scleractinia) revealed by molecular and microstructural analysis. *Invertebrate Systematics* 26: 303-315.

149. Kline, DI, Teneva, L, Schneider, K, Miard, T, Chai, A, Marker, M, Headley, K, Opdyke, B, Nash, M, Valetich, M, Caves, JK, Russell, BD, Connell, SD, Kirkwood, BJ, Brewer, P, Peltzer, E, Silverman, J, Caldeira, K, Dunbar, RB, Koseff, JR, Monismith, SG, Mitchell, BG, Dove, S and Hoegh-Guldberg, O (2012). A short-term *in situ* CO_2 enrichment experiment on Heron Island (GBR). *Scientific Reports* 2: 1-9.

150. Kongjandtre, N, Ridgway, T, Cook, L, Huelsken, T, Budd, A and Hoegh-Guldberg, O (2012). Taxonomy and species boundaries in the coral genus *Favia* Milne Edwards and Haime, 1857 (Cnidaria: Scleractinia) from Thailand revealed by morphological and genetic data. *Coral Reefs* 31(2): 581-601.

151. Kramer, MJ, Bellwood, DR and Bellwood, O (2012). Cryptofauna of the epilithic algal matrix on an inshore coral reef, Great Barrier Reef. *Coral Reefs* 31: 1007–1015.

152. Kulbicki, M, Beets, J, Chabanet, P, Cure, K, Darling, E, Floeter, SR, Galzin, R, Green, A, Harmelin-Vivien, M, Hixon, M, Letourneur, Y, de Loma, TL, McClanahan, T, McIlwain, J, MouTham, G, Myers, R, O'Leary, JK, Planes, S, Vigliola, L and Wantiez, L (2012). Distributions of Indo-Pacific lionfishes *Pterois* spp. in their native ranges: Implications for the Atlantic invasion. *Marine Ecology Progress Series* 446: 189-205.

153. Kuo, CY, Yuen, YS, Meng, PJ, Ho, PH, Wang, JT, Liu, PJ, Chang, YC, Dai, CF, Fan, TY, Lin, HJ, Baird, AH and Chen, CA (2012). Recurrent disturbances and the degradation of hard coral communities in Taiwan. *PLOS ONE* 7(8): e44364.

154. Kvennefors, ECE, Sampayo, E, Kerr, C, Vieira, G, Roff, G and Barnes, AC (2012). Regulation of bacterial communities through antimicrobial activity by the coral holobiont. *Microbial Ecology* 63(3): 605-618.

155. Lawton, R and Pratchett, M (2012). Influence of dietary specialisation and resource availability on geographical variation in abundance of butterflyfishes. *Ecology and Evolution* 2(7): 1347-1361.

156. Lawton, RJ, Cole, AJ, Berumen, ML and Pratchett, MS (2012). Geographic variation in resource use by specialist versus generalist butterflyfishes. *Ecography* 35(6): 566-576.

157. Lawton, RJ, Pratchett, MS and Berumen, ML (2012). The use of specialisation indices to predict vulnerability of coral-feeding

butterflyfishes to environmental change. *Oikos* 121(2): 191-200.

158. Lema, KA, Willis, BL and Bourne, DG (2012). Corals form characteristic associations with symbiotic nitrogen-fixing bacteria. *Applied and Environmental Microbiology* 78(9): 3136-3144.

159. Leuzinger, S, Willis, B and Anthony, K (2012). Energy allocation in a reef coral under varying resource availability. *Marine Biology* 159(1): 177-186.

160. Lewis, SE, Brodie, JE, McCulloch, MT, Mallela, J, Jupiter, SD, Stuart Williams, H, Lough, JM and Matson, EG (2012). An assessment of an environmental gradient using coral geochemical records, Whitsunday Islands, Great Barrier Reef, Australia. *Marine Pollution Bulletin* 65: 306-319.

161. Lewis, SE, Wust, RAJ, Webster, JM, Shields, GA, Renema, W, Lough, JM and Jacobsen, G (2012). Development of an inshore fringing coral reef using textural, compositional and stratigraphic data from Magnetic Island, Great Barrier Reef, Australia. *Marine Geology* 299: 18-32.

162. Lin, MF, Kitahara, MV, Tachikawa, H, Fukami, H, Miller, DJ and Chen, CA (2012). Novel organization of the mitochondrial genome in the deep-sea coral, *Madrepora oculata* (Hexacorallia, Scleractinia, Oculinidae) and its taxonomic implications. *Molecular Phylogenetics and Evolution* 65(1): 323-328.

163. Lin, M-F, Kitahara, MV, Tachikawa, H, Keshavmurthy, S and Chen, CA (2012). A new shallow-water species, *Polycyathus chaishanensis* sp nov (Scleractinia: Caryophylliidae), from Chaishan, Kaohsiung, Taiwan. *Zoological Studies* 51(2): 213-221.

164. Llewellyn, LE, Everingham, YL and Lough, JM (2012). Pharmacokinetic modelling of multi-decadal luminescence time series in coral skeletons. *Geochimica et Cosmochimica Acta* 83: 263-271.

165. Lonnstedt, OM, McCormick, MI and Chivers, DP (2012). Well-informed foraging: Damage-released chemical cues of injured prey signal quality and size to predators. *Oecologia* 168(3): 651-658.

166. Lonnstedt, OM, McCormick, MI, Meekan, MG, Ferrari, MCO and Chivers, DP (2012). Learn and live: predator experience and feeding history determines prey behaviour and survival. *Proceedings of the Royal Society B-Biological Sciences* 279(1736): 2091-2098.

167. Lough, JM (2012). Small change, big difference: Sea surface temperature distributions for tropical coral reef ecosystems, 1950-2011. *Journal of Geophysical Research-Oceans* 117(C9): C09018.

168. Lukoschek, V and Avise, JC (2012). Development of eleven polymorphic microsatellite loci for the sea snake *Emydocephalus annulatus* (Elapidae: Hydrophiinae) and cross-species amplification for seven species in the sister genus *Aipysurus*. *Conservation Genetics Resources* 4(1): 11-14.

169. Lukoschek, V, Keogh, S and Avise, JC (2012). Evaluating fossil calibrations for dating phylogenies in light of rates of molecular evolution: a comparison of three approaches. *Systematic Biology* 61(1): 22-43.

170. Lukoschek, V and Shine, R (2012). Sea snakes rarely venture far from home. *Ecology and Evolution* 2(6): 1113–1121.

171. Maddams, J and McCormick, M (2012). Not all offspring are created equal: Variation in larval characteristics in a serially spawning damselfish. *PLOS ONE* 7(11): e48525.

172. Madin, E, Ban, NC, Doubleday, Z, Holmes, T, Pecl, G and Smith, F (2012). Socio-economic and management implications of range-shifting species in marine systems. *Global Environmental Change* 22(1): 137-146.

173. Madin, JS, Hoogenboom, MO and Connolly, SR (2012). Integrating physiological and biomechanical drivers of population growth over environmental gradients on coral reefs. *Journal of Experimental Biology* 215(6): 968-976.

174. Madin, JS, Hughes, TP and Connolly, SR (2012). Calcification, storm damage and population resilience of tabular corals under climate change. *PLOS ONE* 7(10): e46637.

175. Malcolm, HA, Foulsham, E, Pressey, RL, Jordan, A, Davies, PL, Ingleton, T, Johnstone, N, Hessey, S and Smith, SDA (2012). Selecting zones in a marine park: early systematic planning improves cost-efficiency; combining habitat and biotic data improves effectiveness. *Ocean & Coastal Management* 59: 1-12.

176. Malerba, ME, Connolly, SR and Heimann, K (2012). Nitrate-nitrite dynamics and phytoplankton growth: formulation and experimental evaluation of a dynamic model. *Limnology and Oceanography* 57: 1555-1571.

177. Manassa, RP and McCormick, MI (2012). Risk assessment via predator diet cues in a coral reef goby. *Journal of Experimental Marine Biology and Ecology* 426: 48-52.

178. Manassa, RP and McCormick, MI (2012). Social learning and acquired recognition of a predator by a marine fish. *Animal Cognition* 15(4): 559-565.

179. Manuel, M and Forêt, S (2012). Searching for Eve: Basal metazoans and the evolution of multicellular complexity. *BioEssays* 34(3): 247-251.

180. Marshell, A and Mumby, P (2012). Revisiting the functional roles of the surgeonfish *Acanthurus nigrofuscus* and *Ctenochaetus striatus*. *Coral Reefs* 31: 1093–1101.

181. McClanahan, T, Abunge, C and Cinner, J (2012). Heterogeneity in fishers' and managers' preferences towards management restrictions and benefits in Kenya. *Environmental Conservation* 39(4): 357-369.

182. McClanahan, TR, Donner, SD, Maynard, JA, MacNeil, MA, Graham, NA, Maina, J, Baker, AC, Alemu, JBI, Beger, M, Campbell, SJ, Darling, ES, Eakin, CM, Heron, SF, Jupiter, SD, Lundquist, CJ, McLeod, E, Mumby, PJ, Paddack, MJ, Selig, ER and van Woesik, R (2012). Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLOS ONE* 7(8): e42884.

183. McCormick, MI (2012). Lethal effects of habitat degradation on fishes through changing competitive advantage. *Proceedings of the Royal Society B-Biological Sciences* 279(1744): 3899-3904.

184. McCormick, MI and Weaver, CJ (2012). It pays to be pushy: intracohort interference competition between two reef fishes. *PLOS ONE* 7(8): e42590.

185. McCulloch, M, Falter, J, Trotter, J and Montagna, P (2012). Coral resilience to ocean acidification and global warming through pH up-regulation. *Nature Climate Change* 2: 623-627.

186. McCulloch, M, Trotter, J, Montagna, P, Falter, J, Dunbar, R, Freiwald, A, Foersterra, N, Correa, ML, Maier, C, Ruggeberg, A and Taviani, M (2012). Resilience of cold-water scleractinian corals to ocean acidification: boron isotopic systematics of pH and saturation state up-regulation. *Geochimica et Cosmochimica Acta* 87: 21-34.

187. McLeod, E, Green, A, Game, E, Anthony, K, Cinner, J, Heron, S, Kleypas, J, Lovelock, C, Pandolfi, J, Pressey, R, Salm, R, Schill, S and Woodroffe, C (2012). Integrating climate and ocean change vulnerability into conservation planning. *Coastal Management* 40(6): 357-369.

188. McLeod, IM, Parsons, DM, Morrison, MA, Le Port, AS and Taylor, RB (2012). Factors affecting the recovery of soft-sediment mussel reefs in the Firth of Thames, New Zealand. *Marine and Freshwater Research* 63(1): 78-83.

189. Menard, A, Turgeon, K, Roche, DG, Binning, SA and Kramer, DL (2012). Shelters and their use by fishes on fringing coral reefs. *PLOS ONE* 7(6): e38450.

190. Messmer, V, Jones, GP, Munday , PL and Planes, S (2012). Concordance between genetic and species diversity in coral reef fishes across the Pacific Ocean biodiversity gradient. *Evolution* 66(12): 3902–3917.

191. Metais, I, Ekouma, EM, Ngpan, R, Planes, S and Mouneyrac, C (2012). Oxidative stress responses and biological indices in the giant clam *Tridacna maxima* and the reef fish *Epinephelus merra* from the French Polynesian Moorea Island. *Marine Pollution Bulletin* 64(10): 2233-2237.

192. Middlebrook, R, Anthony, K, Hoegh-Guldberg, O and Dove, S (2012). Thermal priming affects symbiont photosynthesis but does not alter bleaching susceptibility in *Acropora millepora*. *Journal of Experimental Marine Biology and Ecology* 432-433: 64-72.

193. Miller, GM, Watson, S-A, Donelson, JM, McCormick, MI and Munday, PL (2012). Parental environment mediates impacts of elevated CO_2 on a coral reef fish. *Nature Climate Change* 2: 858–861.

194. Mills, M, Adams, VM, Pressey, RL, Ban, NC and Jupiter, S (2012). Where do national and local conservation actions meet? Simulating the expansion of ad hoc and systematic approaches to conservation into the future in Fiji. *Conservation Letters* 5(5): 387-398.

195. Mitchell, M, Cowman, P and McCormick, M (2012). Chemical alarm cues are conserved within the coral reef fish family Pomacentridae. *PLOS ONE* 7(10): e47428.

196. Mooney, CJ and Kingsford, MJ (2012). Sources and movements of *Chironex fleckeri* medusae using statolith elemental chemistry. *Hydrobiologia* 690(1): 269-277.

197. Moya, A, Huisman, L, Ball, EE, Hayward, DC, Grasso, LC, Chua, CM, Woo, HN, Gattuso, JP, Forêt, S and Miller, DJ (2012). Whole transcriptome analysis of the coral *Acropora millepora* reveals complex responses to CO_2-driven acidification during the initiation of calcification. *Molecular Ecology* 21(10): 2440-2454.

198. Muhs, DR, Pandolfi, JM, Simmons, KR and Schumann, RR (2012). Sea-level history of past interglacial periods from uranium-series dating of corals, Curacao, Leeward Antilles islands. *Quaternary Research* 78(2): 157-169.

199. Mumby, PJ, Steneck, RS, Edwards, AJ, Ferrari, R, Coleman, R, Harborne, AR and Gibson, JP (2012). Fishing down a Caribbean food web relaxes trophic cascades. *Marine Ecology Progress Series* 445: 13-24.

200. Munday, PL, McCormick, MI and Nilsson, GE (2012). Impact of global warming and rising CO_2 on coral reef fishes: what hope for the future? *Journal of Experimental Biology* 215: 3865-3873.

201. Nash, KL, Graham, NAJ, Januchowski-Hartley, FA and Bellwood, DR (2012). Influence of habitat condition and competition on foraging behaviour of parrotfishes. *Marine Ecology Progress Series* 457: 113-124.

202. Nesa, B, Baird, AH, Harii, S, Yakovleva, I and Hidaka, M (2012). Algal symbionts increase DNA damage in coral planulae exposed to sunlight. *Zoological Studies* 51(1): 12-17.

203. Nilsson, GE, Dixson, DL, Domenici, P, McCormick, MI, Sorensen, C, Watson, S-A and Munday, PL (2012). Near-future carbon dioxide levels alter fish behaviour by interfering with neurotransmitter function. *Nature Climate Change* 2(3): 201-204.

204. Noonan, SHC, Jones, GP and Pratchett, MS (2012). Coral size, health and structural complexity: effects on the ecology of a coral reef damselfish. *Marine Ecology Progress Series* 456: 127-137.

205. Nowicki, JP, Miller, GM and Munday, PL (2012). Interactive effects of elevated temperature and CO_2 on foraging behavior of juvenile coral reef fish. *Journal of Experimental Marine Biology and Ecology* 412: 46-51.

206. Nyström, M, Norström, AV, Blenckner, T, de la Torre-Castro, M, Eklof, JS, Folke, C, Osterblom, H, Steneck, RS, Thyresson, M and Troell, M (2012). Confronting feedbacks of degraded marine ecosystems. *Ecosystems* 15(5): 695-710.

207. O'Shea, OR, Thums, M, van Keulen, M and Meekan, M (2012). Bioturbation by stingrays at Ningaloo Reef, Western Australia. *Marine and Freshwater Research* 63(3): 189-197.

208. Palmer, C, Graham, E and Baird, A (2012). Immunity through early development of coral larvae. *Developmental and Comparative Immunology* 38: 395-399.

209. Palmer, CV, Bythell, JC and Willis, BL (2012). Enzyme activity demonstrates multiple pathways of innate immunity in Indo-Pacific anthozoans. *Proceedings of the Royal Society B-Biological Sciences* 279(1743): 3879-3887.

210. Pandolfi, J and Budd, A (2012). A festschrift for Jeremy B.C. Jackson and his integration of paleobiology, ecology, evolution, and conservation biology. *Evolutionary Ecology* 26(2): 227-232.

211. Pernice, M, Meibom, A, Van Den Heuvel, A, Kopp, C, Domart-Coulon, I, Hoegh-Guldberg, O and Dove, S (2012). A single-cell view of ammonium assimilation in coral-dinoflagellate symbiosis. *The ISME Journal* 6: 1314–1324.

212. Pisapia, C, Hennige, SJ, Haapkylae, J, Matteucci, R and Smith, DJ (2012). Morphological changes in polyp structure of massive coral species in clear and turbid waters. *Bulletin of Marine Science* 88(1): 183-191.

213. Planes, S, Lecchini, D, Mellin, C, Charton, JG, Harmelin-Vivien, M, Kulbicki, M, Mou-Tham, G and Galzin, R (2012). Environmental determinants of coral reef fish diversity across several French Polynesian atolls. *Comptes Rendus Biologies* 335(6): 417-423.

214. Pommier, T, Douzery, EJP and Mouillot, D (2012). Environment drives high phylogenetic turnover among oceanic bacterial communities. *Biology Letters* 8(4): 562-566.

215. Pratchett, MS, Coker, DJ, Jones, GP and Munday, PL (2012). Specialisation in habitat use by coral reef damselfishes and their susceptibility to habitat loss. *Ecology and Evolution* 2(9): 2168-2180.

216. Puill-Stephan, E, Seneca, F, Miller, D, van Oppen, M and Willis, B (2012). Expression of putative immune response genes during early ontogeny and allorecognition maturation in the coral *Acropora millepora*. *PLOS ONE* 7: e39099.

217. Puill-Stephan, E, van Oppen, MJH, Pichavant-Rafini, K and Willis, BL (2012). 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.

218. Puill-Stephan, E, Willis, BL, Abrego, D, Raina, J-B and van Oppen, MJH (2012). Allorecognition maturation in the broadcast-spawning coral *Acropora millepora*. *Coral Reefs* 31: 1019–1028.

219. Purcell, SW, Hair, CA and Mills, DJ (2012). Sea cucumber culture, farming and sea ranching in the tropics: progress, problems and opportunities. *Aquaculture* 368-369: 68–81.

220. Ramirez-Macias, D, Meekan, M, de la Parra-Venegas, R, Remolina-Suarez, F, Trigo-Mendoza, M and Vazquez-Juarez, R (2012). Patterns in composition, abundance and scarring of whale sharks *Rhincodon typus* near Holbox Island, Mexico. *Journal of Fish Biology* 80(5): 1401-1416.

221. Rau, G, McLeod, E and Hoegh-Guldberg, H (2012). The need for new ocean conservation strategies in a high-carbon dioxide world. *Nature Climate Change* 2: 720–724.

222. Redondo-Rodriguez, A, Weeks, SJ, Berkelmans, R, Hoegh-Guldberg, O and Lough, JM (2012). Climate variability of the Great Barrier Reef in relation to the tropical Pacific and El Nino-Southern Oscillation. *Marine and Freshwater Research* 63(1): 34-47.

223. Reef, R, Pandolfi, JM and Lovelock, CE (2012). The effect of nutrient enrichment on the growth, nucleic acid concentrations, and elemental stoichiometry of coral reef macroalgae. *Ecology and Evolution* 2(8): 1985-1995.

224. Reyes-Bermudez, A, Miller, D and Sprungala, S (2012). The neuronal calcium sensor protein Acrocalcin: a potential target of calmodulin regulation during development in the coral *Acropora millepora*. *PLOS ONE* 7 (12): e51689.

225. Richards, Z and van Oppen, M (2012). Rarity and genetic diversity in Indo-Pacific *Acropora* corals. *Ecology and Evolution* 2(8): 1867-1888.

226. Richardson, A, Brown, C, Brander, K, Bruno, J, Buckley, L, Burrows, M, Duarte, C, Halpern, B, Hoegh-Guldberg, O, Holding, J, Kappel, C, Kiessling, W, Moore, P, O'Connor, M, Pandolfi, J, Parmesan, C, Schoeman, D, Schwing, F, Sydeman, W and Poloczanska, E (2012). Climate change and marine life. *Biology Letters* 8(6): 907-909.

227. Rivera-Posada, J, Owens, L, Caballes, CF and Pratchett, MS (2012). The role of protein extracts in the induction of disease in *Acanthaster planci*. *Journal of Experimental Marine Biology and Ecology* 429: 1-6.

228. Roff, G and Mumby, PJ (2012). Global disparity in the resilience of coral reefs. *Trends in Ecology & Evolution* 27(7): 404-413.

229. Rudi, E, Hoey, A, Campbell, S, Fadli, N, Linkie, M and Baird, A (2012). The Coral Triangle Initiative: what are we missing? A case study from Aceh, Indonesia. *Oryx* 46(4): 482–485.

230. Ruiz-Moreno, D, Willis, BL, Page, CA, Weil, E, Cróquer, A, Vargas-Angel, B, Jordan-Garza, AG, Jordán-Dahlgren, E, Raymundo, L and Harvell, CD (2012). Global coral disease prevalence associated with sea temperature anomalies and local factors. *Diseases of Aquatic Organisms* 100: 249–261.

231. Saenger, C, Affek, H, Felis, T, Thiagarajan, N, Lough, J and Holcomb, M (2012). Carbonate clumped isotope variability in shallow water corals: temperature dependence and growth-related vital effects. *Geochimica et Cosmochimica Acta* 99: 224-242.

232. Saenz-Agudelo, P, Jones, GP, Thorrold, SR and Planes, S (2012). Patterns and persistence of larval retention and connectivity in a marine fish metapopulation. *Molecular Ecology* 21(19): 4695-4705.

233. Sequeira, A, Mellin, C, Rowat, D, Meekan, MG and Bradshaw, CJA (2012). Ocean-scale prediction of whale shark distribution. *Diversity and Distributions* 18(5): 504-518.

234. Setiawan, A, Cinner, JE, Sutton, SG and Mukminin, A (2012). The perceived impact of customary marine resource management on household and community welfare in northern Sumatra, Indonesia. *Coastal Management* 40(3): 239-249.

235. Sheppard, CRC, Ateweberhan, M, Bowen, BW, Carr, P, Chen, CA, Clubbe, C, Craig, MT, Ebinghaus, R, Eble, J, Fitzsimmons, N, Gaither, MR, Gan, CH, Gollock, M, Guzman, N, Graham, NAJ, Harris, A, Jones, R, Keshavmurthy, S, Koldewey, H, Lundin, CG, Mortimer, JA, Obura, D, Pfeiffer, M, Price, ARG, Purkis, S, Raines, P, Readman, JW, Riegl, B, Rogers, A, Schleyer, M, Seaward, MRD, Sheppard, ALS, Tamelander, J, Turner, JR, Visram, S, Vogler, C, Vogt, S, Wolschke, H, Yang, JMC, Yang, SY and Yesson, C (2012). Reefs and islands of the Chagos Archipelago, Indian Ocean: why it is the world's largest no-take marine protected area. *Aquatic Conservation-Marine and Freshwater Ecosystems* 22(2): 232-261.

236. Shi, J, Fan, E, Huang, Y, Gu, L and Fabinyi, M (2012). Australian aquaculture production and environmental management (in Chinese). *Jiangsu Journal of Agricultural Sciences* 40(2): 250-252.

237. Speed, C, Meekan, M, Field, I, McMahon, C, Abrantes, K and Bradshaw, C (2012). Trophic ecology of reef sharks determined using stable isotopes and telemetry. *Coral Reefs* 31(2): 357-367.

238. Speed, CW, Meekan, MG, Field, IC, McMahon, CR and Bradshaw, CJA (2012). Heat-seeking sharks: support for behavioural thermoregulation in reef sharks. *Marine Ecology Progress Series* 463: 231-244.

239. Sprenger, D, Dingemanse, NJ, Dochtermann, NA, Theobald, J and Walker, SPW (2012). Aggressive females become aggressive males in a sex-changing reef fish. *Ecology Letters* 15(9): 986-992.

240. Stat, M, Baker, AC, Bourne, DG, Correa, AMS, Forsman, Z, Huggett, MJ, Pochon, X, Skillings, D, Toonen, RJ, van Oppen, MJH and Gates, RD (2012). Molecular delineation of species in the coral holobiont. *Advances in Marine Biology* 63: 1-65.

241. Steneck, RS (2012). Apex predators and trophic cascades in large marine ecosystems: Learning from serendipity. *Proceedings of the National Academy of Sciences* 109(21): 7953-7954.

242. Sun, D, Blomberg, SP, Cribb, TH, McCormick, MI and Grutter, AS (2012). The effects of parasites on the early life stages of a damselfish. *Coral Reefs* 31: 1065–1075.

243. Takahashi, M, Mc Cormick, MI, Munday, PL and Jones, GP (2012). Influence of seasonal and latitudinal temperature variation on early life history traits of a coral reef fish. *Marine and Freshwater Research* 63(10): 856-864.

244. Templeman, MA and Kingsford, MJ (2012). Variation in soft tissue chemistry among scyphozoan and cubozoan jellyfishes from the Great Barrier Reef, Australia. *Hydrobiologia* 690(1): 279-290.

245. Thibaut, LM, Connolly, SR and Sweatman, HPA (2012). Diversity and stability of herbivorous fishes on coral reefs. *Ecology* 93(4): 891-901.

246. Thomas, MC, Dunn, SR, Altvater, J, Dove, SG and Nette, GW (2012). Rapid identification of long-chain polyunsaturated fatty acids in a marine extract by HPLC-MS using data-dependent acquisition. *Analytical Chemistry* 84(14): 5976-5983.

247. Tillett, BJ, Field, IC, Bradshaw, CJA, Johnson, G, Buckworth, RC, Meekan, MG and Ovenden, JR (2012). Accuracy of species identification by fisheries observers in a north Australian shark fishery. *Fisheries Research* 127: 109-115.

248. Tillett, BJ, Meekan, MG, Broderick, D, Field, IC, Cliff, G and Ovenden, JR (2012). Pleistocene isolation, secondary introgression and restricted contemporary gene flow in the pig-eye shark, *Carcharhinus amboinensis* across northern Australia. *Conservation Genetics* 13(1): 99-115.

249. Tillett, J, Meekan, MG, Field, IC, Thorburn, DC and Ovenden, JR (2012). Evidence for reproductive philopatry in the bull shark *Carcharhinus leucas*. *Journal of Fish Biology* 80(6): 2140-2158.

250. Timm, J, Planes, S and Kochzius, M (2012). High similarity of genetic population structure in the false clown anemonefish (*Amphiprion ocellaris*) found in microsatellite and mitochondrial control region analysis. *Conservation Genetics* 13(3): 693-706.

251. van der Meer, M, Hobbs, J, Jones, G and van Herwerden, L (2012). Genetic connectivity among and self-replenishment within island populations of a restricted range subtropical reef fish. *PLOS ONE* 7(11): e49660.

252. van der Meer, MH, Gardner, MG, Hobbs, J-PA, Jones, GP and van Herwerden, L (2012). Identification of seventeen microsatellite markers for conservation genetic studies of the endemic anemonefish, *Amphiprion mccullochi*. *Conservation Genetics Resources* 4(2): 247-250.

253. van der Meer, MH, Gardner, MG, Hobbs, J-PA, Pratchett, M and van Herwerden, L (2012). Identification of twenty one microsatellite loci for conservation genetic studies of the endemic butterflyfish *Chaetodon tricinctus*. *Conservation Genetics Resources* 4(2): 243-246.

254. van der Meer, MH, Jones, GP, Hobbs, JPA and van Herwerden, L (2012). Historic hybridization and introgression between two iconic Australian anemonefish and contemporary patterns of population connectivity. *Ecology and Evolution* 2(7): 1592-1604.

255. Van Wynsberge, S, Andréfouët, S, Hamel, MA and Kulbicki, M (2012). Habitats as surrogates of taxonomic and functional fish assemblages in coral reef ecosystems: a critical analysis of factors driving effectiveness. *PLOS ONE* 7(7): e40997.

256. Vergés, A, Bennett, S and Bellwood, D (2012). Diversity among macroalgae-consuming fishes on coral reefs: a transcontinental comparison. *PLOS ONE* 7(9): e45543.

257. Vianna, GMS, Meekan, MG, Pannell, DJ, Marsh, SP and Meeuwig, JJ (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. *Biological Conservation* 145(1): 267-277.

258. Villeger, S, Ferraton, F, Mouillot, D and de Wit, R (2012). Nutrient recycling by coastal macrofauna: intra- versus interspecific differences. *Marine Ecology Progress Series* 452: 297-303.

259. Villeger, S, Miranda, JR, Hernandez, DF and Mouillot, D (2012). Low functional beta-diversity despite high taxonomic beta-diversity among tropical estuarine fish communities. *PLOS ONE* 7(7): e40679.

260. Wamukota, AW, Cinner, JE and McClanahan, TR (2012). Co-management of coral reef fisheries: a critical evaluation of the literature. *Marine Policy* 36(2): 481-488.

261. Wei, NV, Hsieh, HJ, Dai, C-F, Wallace, CC, Baird, AH and Chen, CA (2012). Reproductive isolation among *Acropora* species (Scleractinia: Acroporidae) in a marginal coral assemblage. *Zoological Studies* 51(1): 85-92.

262. Welsh, J and Bellwood, D (2012). Spatial ecology of the steephead parrotfish (*Chlorurus microrhinos*): an evaluation using acoustic telemetry. *Coral Reefs* 31(1): 55-65.

263. Welsh, JQ and Bellwood, DR (2012). How far do schools of roving herbivores rove? A case study using *Scarus rivulatus*. *Coral Reefs* 31: 991–1003.

264. Welsh, JQ and Bellwood, DR (2012). Regional endothermy in a coral reef fish? *PLOS ONE* 7(3): e33187.

265. Wen, C, Almany, G, Williamson, D, Pratchett, M and Jones, G (2012). Evaluating the effects of marine reserves on diet, prey availability and prey selection by juvenile predatory fishes. *Marine Ecology Progress Series* 469: 133–144.

266. Wenger, AS, Johansen, JL and Jones, GP (2012). Increasing suspended sediment reduces foraging, growth and condition of a planktivorous damselfish. *Journal of Experimental Marine Biology and Ecology* 428: 43-48.

267. Wilson, S, Graham, N, Fisher, R, Robinson, J, Nash, K, Chong-Seng, K, Polunin, N, Aumeeruddy, R and Quatre, R (2012). Effect of macroalgae expansion and marine protected areas on coral recovery following a climatic disturbance. *Conservation Biology* 26(6): 995-1004.

268. Woolsey, E, Bainbridge, S, Kingsford, M and Byrne, M (2012). Impacts of cyclone Hamish at One Tree Reef: integrating environmental and benthic habitat data. *Marine Biology* 159(4): 793-803.

269. Wyatt, ASJ, Falter, JL, Lowe, RJ, Humphries, S and Waite, AM (2012). Oceanographic forcing of nutrient uptake and release over a fringing coral reef. *Limnology and Oceanography* 57(2): 401-419.

270. Young, M and Bellwood, D (2012). Fish predation on sea urchins on the Great Barrier Reef. *Coral Reefs* 31(3): 731-738.

271. Yu, KF, Zhao, JX, Roff, G, Lybolt, M, Feng, YX, Clark, T and Li, S (2012). High-precision U-series ages of transported coral blocks on Heron Reef (southern Great Barrier Reef) and storm activity during the past century. *Palaeogeography Palaeoclimatology Palaeoecology* 337: 23-36.

272. Zhang, Z, Falter, J, Lowe, R and Ivey, G (2012). The combined influence of hydrodynamic forcing and calcification on the spatial distribution of alkalinity in a coral reef system. *Journal of Geophysical Research-Oceans* 117(C4): C04034.

Other (6)

1. Baird, A, Sommer, B and Madin, J (2012). Pole-ward range expansion of *Acropora* spp. along the east coast of Australia. *Coral Reefs* 31: 1063.
2. Bongaerts, P, Hoeksema, B, Hay, K and Hoegh-Guldberg, O (2012). Mushroom corals overcome live burial through pulsed inflation. *Coral Reefs* 31(2): 399.
3. Ceccarelli, D and Williamson, D (2012). Sharks that eat sharks: opportunistic predation by wobbegongs. *Coral Reefs* 31(2): 471-471.
4. Cumbo, VR, Fan, T-Y and Edmunds, PJ (2012). Scleractinian corals capture zooplankton within days of settlement and metamorphosis. *Coral Reefs* 31: 1155.
5. Stella, JS (2012). Evidence of corallivory by the keyhole limpet *Diodora galeata*. *Coral Reefs* 31(2): 579.
6. van de Water, JAJM, van Oppen, MJH and Willis, BL (2012). Absence of skeleton deposition in juveniles of the scleractinian coral *Acropora millepora*. *Coral Reefs* 31: 1111.

Conference Paper (18)

1. Anderson, K, Pratchett, M and Baird, A (2012). Summer growth rates of corals at Lord Howe Island, Australia, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
2. Baird, AH, Emslie, MJ and Lewis, AR (2012). Extended periods of coral recruitment on the Great Barrier Reef, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
3. Cappo, M, Stowar, M, Stieglitz, T, Lawrey, E, Johansson, C and Macneil, A (2012). Measuring and communicating effects of MPAs on deep "shoal" fisheries, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
4. Chua, C-M, Schupp, P, Leggat, W and Baird, A (2012). Effects of ocean acidification on metamorphosis: brooding and spawning larvae, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
5. Coles, R, Grech, A, Rasheed, M and McKenzie, L (2012). Evaluating risk to seagrasses in the Tropical Indo-Pacific Region, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
6. Devlin, M, Wenger, A, Da Silva, E, Alvarez Romero, JG, Waterhouse, J and McKenzie, L (2012). Extreme weather conditions in the Great Barrier Reef: drivers of change?, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
7. Doshi, A, Pascoe, S, Thébaud, O, Thomas, CR, Setiasih, N, Hong, JTC, True, J, Schuttenberg, HZ and Heron, SF (2012). Loss of economic value from coral bleaching in S.E. Asia, In *12th International Coral Reef Symposium,* Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
8. Heron, S, Pressey, RL, Skirving, WJ, Rauenzahn, JL, Parker, B-AA and Eakin, CM (2012). Identifying oceanic thermal anomalies in the Coral Triangle region, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
9. Heron, SF, Maynard, J, Willis, B, Christensen, T, Harvell, CD, Vargas-Angel, B, Beeden, R, Sziklay, J, Aeby, G, Franklin, EC, Skirving, W, Eakin, CM, Burgess, T, Li, J, Liu, G, Lucas, E, Rauenzahn, J and Strong, A (2012). Developments in understanding relationships between environmental conditions and coral disease, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
10. 1McCowan, DM, Pratchett, MS and Baird, AH (2012). Bleaching susceptibility and mortality among corals with differing growth forms, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 6 pp.
11. Paley, AS and Bay, LK (2012). Bleaching condition varies among *Acropora millepora* color morphs, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
12. Pisapia, C, Cole, AJ and Pratchett, MS (2012). Changing feeding preferences of butterflyfishes following coral bleaching, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
13. Pratchett, M, Hoey, A, Coker, D and Gardiner, N (2012). Interdependence between reef fishes and scleractinian corals, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
14. Reymond, C, Uthicke, S and Pandolfi, JM (2012). Tropical Foraminifera as indicators of water quality and temperature, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
15. Rocker, MM, Willis, BL and Bay, LK (2012). Thermal stress-related gene expression in corals with different *Symbiodinium* types, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
16. Tan, JCH, Pratchett, MS, Bay, LK and Baird, AH (2012). Massive coral mortality following a large flood event, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 4 pp.
17. Wia, J, Januchowski-Hartley, F, Lahari, RU, Morove, T, Perks, HM and Holmes, KE (2012). Coral farming as means of sustaining livelihoods and promoting resource management, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 5 pp.
18. Woolsey, E (2012). Self-fertilization suppresses thermal tolerance in embryos of reef-building coral, In *12th International Coral Reef Symposium*, Yellowlees, D and Hughes, TP, (Eds.). James Cook University, Cairns, Australia, 4 pp.

Conference Proceedings (1)

1. Yellowlees, D and Hughes, TP (2012). Proceedings of the 12th International Coral Reef Symposium. In *12th International Coral Reef Symposium*. Cairns, Australia, James Cook University. http://www.icrs2012.com/Proceedings.htm.

Report (15)

1. Bridge, T and Guinotte, J (2012). *Mesophotic coral reef ecosystems in the Great Barrier Reef World Heritage Area: their potential distribution and possible role as refugia from disturbance*. Great Barrier Reef Marine Park Authority, Townsville, 51 pp.
2. Cinner, J (2012). *The effectiveness of community based organizations for managing coastal resources in the Western Indian Ocean*. Report to the Western Indian Ocean Marine Science Association, 159 pp.
3. Craigie, I (2012). *Resourcing the aichi biodiversity targets: a first assessment of the resources required for implementing the strategic plan for biodiversity 2011-2020*. Hyderabad, India, 83 pp.
4. Fabinyi, M, Pido, M, De las Alas, A, Ponce de Leon, EM, Buenconsejo, J, Uyami-Bitara, A, Harani, B and Caceres, J (2012). *Livelihoods and the live reef fish for food trade in the municipality of Balabac, Palawan province, Philippines*. ARC Centre of Excellence for Coral Reef Studies, James Cook University, and Center for Strategic Policy and Governance, Palawan State University, Townsville and Puerto Princesa City, 59 pp.
5. Fernandes, L, Green, A, Tanzer, J, White, A, Aliño, P, M, Jompa, J, Lokani, P, Soemodinoto, A, Knight, M, Pomeroy, B, Possingham, H and Pressey, B (2012). *Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle.* Coral Triangle Support Partnership, Jakarta., 152 pp.
6. Fuentes, M and Marsh, H (2012). *Informing dugong hunting management in Torres Strait by studying dugong movements and habitat usage*. Final Report to the Australian Marine Mammal Centre, 34 pp.
7. Graham, N and Huchery, C (2012). *The effects of recreational fishing at Diego Garcia on reef fish assemblages*. Report for the British Indian Ocean Territory Administration, 14 pp.
8. Hughes, T (2012). *Review of Draft Regional State of the Coral Triangle Report*. Report to the Department of Sustainability, Environment, Water, Population and Communities, 18 pp.
9. Mills, DJ, Mutimukuru-Maravanyika, T, Ameyaw Asiedu, G and Asare, C (2012). *Ghana Coastal Fisheries governance dialogue: Presentations, discussions and outcomes from a stakeholder forum on issues for reforming governance of Ghana's coastal fisheries*. WorldFish and University of Rhode Island, Ghana, 51 pp.
10. Paley, A, Abrego, D, Haapkyla, J and Willis, B (2012). *Coral disease outbreak monitoring program - Implications for management*. Report for Great Barrier Reef Marine Park Authority, 55 pp.
11. Ratner, BD, Barman, B, Cohen, P, Mam, K, Nagoli, J and Allison, EH (2012). *Strengthening governance across scales in aquatic agricultural systems*. Working Paper. The WorldFish Center, Penang, 18 pp.
12. Rivera-Posada, J and Pratchett, M (2012). Acanthaster planci *controls: A review*. Report to the Department of Sustainability, Environment, Water, Population & Communities - National Environmental Research Program - Tropical Ecosystems Hub, 30 pp.
13. Rivera-Posada, J and Pratchett, M (2012). *A review of existing control efforts for A. planci; limitations to success*. Report to the Department of Sustainability, Environment, Water, Population & Communities - National Environmental Research Program - Tropical Ecosystems Hub, 20 pp.
14. Sheppard C, Carr P, Graham N, Harris A, Head C, Koldewey H, Meeuwig J, Mortimer J, Purkis S, Price A, Roberts C, Schleyer MH, Sheppard A, Tamelander J and J, T (2012). *Conservation and management in British Indian Ocean Territory (Chagos Archipelago)* British Foreign and Commonwealth Office, 28 pp.
15. Sobtzick, S, Hagihara, R, Grech, A and Marsh, H (2012). *Aerial survey of the urban coast of Queensland to evaluate the response of the dugong population to the widespread effects of the extreme weather events of the summer of 2010-11*. Final report to the Australian Marine Mammal Centre and the National Environment Research Facility, Hobart Australia, 63 pp.

Popular books (1)

1. Fuentes, M (2012). Dhyum the dugong, Reef & Rainforest Research Centre Limited, Cairns, Australia, 32 pp.

Audiovisual Material (1)

1. Foale, S (2012). Fish and people: lesson plan and teacher's guide, *http://eprints.jcu.edu.au/23734/*.

A Reef Too Far?

MARY BONIN, GLENN ALMANY & GEOFF JONES

Goldtail damselfish. Credit: Mary Bonin

Coral reefs are being subjected to more disturbances than ever before, but a new study has surprisingly found that reef fish can benefit from habitat fragmentation.

Corals are pretty amazing animals. These tiny creatures are capable of building huge reef structures like the Great Barrier Reef, which is the world's largest structure created by animals and can be seen from outer space.

Corals are like the trees in a rainforest, providing habitat for the animals that make reefs their home. They are so important to the coral reef fish community that at least 10% of the fish species on the Great Barrier Reef cannot survive without live corals.

Living corals are especially important for juvenile fish, which shelter in coral branches to avoid predators. The survival of these young fish is critical for the replenishment of adult populations – fewer juveniles mean fewer adults.

Unfortunately, these vital coral habitats are subjected to more frequent and intense disturbances than ever before. Every summer, severe tropical storms leave large expanses of coral habitat battered and broken. Warming ocean temperatures are causing more frequent coral bleaching events, which can kill corals and cause widespread habitat degradation. These habitats are also increasingly threatened by outbreaks of disease, predatory crown-of-thorns starfish, and decreased water quality due to coastal deforestation and development.

As a consequence of these impacts, the coral habitat is already extensively damaged on 20% of the world's coral reefs, and 50% of the remaining reefs face a similar fate if these disturbances continue.

More than 60% of the fish species in the reef community decline in abundance by least a 50% following disturbances that reduce live coral cover. Many fish species that have no direct dependence on corals for food or shelter also become much less abundant when live coral cover declines, suggesting that live coral is even more important for fish communities than first expected.

The Problem

When disturbances occur they usually have two effects on the habitat: they reduce the total amount of habitat available and they change the configuration of the habitat that remains. Disturbance often creates greater habitat patchiness; what was previously one continuous stretch of habitat may now be broken up into smaller fragments that are separated by uninhabitable space.

Since habitat loss and habitat fragmentation usually happen simultaneously, their individual effects are confounded. This makes it difficult to determine which type of habitat change is responsible for declines in coral reef fishes after a disturbance. Is it the reduction in the total amount of habitat available, the increased habitat patchiness, or a combination of both?

To address this problem we measured the independent effects of habitat loss and habitat fragmentation, as well as their combined effects, on the survival of juvenile coral reef fish. We also examined the effects of these different types of habitat change on the abundance and diversity of new juvenile fish that colonised following disturbance.

Separating the effects of habitat loss and habitat fragmentation is vitally important, not only for coral reef fishes but also for animals in tropical and temperate forests, grasslands and freshwater ecosystems. Indeed, significant habitat degradation is occurring in almost every ecosystem on the planet, and is considered to be the primary cause of the current extinction crisis.

In an era of increasing habitat degradation, effective conservation and management requires knowledge about the underlying cause of species declines. However, to date very few studies in any ecosystem have successfully separated the effects of habitat fragmentation from those of habitat loss.

Building Reef Microcosms

To tease apart the effects of habitat loss and fragmentation, we conducted a patch reef experiment. This involves building a system of identical coral reefs, each of which represents a microcosm of a natural coral reef.

This is a common technique used by coral reef fish ecologists, and it has two important advantages. First, it is possible to manipulate both the fish community and the habitat on these small experimental reefs. This is nearly impossible to do at the larger scale of a natural coral reef. Second, because the experimental reefs are constructed in the natural environment, they experience the same conditions as natural reefs and therefore provide much more realistic insights than laboratory experiments conducted in aquaria.

We built our system of experimental reefs on a large expanse of sandy seafloor along the coastline of Kimbe Bay in Papua New Guinea. This bay is located in the heart of the Coral Triangle, the world's epicentre for marine biodiversity, and is renowned for its diverse assemblage of fishes and corals. We have a long-standing relationship with the subsistence fishing communities in the area and work closely with a local non-government organisation to conduct conservation-based research.

Building experimental reefs is no easy task! It took three of us three full weeks of hard manual labour to build the 30 reefs in our experimental system.

The first step was to lay down a grid on the sea floor to map out the location of each reef. Reefs in the grid were separated from one another by 15 metres of open sand and were at least 20 metres away from the nearest natural reefs in the area, ensuring that each reef was independent of all other reefs.

We collected live branching corals from nearby natural reefs and carefully transported them to the study site. Corals were arranged on top of rock foundations to provide 1 m^2 of live coral habitat on each experimental reef.

Many coral reef fish spend their entire lives on only a few metres of reef. The habitat on the experimental reefs therefore provided fish with a similar home range to what would be used in a natural reef environment.

Experimental Disturbance

Our study species for the experiment was the goldtail damselfish (*Chrysiptera parasema*). Like many coral reef fish, this species lives exclusively in branching corals during its juvenile phase, so it is vulnerable to coral habitat degradation. We collected juveniles from natural reefs using small aquarium hand nets and a mild anaesthetic, and then released 20 fish onto each experimental reef.

These relocated fish were monitored closely over the first week, and there were very few disappearances, suggesting that most had adjusted quite well to their new home. This was expected because the reefs provided vital shelter from predators and the juvenile fish were unlikely to travel over an expanse of featureless sand in search of other habitat.

After the fish had settled in, we experimentally disturbed the habitat. Each of the 30 reefs was randomly assigned to experience one of five different disturbance treatments:

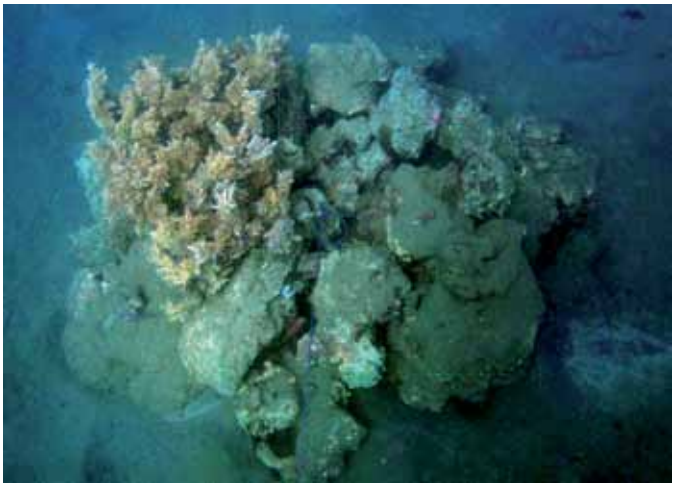
1. *Habitat Loss* – removal of 75% of the live coral from the reef;
2. *Habitat Fragmentation* – dividing the reef into three fragments but no loss of habitat;
3. *Habitat Loss and Fragmentation* – removal of 75% of the live coral and then dividing up the remaining habitat into three fragments;
4. *Disturbance Control* – disturbance and then reassembly of coral habitat to confirm that disruption by divers was not responsible for the trends observed for the habitat loss and habitat fragmentation reefs; and
5. *Control* – reefs were left completely undisturbed to provide a baseline to which we compared survival and colonisation trends observed for the other treatments.

We monitored the reefs once per week for the first 6 weeks after the experimental disturbance, and then again 4 months after the disturbance. Each time we visited the reefs we counted the number of juveniles that remained and also identified and counted all the new juvenile coral reef fish that had colonised the reefs. We expected that habitat loss, fragmentation or both would decrease the survival of *C. parasema* and also the abundance and diversity of new juveniles that colonised the reefs.

Surprising Results

We found that habitat loss alone had a strong negative effect on the survival of juvenile coral reef fish after 4 months. Of the 20 juvenile *C. parasema* initially present on these reefs, only one or two survived after 4 months. This was an eightfold decrease in survival compared with undisturbed control reefs.

However, contrary to our expectations, habitat fragmentation actually had a positive effect on juvenile fish survival. *C. parasema* survived equally well on the fragmented reefs and control reefs, suggesting that habitat patchiness is not problematic for juvenile coral reef fish.



LEFT: A reef subjected to 75% habitat loss reef. RIGHT: A reef subjected to both habitat loss and fragmentation. Credit: Mary Bonin

In fact, fragmentation was actually beneficial to survival when habitat was in short supply. On reefs where habitat had been lost, fragmenting the remaining habitat actually allowed three times as many *C. parasema* to persist compared with reefs with habitat loss alone.

Similarly, the abundance and diversity of new colonisers was positively affected by habitat fragmentation and negatively affected by habitat loss. On average, new colonisers were at least twice as abundant and diverse on fragmented reefs compared with control reefs. In contrast, reefs with 75% habitat loss had the lowest abundance and diversity of colonisers of any reefs in the study.

Does one positive effect and one negative effect mean that the effects of habitat loss and fragmentation cancel one another out? Unfortunately not, because the strength of these effects differs. Although the positive effects of increased habitat patchiness were highly beneficial to the survival and colonisation of juvenile fish in the 6 weeks following the disturbance, after 4 months the negative effects of habitat loss far outweighed the benefits of fragmentation. Consequently, when both habitat loss and fragmentation occurred together the result was an overall net decline in fish survival, abundance and diversity 4 months after the disturbance.

While the negative impacts of habitat loss were expected, the positive effects of habitat fragmentation were quite surprising. The term "habitat fragmentation" usually has negative connotations, but our results suggest that this is probably because it is usually linked to disturbances that also cause habitat loss. Our experiment revealed that when a reef suffers a disturbance it is actually the reduction in live coral habitat, not increased habitat patchiness, that causes declines in reef fish abundance and diversity.

Why would habitat fragmentation be beneficial? We believe that fragmentation reduces competition between fish for habitat space. When the habitat is a single continuous patch, strong competitors will tend to dominate the whole area and drive the weaker ones away. A patchier habitat allows greater spatial separation between competitors, allowing weaker ones and new colonisers to avoid bullying by dominant individuals.

Conservation Implications

These findings can be used to set priorities for effective management of coral reef fish communities and also inform habitat restoration programs.

Management strategies may differ depending on whether habitat loss or fragmentation is the primary threat. If habitat fragmentation is the primary threat, the most important task for managers would be to facilitate the movement of fish between isolated habitat patches. But if habitat loss poses the greatest risk, then limiting the extent of this loss would be the management priority.

Our study clearly shows that preventing habitat loss should be the main priority for managers working to conserve coral reef fish communities. One way to address this management objective is by protecting larger areas of habitat from the human impacts that contribute to live coral degradation.

If coral habitat does suffer damage despite the best efforts of protection, active restoration can help to boost recovery. Restoration programs involve transplanting corals from healthy reefs to those that are badly damaged. Our results suggest that patchy placement of these coral transplants would increase the abundance and diversity of fish that colonise this new habitat.

The discovery that habitat patchiness can actually benefit coral reef fish communities offers hope for the conservation and management of these extraordinary ecosystems. Coral reefs are undoubtedly under an enormous amount of pressure, and combating their various threats may seem an impossible task. However our study suggests that even if it's not possible for managers to restore habitat on an entire reef, restoring small patches of habitat could still be highly beneficial to the recovery of the reef fish community.

Mary Bonin is a postdoctoral researcher in the ARC Centre of Excellence for Coral Reef Studies and the School of Marine and Tropical Biology at James Cook University. Glenn Almany is a Future Fellow in the ARC Centre of Excellence for Coral Reef Studies at JCU. Geoff Jones is a Professor in the School of Marine and Tropical Biology at JCU and a Chief Investigator in the Centre.

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> They have clearly demonstrated by their research and applications that local and global level environmental stressors are not simply an issue for coral reefs, but for all of human kind, and whatever we do that helps coral reefs is also the right choice for present and future generations of people.
>
> – Professor Bob Richmond, President of the International Society for Reef Studies

Photo by: Ross Hill

RECOGNITION OF EXCELLENCE BY
CENTRE MEMBERS

Laureate boost for coral reef research

The ARC Centre of Excellence for Coral Reef Studies was awarded three Laureate Fellowships in the latest round, announced on Monday 30 July 2012 by Senator Chris Evans, Minister for Tertiary Education, Skills, Science and Research. Australia's most prestigious fellowships were awarded to the Centre Director, Professor Terry Hughes and the two Deputy Directors, Professors Malcolm McCulloch and Ove Hoegh-Guldberg.

"Ensuring Australia maintains a world-class research reputation is vital if we are to drive innovation and remain internationally competitive," Senator Evans said.

"The Laureate Fellowships give some of our best researchers the ability to tackle complex problems and undertake groundbreaking research - research that will deliver real benefits to Australians."

"The fellowships are about boosting our research workforce by providing new opportunities in Australia for the world's best researchers," Senator Evans said.

"The Laureate Fellowships allow us to attract some of the best international researchers and forge strong international links - a growing priority as we head further into the Asian Century."

Professor Hughes, who has previously been awarded two ARC Federation Fellowships, said, "These Laureates will also help foster the next generation of researchers by giving us the opportunity and resources to recruit twelve outstanding early career coral reef researchers, who will benefit from the training and mentoring that a vibrant ARC Centre can provide."

Each Australian Laureate Fellow plays an important role in increasing Australia's research capacity. As part of their fellowship, they receive funding that enables them to lead and mentor a team of postdoctoral and postgraduate researchers, building Australia's next generation of research leaders.

Professor Hughes will lead an international team to undertake a novel, multi-disciplinary program of research on coral reefs to better understand and avoid dangerous ecological tipping points. His Fellowship project will cement Australia's leading contribution to reef science, and will guide the management and sustainable use of ecosystems around the world.

Professor McCulloch will investigate how coral reefs respond to changes in the chemistry of tropical seas due to ocean acidification and global warming. His multi-disciplinary research project will predict the future of coral reefs and marine calcifiers in response to rising carbon dioxide and declining ocean pH. This will inform best-practice adaptive management of reefs at local and regional-scales for marine-dependent industries.

Professor Hoegh-Guldberg's project will also fill important knowledge gaps and provide key tools for responding to future challenges for the sustainability of coral reefs under the uncertainty of climate change.

Professor Hughes and McCulloch were elected Fellows of the Australian Academy of Science in 2001 and 2004 for their globally significant contribution to coral reef science.

OTHER EXAMPLES OF AWARDS AND PEER-RECOGNITION

- Nick Graham was awarded The Queensland Tall Poppy Scientist of the Year from a field of six finalists including Morena Mills, who graduated with a PhD from the ARC Centre in 2012. Nick received $10,000 "for use in support of the awardee's research and/or directly related science promotion activities".
- Alana Grech was awarded a Churchill Fellowship by the Winston Churchill Memorial Trust. This enabled Alana to travel to a conference on cultural heritage and risk in Istanbul, Turkey, and a one month fellowship at the International Centre for the Study of the Preservation and Restoration of Cultural Property in Rome, Italy. Jennifer Donelson, a former Centre PhD student with Philip Munday and who graduated in 2012, was also a recipient of a Churchill Fellowship.
- Tracy Ainsworth was awarded a Queensland International Fellowship which enabled her to spend four months conducting research in collaboration with Professor Ruth Gates at the Hawai'i Institute of Marine Biology on Coconut Island. Tracy was also successful in being awarded a place in the Women in Research Leadership Course run by the University of Queensland Business School.
- Ove Hoegh-Guldberg received a Thomson Citation Award for being one of 12 authors with the highest impact in their field (ecology) using Thomson Reuters *Web of Science* and research evaluation tool *In Cites*.
- Morgan Pratchett was elected a Fellow of the Linnean Society of London for his contributions to coral reef science and management in Chagos.
- Terry Hughes was the keynote speaker at the "Forum on the CTI" organised by the Australian Embassy in Manila in partnership with the Philippines' National Coral Triangle Initiative Coordinating Committee. Terry was also selected as the Distinguished Speaker and guest for the 37th Annual Albert L. Tester Symposium at the University of Hawai'i at Manoa. This event showcases the best of graduate and undergraduate natural science research at the University of Hawai'i. Previous invited speakers have included Stephen Jay Gould, Jared Diamond and John Maynard Smith.

At James Cook University, Centre researchers were recognised within the University:

- Mariana Fuentes was presented with an Outstanding Alumni – Early Career Award for her research on turtles and dugongs and the publication of her two children's books.
- Nick Graham was the JCU Advisor of the Year 2012 in the early career advisor category, an award made annually based on recommendations from postgraduate students supervised by the nominee.

At the sharp end of reef science

By NIGEL BOWEN

The woman whose research just might help preserve the world's imperilled reefs has been obsessed with the ocean ever since she can remember. After growing up as 'a beach girl' on the coast of northern New South Wales, Tracy Ainsworth moved to Townsville, Queensland, to study marine biology and aquaculture at James Cook University.

Tracy completed a PhD at the University of Queensland in 2008, investigating microbial communities associated with coral suffering disease and stress. Her innovative research, which investigates whether bacteria, as well as algae, play a significant part in the life of coral, has determined that coral bleaching is a far more complex process than previously believed. Her work has attracted significant international attention, prompting invitations to present her research, undertake further research and be involved in postgraduate teaching at universities around the world.

"Coral reefs are beautiful, diverse, amazing structures and arguably the most beautiful places on earth," says Ainsworth. "They can range from small areas to massive structures that compare in size to anything humans have managed to build. They are found in environments from the cold, dark depths of the ocean to shallow tropical waters. And all of this is achieved by a coral polyp – a simple basal organism – predominantly in symbiosis with single-celled algae. In surface reefs, the polyps provide algae with a home in return for the sugars created from its photosynthesis. How so much is achieved with so little fascinates me."

But those amazing structures, which provide habitats for countless species and contribute trillions of dollars to the global economy, are under increasing threat. "Global and ocean warming is occurring and it is negatively impacting our reef systems. Coral reefs in Australia, and worldwide, have been significantly impacted by a myriad of local and global stressors, which are driving them towards collapse," warns Ainsworth.

Australia has a diverse range of coral reef systems.

Coral polyps are the building block of many marine ecosystems.

Article reproduced with thanks to Brand Australia. Article originally appeared online **www.australiaunlimited.com/science/sharp-end-reef-science**.

In order to save the world's reefs it is first necessary to understand how coral functions, something that marine science knows surprisingly little about. For example, it had long been believed that the annual summer coral bleaching in the Mediterranean was due to bacteria. But during a six-month stint at Israel's Tel Aviv and Haifa universities, Ainsworth proved bacteria wasn't responsible and hypothesised that a range of environmental and physiological changes were causing the bleaching.

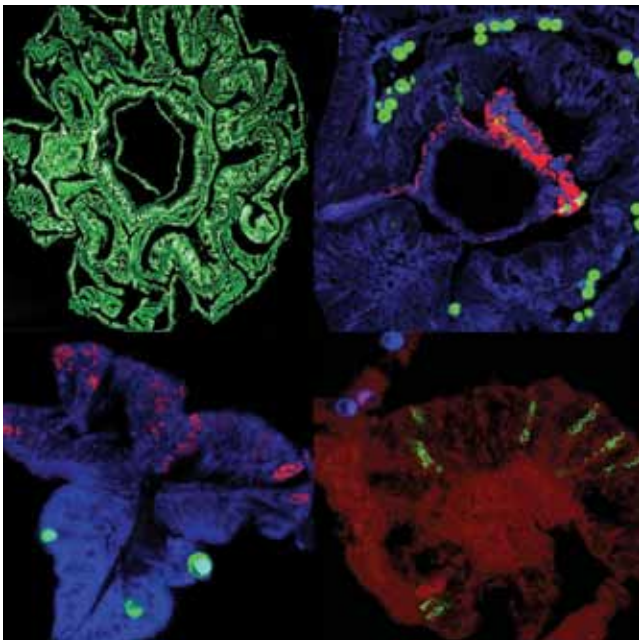
"That was important because it demonstrated that a reef system can change rapidly," says Ainsworth. "Bacterial drivers may have been involved in previous bleaching events but removing that bacteria didn't prevent the bleaching event happening. That suggests that there's no single treatment to protect reefs and that they are complex systems where a single change can result in a myriad of responses happening at any one time."

"Global and ocean warming is occurring and it is negatively impacting our reef systems. Coral reefs in Australia, and worldwide, have been significantly impacted by a myriad of local and global stressors, which are driving them towards collapse."

Ainsworth's ongoing research has led to a greater appreciation of the complexity of the interactions that create and animate coral. "My research aims to understand the responses of the coral as whole – animal, algae, microbial consortia – to subtle changes in the environmental conditions and to determine how each component of the system can contribute to long-term health and survival of the reef system."

But can unlocking these secrets help save the world's reefs? Ainsworth is cautiously optimistic. "Australian institutions are leading the world in marine research and we are lucky to have internationally renowned researchers working here on improving our understanding and management of reef systems. I do think real-world solutions can be derived from the work myself and others are doing in this area. For example, my work on pre-bleaching stress responses in coral highlights the need to manage stresses long before we see bleaching occurring. Bleaching indicates the algae have abandoned the coral polyp, and it used to be conventional wisdom that didn't happen until water temperature reached about 32°C. I discovered that the symbiotic relationship coral has with algae and bacteria begins to break down at temperatures below 30°C. But it has to be realised that coral reefs are massive structures and single treatments are not necessarily logistically possible. Our best hope is to reduce the stress events and aim to provide the best possible environment to aid their recovery at key times."

Dr Tracy Ainsworth working on a confocal microscope.



Coral remains colourful even under microscopic inspection.

If there's one thing Ainsworth is more passionate about than researching coral, it's raising public awareness about its ecological, economic and aesthetic significance. "Reefs are extremely important to human populations, and not just as habitats for our fisheries or large contributors to tourism revenue. They show us the beauty and phenomenal capacity of the natural world. So we have an obligation to ensure that future generations are able to benefit from, and marvel at, these systems," she says.

PERFORMANCE MEASURES

RESEARCH FINDINGS

Measure	Target 2012	Outcome 2012
Number of publications (p68)	185	325
Publications in journals with an impact factor > 4	42	94
Number of citations (p68)	11,500	22,130
Invitations to provide plenary addresses at international conferences	30	53
Invitations to provide review articles	36	47
Number and nature of commentaries about the Centre's achievements	1,300	7,856
Awards, prizes or recognition (p86)	22	42

RESEARCH TRAINING AND PROFESSIONAL EDUCATION

Measure	Target 2012	Outcome 2012
Number of postgraduates enrolled (p35)	140 over 5 years	205 enrolled in 2012 390 enrolled 2006-2012
Number of postgraduate completions	100 over 5 years	32 in 2012 191 completions 2006-2012
Number of Honours students	60 over 5 years	16 enrolled in 2012 93 enrolled 2006-2012
Number of professional workshops	20	34
Participation in professional workshops	24	90
Number and level of graduate student courses and workshops in the priority area(s)	14	38

INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

Measure	Target 2012	Outcome 2012
Number of international visitors	80	104
Number of national and international Working Groups	16	84 researcher participations in 41 working groups
Number of visits to overseas laboratories and research facilities	55	118
Membership of national and international boards and advisory committees	45	85
Number of cross-institutional publications	105	195
Number of multi-institutional supervisory arrangements of graduate students	54	72
Number of internationally funded students **Number of consultancies and contract research**	60 over 5 years 15	85 in 2012 27
Number of government, industry and business briefings	60	87
Number of Centre trained/ing personnel in knowledge / technology transfer and commercialization	8	8
Public awareness programs **Website hits** **Public awareness presentations**	 3.5m 24	 14.3m 64

ORGANISATIONAL SUPPORT

Measure	Target 2012	Outcome 2012
Annual cash contributions from Collaborating Organisations	$1.7m	$2.7m
Annual in-kind contributions from Collaborating Organisations	$4.5m	$ 8.4m
Number of new Organisations recruited to or involved in the Centre	6	11
Level and quality of infrastructure provided to the Centre	$1.18m	$1.3m
Annual cash contributions from other organisations	$0.75m	$4.1m

GOVERNANCE

Measure	Target 2012	Outcome 2012
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 7
Frequency and effectiveness of Advisory Board meetings	2 Centre Advisory Board meetings p.a. 4 Scientific Management Committee meetings p.a.	See page 7
Quality of the Centre strategic plan	The Centre's progress against the plan will be formally reported to the Advisory Board and be renewed in light of outcomes	Strategic Plan reviewed and endorsed by the Centre Advisory Board. Ongoing performance against plan reviewed at Scientific Management Committee meetings
Effectiveness of arrangements to manage Centre nodes	Meetings of the Scientific Management Committee where each node and program is represented	All research programs represented at Scientific Management Committee meetings
	Monthly nodal leader phone or video conferences	Regular nodal and program leader meetings held
	Annual rotational visits to the nodes	There were 49 cross-nodal visits in 2012. Additionally, members travelled to Cairns for the International Coral Reef Symposium where a range of meetings and events were held.
	Annual research retreats for all Centre participants	Research planning meetings were held by each research program
	Annual research program planning meetings with cross-nodal attendance	Cross-nodal attendance at all research planning meetings
	number of co-supervisory arrangements for students	72
	number of multi-nodal seminar and discussion groups	51
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 2012	Outcome 2012
Measures of expansion of Australia's capability in the priority area(s)	150% increase on 2004 benchmark by 2013 60 briefings to government, business and industry groups 17 cross-nodal publications 105 cross-institutional publications	260% above the 2004 publications benchmark 640% above the 2004 citations benchmark 87 briefings 51 cross-nodal publications 195 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 64–67

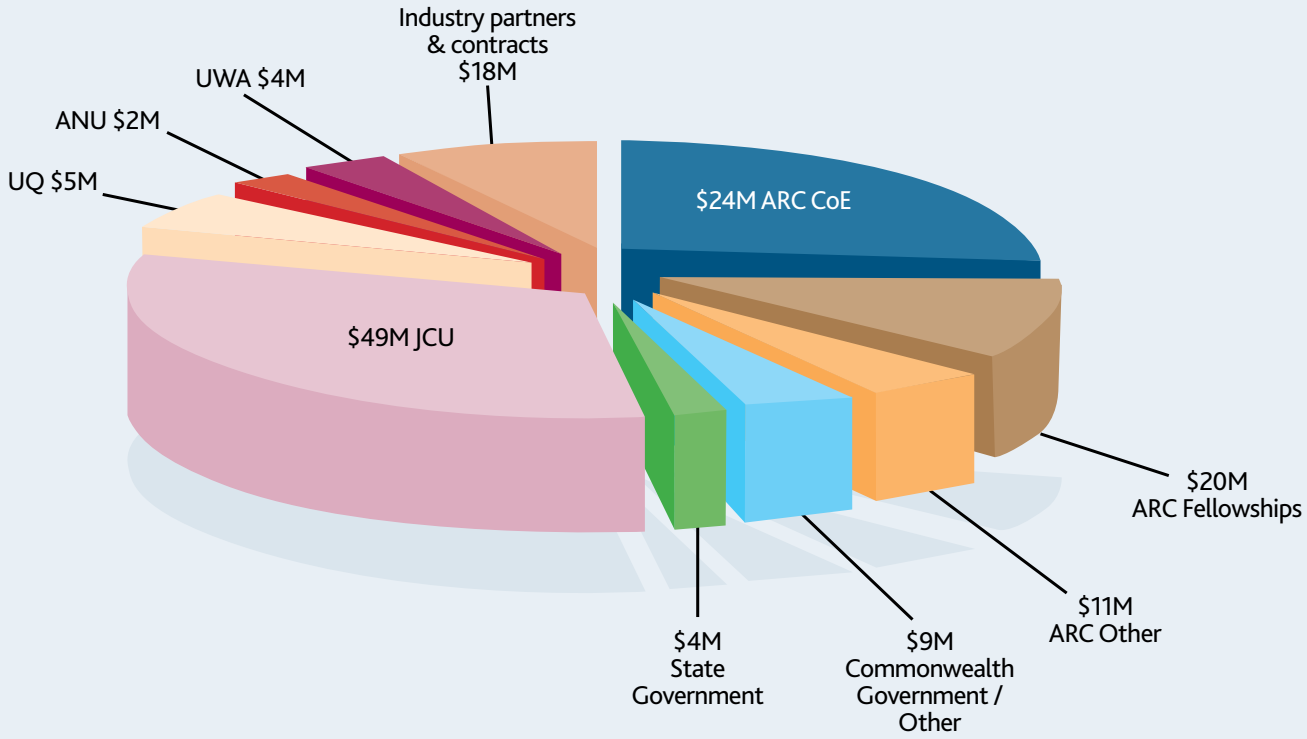
FINANCIAL STATEMENT

ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES STATEMENT OF OPERATING INCOME AND EXPENDITURE FOR YEAR ENDED 31 DECEMBER 2012

	2011	2012
Income	**$**	**$**
ARC Centre Grant	$2,961,905	$3,075,865
ARC Fellowships	1,739,402	1,872,293
ARC Discovery	129,072	79,112
ARC Linkages	232,998	231,196
Host Institutions cash support	2,628,057	2,710,937
State Government	402,213	432,500
Commonwealth Government other grants	853,280	994,512
International and other contracts	590,279	970,172
Total Income	**$9,537,205**	**$10,366,587**
Expenditure		
Salaries	$5,851,678	$6,659,259
Equipment	503,966	500,157
Travel	1,541,497	1,631,194
Research maintenance and consumables	1,214,888	1,455,466
Scholarships	85,629	95,478
Public outreach and administration	209,656	298,421
Total Expenditure	**9,407,313**	**$10,639,974**
Surplus (Deficit)	**129,892**	**($273,386)**

FINANCIAL OUTLOOK

As at December 2012, the total cash and inkind budget for the ARC Centre of Excellence for Coral Reef Studies for 1 July 2005 to 31 December 2013 totals $146M, 4.5 times the funding outlook when the Centre was established in 2005.



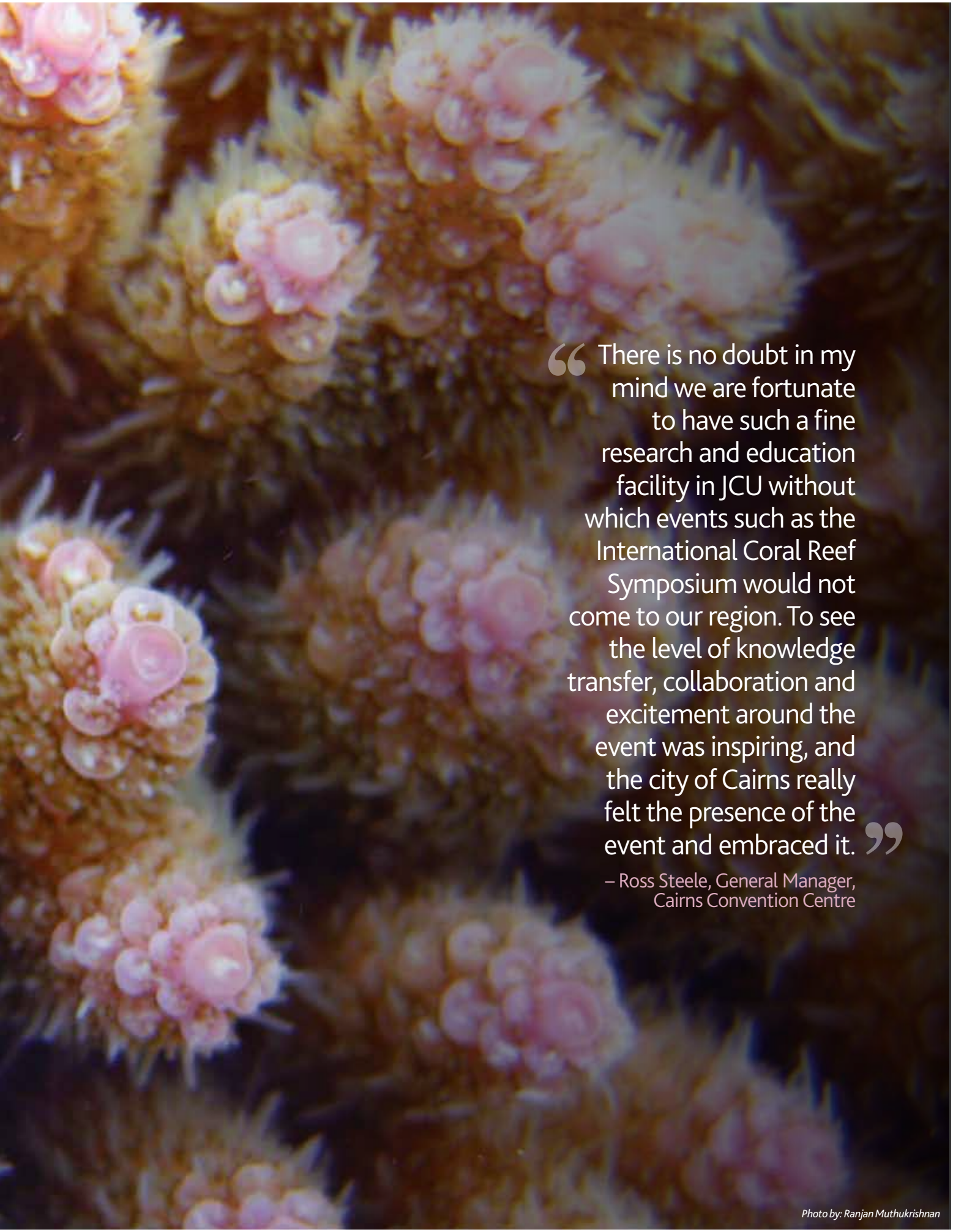
ACKNOWLEDGEMENTS

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

- Australian Academy of Science, Canberra
- Australian Genome Research Facility (AGRF), Brisbane
- Australian Government: AusAID
- Australian Government: Department of Sustainability, Environment, Water, Population and Communities
- Australian Government: Department of Agriculture, Fisheries and Forestry
- Australian Institute of Marine Science (AIMS), Townsville
- Australian Coral Reef Society, Australia
- Australian Museum, Sydney
- Beijer Institute for Ecological Economics, Stockholm
- Cairns Chamber of Commerce
- Cairns Regional Council
- 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), Australia
- Conservation International, Philippines
- Coral Bay Research Station, Western Australia
- Coral Reef Initiatives for the Pacific (CRISP), Noumea
- Daly River Management Advisory Committee
- David & Lucile Packard Foundation, USA
- Deutsche Forschungsgemeinschaft Excellence Cluster, University of Kiel, Germany
- ETH Zurich, Switzerland
- Eye to Eye Marine Encounters, Port Douglas
- Fisheries Research and Development Corporation, Canberra
- Food and Agriculture Organisation of the United Nations, Italy
- 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
- InDepth Video & Photography, Cairns
- International Society for Reef Studies (ISRS)
- Japan Society for the Promotion of Science (JSPS)
- 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'Oréal, Australia
- Marine Parks Authority, Lord Howe Island Marine Park
- Mike Ball Dive Expeditions, Cairns
- Museum of Tropical Queensland, Townsville
- 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
- National Science Foundation, USA
- New York University Abu Dhabi Institute, United Arab Emirates
- Northern Gulf Resource Management Group, Queensland
- Northern Fisheries Centre, Queensland Department of Agriculture, Fisheries and Forestry
- NSF Research Coordination Network for Marine Disease, USA
- Palawan State University, Philippines
- Palmyra Atoll Research Station,
- Passions of Paradise, Cairns
- Queensland Department of Employment, Economic Development and Innovation
- Queensland Department of National Parks, Recreation, Sport and Racing
- Queensland Department of Science, Information Technology, Innovation and the Arts
- Queensland Department of the Premier and Cabinet
- RARE Conservation, Philippines
- Reef Catchments Natural Resource Management, Mackay
- Resilience Alliance, Sweden

- Royal Swedish Academy of Science, Sweden
- Rufford Small Grants Association, United Kingdom
- Sasakawa Peace Foundation, International
- Save Our Seas Foundation, Switzerland
- Secretariat for the Pacific Community, Noumea
- 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 Computational Biology Group, University of Amsterdam
- The Nature Conservancy, USA
- The Winston Churchill Memorial Trust, Canberra
- Torres Strait Regional Authority, Queensland
- University of Delaware, USA
- University of Maine, USA
- University of Montpellier 2, Sciences and Technology, France
- University of Oxford, UK
- University of Perpignan, France
- University of Technology Sydney
- Virginia Chadwick Foundation, Australia
- Western Australian Department of Environment and Conservation
- Western Australian Department of Premier and Cabinet
- Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, New York
- Woods Hole Oceanographic Institution, USA
- World Commission on Protected Areas, Switzerland
- WorldFish, Malaysia
- World Wildlife Fund (International), USA
- WWF, Australia

CORAL
REEF
STUDIES



> There is no doubt in my mind we are fortunate to have such a fine research and education facility in JCU without which events such as the International Coral Reef Symposium would not come to our region. To see the level of knowledge transfer, collaboration and excitement around the event was inspiring, and the city of Cairns really felt the presence of the event and embraced it.
>
> – Ross Steele, General Manager, Cairns Convention Centre

Photo by: Ranjan Muthukrishnan

NOTES

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Coral Reef Studies

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