ARC Centre of Excellence
Coral Reef Studies

ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES

2010 ANNUAL REPORT

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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.

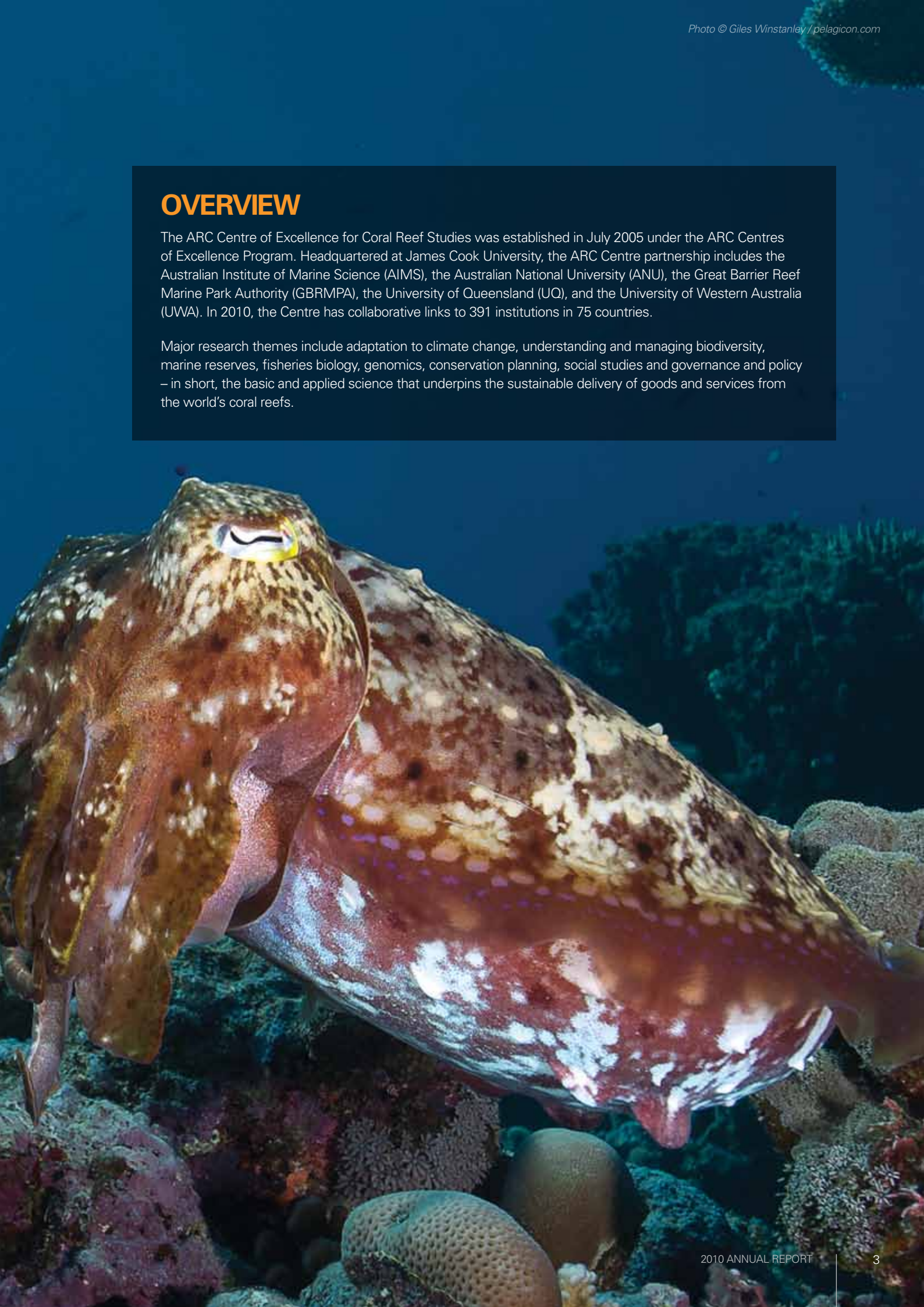
2. **Research Training and Professional Education**
   The Centre attracts and trains outstanding coral reef scientists at all stages of career, to build human capacity and expertise in coral reef science world-wide.

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 Centre, through its networks and activities nationally and internationally, creates a global hub for coral reef science collaborations.

5. **Management and Governance**
   Centre management is collaborative, co-operative, multi-institutional, communicative and continuously improving.

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



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OVERVIEW

The ARC Centre of Excellence for Coral Reef Studies was established in July 2005 under the ARC Centres of Excellence Program. Headquartered at James Cook University, the ARC Centre partnership includes the Australian Institute of Marine Science (AIMS), the Australian National University (ANU), the Great Barrier Reef Marine Park Authority (GBRMPA), the University of Queensland (UQ), and the University of Western Australia (UWA). In 2010, the Centre has collaborative links to 391 institutions in 75 countries.

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

DIRECTOR'S REPORT

Welcome to the ARC Centre's 2010 Annual Report, our 5th full year of operation. This year the Centre has continued to mature and expand with the appointment of 13 new fellows, increases in publications, citations, and graduate training and more engagement with government agencies, Non-Government Organisations (NGOs) and the media. The Centre's research program summaries on pp.16–30 provide many examples of our activities throughout 2010.

The Centre's fieldwork in 2010 was undertaken in 25 tropical countries, with a major focus on Australia, Fiji, French Polynesia, Kenya, the Philippines, Indonesia, Papua New Guinea and the Solomon Islands. Programs 3, 5, 6 and 7 were particularly active in the Coral Triangle region to the north of Australia, focusing on the ecology and design of marine parks, social science, and coral reef management and governance.

The Centre's publication output continues to grow, with a record 229 publications in 2010. Our co-authors this year come from 391 institutions in 75 countries, reflecting our extensive network and activities around the world. Among this year's publications is a Feature Section in *Proceedings of the National Academy of Sciences*, on Marine Reserves (see p.54, National Benefit Case Study), and a Special Issue of the *Philosophical Transactions of the Royal Society (B)*, entitled Biological diversity in a changing world.

Membership of the Centre has been further enhanced by the award of ten prestigious ARC Fellowships during 2010. These comprise 5 Super Science Fellowships and an Australian Research Fellowship (ARF, Joshua Cinner) at James Cook University, and two additional Super Science Fellowships at both the University of Queensland and University of Western Australia. The Centre's newest node at UWA is expanding under the leadership of Deputy Director Malcolm McCulloch, while Chris Fulton at the Australian National University is also recruiting new personnel. At the end of 2010, the Centre's membership stands at 19 Chief Investigators, 42 full-time Research Fellows and 192 graduate and honours students (from 42 countries, see pp.34–43).

We provided more than 100 briefings, workshops and consultancies during the year to governments, management agencies, NGOs and business organisations. Examples include Australian Commonwealth Departments, the Association of Marine Park Tourism Operators (Queensland), Deutsche

Forschungsgemeinschaft, Fisheries Research & Development Corporation, the Great Barrier Reef Marine Park Authority, International Union for Conservation of Nature (IUCN), National Oceanic and Atmospheric Administration (NOAA), Solomon Island ministries, and The Nature Conservancy.

Outreach activities during 2010 included our annual symposium entitled *Coral Reefs in a Changing Environment*. It was held at the Australian Academy of Science in Canberra, where we helped to celebrate the Royal Society's 350th anniversary and their early contribution to coral reef expeditions to Australia (see p.45). Web recordings of 35 talks, including a very successful public forum, are posted at www.coralcoe.org.au/events/symposium2010/program.html. Our next coral reef symposium in October 2011 will be held in Western Australia.

The Centre's website received 5.7 million hits and 294,462 visits in 2010, with 96% coming from outside Australia. The Centre's media coverage has continued to grow rapidly during 2010 - well over 2000 stories featuring the Centre's research activities were published or broadcast around the world in the past year (p.50).

We were particularly delighted to see Malcolm McCulloch FRS add a few more letters after his name in 2010 when he was elected Fellow of the Royal Society. Not to be outdone, Bob Pressey was elected as the Centre's third Fellow of the Australian Academy of Science.

The membership of our Advisory Board was expanded during the year with the appointment of Mandy Thomas (Pro Vice-Chancellor for Research and Graduate Studies at the Australian National University), John Tanzer (Environmental Consultant), and Neil Andrews (Director, Natural Resources Management, The WorldFish Center, Penang). A new Chair was also appointed, Brian Walker (CSIRO and Director of the Resilience Alliance).

Looking forward to 2012, the ARC Centre will host in Australia more than 2000 conference delegates from the global coral reef research community, when we convene the 12th International Coral Reef Symposium (ICRS) in Cairns. These 4-yearly meetings are the world's largest and premier forum for the dissemination and discussion of coral reef science and management (see p.49). This year we received 129 proposals for symposium sessions, promising a varied and exciting program of more than 1500 talks and posters.

Lastly, I'd like to express my gratitude to our many other friends around the world for their contributions to a fifth outstanding year, and to the Centre's Advisory Board, and our partners from the *Australian Institute of Marine Science, The Nature Conservancy, The WorldFish Center* and the *Great Barrier Reef Marine Park Authority*. I am especially grateful to the Centre's talented administrative team – Jenny Lappin, David Yellowlees, Olga Bazaka, Rose-Marie Vasiljuk, Monica Gaffney, Janet Swanson and Eliza Glasson – for their stoic enthusiasm.

Terry Hughes
Director

GOVERNANCE

James Cook University is the administering organisation of the ARC Centre with the Centre Director, Terry Hughes reporting directly to Professor Chris Cocklin, the Deputy Vice-Chancellor (Research and Innovation). The Centre's Chief Investigators are located in three faculties at JCU, and at the Australian National University, the University of Queensland and the University of Western Australia. Partner Investigators are based at the Australian Institute of Marine Science, the Great Barrier Reef Marine Park Authority, and in overseas institutions. Day-to-day operations are managed by the Chief Operations Officer, Jenny Lappin, in consultation with the Centre Director and Assistant Director, David Yellowlees. The Centre Director oversees the Centre's research programs together with the two deputy directors, Ove Hoegh-Guldberg (UQ) and Malcolm McCulloch (UWA).

The Centre's governance structures are designed to involve stakeholders in planning and management processes. The chart (see p.8) illustrates the current governance structure and relationships.

Centre Advisory Board

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

In 2010, the ARC Centre of Excellence welcomed a new Advisory Board which was appointed following the recommendations of the review undertaken by an independent ARC Panel in 2009. The new Chair of the Board is Dr Brian Walker, an internationally acclaimed scientist working on sustainability and resilience in social-ecological systems. Brian brings a wealth of science leadership experience at both a national and international level including 15 years as Chief of the former CSIRO Division of Wildlife and Ecology (now CSIRO Sustainable Ecosystems).

Representation on the Advisory Board has evolved to match the Centre's strong global research activities, international linkages and multi-disciplinary research activities. We are privileged to have access to the expertise and experience of these leaders and extend our thanks to them for their advice. The new Board met twice in 2010: on 29th March in Townsville and 6th October in Canberra. In conjunction with the change to the Advisory Board membership, the terms of reference for the Board have been revised to take account of the Centre's international profile and to reflect the Centre's focus on sustainable management of coral reefs.

The new Advisory Board's membership comprises:

Dr Brian Walker (Chair), CSIRO
Sustainable Ecosystems

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

Professor Terry Hughes
ARC Centre Director and Federation Fellow

Dr Ian Poiner
Chief Executive Officer
Australian Institute of Marine Science

Andrew Skeat
General Manager
Great Barrier Reef Marine Park Authority

John Tanzer
Principal
Environmental Pathways and Solutions

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

Scientific Management Committee

Ongoing operational management of the Centre and planning for its scientific research program is the responsibility of the Scientific Management Committee (SMC). The SMC is chaired by an eminent Israeli researcher, Professor Yossi Loya. Other members are the leaders of

each of the Centre's eight Research Programs, and the Chief Scientist and Director of Science Co-ordination at the Great Barrier Reef Marine Park Authority, the Centre's principal end-user in Australia. Priorities for each meeting include reviewing and expanding the objectives and operations for the Centre's research programs, developing international collaborations and engagements, recruiting high-quality postdoctoral fellows, and effectively communicating the Centre's research. The Committee met formally twice in 2010: on 2nd March in Townsville and 5th October in Canberra.

In 2010, the Scientific Management Committee focused on further development of two new research programs, Program 7: *Policy development, institutions and governance of coral reefs* and Program 8: *Genomics and metagenomics of coral reefs,* both established in 2009. Mentoring and coaching the thirteen new research fellows recruited into the Centre in 2010 was also a priority. Planning for the International Coral Reef Symposium (ICRS) in 2012 (see p.49), updating the Centre's website and longer term positioning of the Centre for its business continuity were also a focus of discussions.

Scientific Management Committee Members are:

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

Dr David Wachenfeld
Chief Scientist
Director, Science Co–ordination
Great Barrier Reef Marine Park Authority

Professor Malcolm McCulloch
Leader, Research Program 1
University of Western Australia

Professor Sean Connolly
Leader, Research Program 2
James Cook University

Professor Garry Russ
Leader, Research Program 3
James Cook University

Professor Ove Hoegh-Guldberg
Leader, Research Program 4
University of Queensland

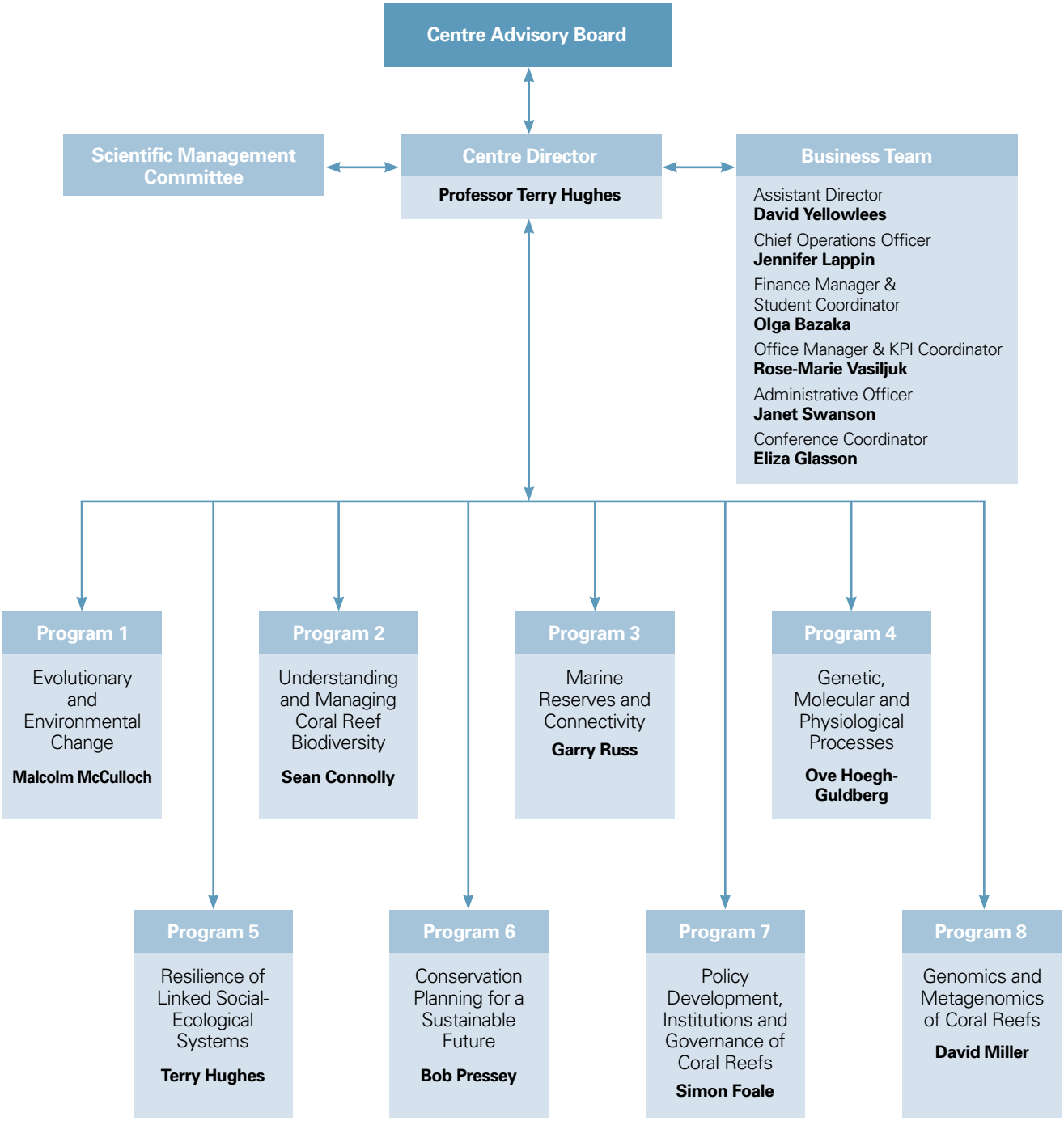
Professor Terry Hughes
Leader, Research Program 5
James Cook University

Professor Bob Pressey
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

MANAGEMENT STRUCTURE



MEMBERSHIP

Researchers

In 2010, the Centre's membership comprised 49 Chief Investigators and research fellows, 8 Partner Investigators, 11 resident international scholars and 12 adjunct researchers. Thirteen of the Centre's research fellows are funded by ARC schemes (Federation, Laureate, Linkage, Future and Super Science), three are Queensland Smart Futures Fellows, one is Queensland Premier's Fellow and one is a Western Australian Premier's Fellow.

Chief Investigators, Research Fellows and Partner Investigators

Professor Terry Hughes
Centre Director and ARC Federation Fellow, Program 5 Leader
James Cook University

Dr Tracy Ainsworth
ARC Australian Postdoctoral Fellow
James Cook University

Dr Glenn Almany
ARC Future Fellow
James Cook University

Dr Kenneth Anthony
Chief Investigator
University of Queensland

Dr Andrew Baird
ARC Future Fellow
James Cook University

Dr Natalie Ban
ARC Australian Postdoctoral Fellow
James Cook University

Dr Line Bay
Queensland Smart State Fellow
James Cook University

Professor David Bellwood
Chief Investigator
James Cook University

Dr Joshua Cinner
ARC Australian Postdoctoral Fellow
James Cook University

Professor Sean Connolly
ARC Australian Professorial Fellow and Program 2 Leader
James Cook University

Dr Debora de Freitas
Research Associate
James Cook University

Dr Guillermo Diaz-Pulido
Research Fellow
University of Queensland

Dr Delphine Dissard
Research Fellow
University of Western Australia

Associate Professor Sophie Dove
Chief Investigator
University of Queensland

Dr Simon Dunn
Research Fellow
University of Queensland

Dr Louisa Evans
Research Fellow
James Cook University

Dr Michael Fabinyi
Research Fellow
James Cook University

Dr James Falter
Research Fellow
University of Western Australia

Dr Pedro Fidelman
Research Fellow
James Cook University

Dr Simon Foale
Research Fellow and Program 7 Leader
James Cook University

Professor Carl Folke
Partner Investigator
Stockholm University

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

Dr Ashley Frisch
Super Science Fellow
James Cook University

Dr Mariana Fuentes
Super Science Fellow
James Cook University

Dr Christopher Fulton
Chief Investigator
Australian National University

Dr Nick Graham
ARC Australian Postdoctoral Fellow and Queensland Smart Futures Fellow
James Cook University

Dr Lauretta Grasso
Research Associate
James Cook University

Dr Alana Grech
Research Fellow
James Cook University

Professor Ove Hoegh-Guldberg
Deputy Director
Queensland Smart State Premier's Fellow and Program 4 Leader
University of Queensland

Professor Geoffrey Jones
Chief Investigator
James Cook University

Dr Paulina Kaniewska
Research Fellow
University of Queensland

Professor Ronald Karlson
Partner Investigator
University of Delaware

Professor Michael Kingsford
Chief Investigator
James Cook University

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

Dr Bill Leggat
Chief Investigator
James Cook University

Professor Janice Lough
Partner Investigator
Australian Institute of Marine Science

Dr Vimoksalehi Lukoschek
Queensland Smart Futures Fellow
James Cook University

Dr Jennie Mallella
Research Fellow
Australian National University

Dr Laurence McCook
Partner Investigator
Great Barrier Reef Marine Park
Authority

Dr Mark McCormick
Chief Investigator
James Cook University

Professor Malcolm McCulloch
Deputy Director
Western Australian Premier's Fellow
and Program 1 Leader
University of Western Australia

Dr Mark Meekan
Partner Investigator
Australian Institute of Marine Science

Professor David Miller
Chief Investigator
and Program 8 Leader
James Cook University

Professor Peter Mumby
Australian Laureate Fellow
University of Queensland

Professor Philip Munday
ARC Queen Elizabeth II Fellow
James Cook University

Professor John Pandolfi
Chief Investigator
University of Queensland

Dr Serge Planes
Partner Investigator
University of Perpignan

Dr Morgan Pratchett
ARC Australian Research Fellow
James Cook University

Professor Bob Pressey
Research Fellow
and Program 6 Leader
James Cook University

Professor Garry Russ
Chief Investigator
and Program 3 Leader
James Cook University

Dr Susanne Sprungala
Research Associate
James Cook University

Professor Robert Steneck
Partner Investigator
University of Maine

Dr Linda Tonk
Research Fellow
University of Queensland

Professor Madeleine van Oppen
Partner Investigator
Australian Institute of Marine Science

Dr David Williamson
Research Fellow
James Cook University

Professor Bette Willis
Chief Investigator
James Cook University

Professor David Yellowlees
Chief Investigator
James Cook University

Resident International Scholars

Professor Chaolun Allen Chen
Research Centre
Academia Sinica
Taiwan

Dr Muriel de Boer
University of Amsterdam
Netherlands

Dr Tatjana Good
Swiss National Foundation
Switzerland

Dr Joana Figueiredo
Foundation for Science and
Technology Fellow
Portugal

Professor Hui Huang
Chinese Academy of Sciences
China

Dr Cristina Linares
University of Barcelona
Spain

Professor David Mouillot
Marie Curie Fellow
Montpellier University
France

Dr Aurélie Moya
Marie Curie Fellow
University of Nice
France

Dr Lucie Penin
Marie Curie Fellow
University of Perpignan
France

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

Professor Robert Warner
University of California
Santa Barbara
USA

Adjunct Researchers

Professor Serge Andréfouet
Institut de Recherche pour le Développement
New Caledonia

Professor Eldon Ball
Australian National University

Dr Leanne Fernandes
Earth to Ocean Consulting

Dr Alison Green
The Nature Conservancy

Dr Alexander Kerr
University of Guam
USA

Professor Janice Lough
Australian Institute of Marine Science

Professor Yossi Loya
Tel Aviv University
Israel

Dr Tim Lynam
CSIRO

Dr Laurence McCook
Great Barrier Reef Marine Park Authority

Professor Madeleine van Oppen
Australian Institute of Marine Science

Professor John Tanzer
Environmental Pathways and Solutions

Dr David Wachenfeld
Great Barrier Reef Marine Park Authority

Graduate Students
(see page 36)

Research Support Staff

Lewis Anderson
James Cook University

Maya Carmi
University of Queensland

Aaron Chai
University of Queensland

Mizue Hisano
James Cook University

James Kar-Hei Fang
University of Queensland

Kirsty Nash
James Cook University

Alex Piekutowski
University of Western Australia

Dr Nela Rosic
University of Queensland

Dr Francois Seneca
James Cook University

Dr Maya Srinivasan
James Cook University

Jenn Tanner
James Cook University

Dr Sue-Ann Watson
James Cook University

Matthew Young
James Cook University

Business Team

Jennifer Lappin
Chief Operations Officer
James Cook University

David Yellowlees
Assistant Director
James Cook University

Olga Bazaka
Finance Manager and Graduate Coordinator
James Cook University

Monica Gaffney
Office Manager and KPI Officer
James Cook University
(Jan-June 2010)

Eliza Glasson
ICRS Conference Coordinator
James Cook University

Janet Swanson
Administrative Assistant
James Cook University

Rose-Marie Vasiljuk
Office Manager and KPI Officer
James Cook University (Aug 2010 –)

Georgia Wachmer
Administrative Officer
University of Western Australia

RESEARCH PROGRAM LEADERS

Professor Malcolm McCulloch

Professor Malcolm McCulloch is one of the Centre's two Deputy Directors and Leader of Program 1: *Evolutionary and Environmental Change*. He is a Professor in the School of Earth and Environment at the University of Western Australia, Perth, and a Western Australian Premier's Fellow (2009-2013). In 2010, Malcolm was elected as Fellow of the Royal Society in recognition of his work in developing innovative new indicators of climate change preserved in coral skeletons. Malcolm's research interests focus on the recent geologic record using isotopic and trace element geochemical methods to determine how climate and anthropogenic processes have influenced both past and present marine environments, with particular emphasis on coral reefs. Malcolm has received a number of prestigious awards, including Fellowships of the Australian Academy of Science (2004), the Geological Society of Australia (2007), the Geochemical Society (2008) and the American Geophysical Union (2002) and the *Jaeger Medal in Earth Sciences* by the Australian Academy of Science (2009). Malcolm holds an Honorary Doctorate from Curtin University, and he is an *ISI Highly Cited Researcher*. His 249 scientific papers have been published in leading international journals including 23 articles in *Science* or *Nature*.

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 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 43 publications in leading international journals, including 5 in *Science* or *Nature*, and he has supervised 25 Postgraduate and Honours students since 2001. He currently holds an Australian Professorial Fellowship from the Australian Research Council, and was most recently honoured by the award of the 2009 *Fenner Medal* of the Australian Academy of Science, for pioneering new approaches to understanding biodiversity.

Professor Garry Russ

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

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 new 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 185 papers, including 16 in *Science* or *Nature*. He is currently Coordinating Lead Author for the 'Oceans' chapter within the IPCC 5th assessment report. He is well known as an advocate for coral reefs and their future fate in the face of rapid climate change, and maintains an active blog, which regularly features the ARC Centre's research. In 2008, Ove was awarded the prestigious Queensland Premier's Smart State Fellowship (2008-2013).

Professor Terry Hughes

Professor Terry Hughes is the Director of the ARC Centre of Excellence and Leader of Program 5: *Resilience of linked social-ecological systems*. He received his PhD in 1984 from Johns Hopkins University in Baltimore, USA and was an NSF Postdoctoral Fellow at the University of California, Santa Barbara before moving to Australia and James Cook University in 1990. Terry was elected a Fellow of the Australian Academy of Science in 2001 in recognition of "a career which has significantly advanced the world's store of scientific knowledge". He has been awarded two Federation Fellowships by the Australian Research Council, from 2002-2012, and is a Fellow of the *Beijer Institute for Ecological Economics*, in Stockholm. In 2007 he was awarded the *Sherman Eureka Prize for Environmental Research*. In 2010, he was a member of the *ARC Advisory Council* and Board Member of the *Resilience Alliance* and the *Beijer Institute*. Terry has broad research interests in ecology, marine biology and the social-ecological dynamics of coral reefs. As Centre Director, he provides academic leadership and is responsible for the strategic development of the Centre. He is an *ISI Highly Cited Researcher* with 24 papers in *Science* or *Nature* and ranked first in Australia for citations in Ecology & Evolution. In 2008, he was awarded the prestigious quadrennial *Darwin Medal* by the International Society for Reef Studies.

Professor 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 JCU he was a research scientist for the New South Wales National Parks and Wildlife Service for almost 20 years. During that time, Bob developed and applied leading-edge techniques in conservation planning, influencing policy and conservation practice. He is an *ISI Highly Cited Researcher* and serves on the editorial boards of leading conservation biology journals. Bob was awarded *The Royal Botanic Gardens' Eureka Prize* for Biodiversity Research in 2002, and the inaugural (2008) *Australian Ecology Research Award* from the Ecological Society of Australia. In 2009, he was awarded the title of James Cook University Distinguished Professor. His most recent recognition is his election in 2010 as a Fellow of the Australian Academy of Science, for his contributions to the field of systematic conservation planning.

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 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 from Adelaide in 1984 and is currently a Professor in molecular genetics and genomics. David's main claim to fame is the discovery that "simple" animals such as corals have genomes as complex as those of man and other vertebrates, and in highlighting the role of gene loss in shaping animal genomes. He plays a leading role in a number of genome projects on various lower animals, including the first coral genome project and the first all-Australian whole genome project, and is a regular commentator on animal genome evolution for a number of high profile journals.

BUSINESS LEADERS

Jennifer Lappin

Jennifer Lappin is the Chief Operations Officer of the ARC Centre of Excellence. Jennifer has a Bachelor of Commerce degree from the University of Queensland and is a Certified Practicing Accountant. She has over 20 years of senior management experience with responsibilities for strategic planning, finance management, human resources, communications, business process engineering, change management and policy development. Starting work as an accountant in Townsville she progressed her career in Sydney, Melbourne and London before returning to Australia. She started as an academic in the Department of Commerce at James Cook University in 1988, moving to general financial management positions soon after. Following various leadership positions in finance, research, foreign aid projects and as an executive officer at JCU, she moved in October 2005 to the Centre of Excellence to oversee, with the Centre Director, its establishment and development.

Professor David Yellowlees

Professor David Yellowlees is the Assistant Director of the ARC Centre of Excellence and a Chief Investigator in Programs 4 and 8. Trained in Scotland as a biochemist, he has undertaken extensive research on the symbiosis between coral reef organisms, particularly in corals and tridacnid clams, since the mid 1980s. His major interests have centred on the metabolic relationship between the symbiotic partners. His research on the acquisition of inorganic carbon, its photosynthetic fixation and the transfer of this to the animal host forms the basis of much of our understanding of these organisms at the metabolic level. David has published over 80 papers in international journals. He has had a long career at James Cook University commencing in the Department of Chemistry and Biochemistry in 1971. After resigning as Head of the School of Pharmacy and Molecular Sciences at the beginning of 2007, he joined the staff of the Centre in a part time capacity as its Assistant Director. He now applies many of these skills learned as Head of School to assisting with the running of the Centre.

RESEARCH PROGRAM 1

Evolutionary and Environmental Change

Researchers

- **Malcolm McCulloch** *Program Leader*
- **Sean Connolly** *Research Fellow*
- **Delphine Dissard** *Research Fellow*
- **James Falter** *Research Fellow*
- **Ove Hoegh-Guldberg** *Research Fellow*
- **Terry Hughes** *Research Fellow*
- **Michael Kingsford**
- **Janice Lough**
- **Jennie Mallela** *Research Fellow*
- **John Pandolfi**
- **Robert Steneck**

The highlight of Program 1 in 2010 has been the establishment of a new node of the ARC Centre at The University of Western Australia, providing opportunities to extend and diversify the Centre's activities to the coral reef systems of Australia's Indian Ocean margin. Uniquely, the coral reefs of Western Australia (WA) occur over an extremely large latitudinal gradient of several thousand kilometres, from the tidally-dominated tropical reefs of the Kimberley region to the temperate sub-tropical reefs of the Houtman-Abrolhos Islands and marginal reefs offshore from Perth. The fringing reef systems along the mainly desert coastline of WA are still relatively undisturbed from land-based sources of pollution. However, they are subject to the combined impacts of global warming and ocean acidification caused by rising levels of atmospheric CO_2. A simplistic view is that rising ocean temperatures from global warming will allow coral reefs to migrate southwards as occurred during the Last Interglacial, a period of 'natural' global warming that occurred ~125,000 years ago. This southwards migration of coral was due to warming from changes in the Earth's orbital parameters and has been extensively documented by Malcolm McCulloch and John Pandolfi. The Last Interglacial warming occurred with atmospheric levels of CO_2 remaining at < 300 ppm, similar to pre-industrial levels. McCulloch's move to WA enables him and other members of Program 1 to now focus on the effect of the current climate change events on WA coral reefs.

The Ningaloo Reef of WA has been selected as one of the Centre's key study sites to investigate these processes. It is Australia's largest fringing reef system, has exceptionally high coral cover, and stretches for ~290 km along the desolate northwest coast. Jim Falter, Research Fellow, has shown that this relatively 'pristine' reef system is characterised by both high productivity and high carbonate saturation states, and appears to remain largely unaffected by the confounding influence of direct local (human) impacts from land-based pollution. It is also in a unique oceanographic position being influenced by the southwards flowing warm Leeuwin Current as well as wind-driven inshore counter-currents. Program 1's research is improving our understanding of the interaction between local and oceanography factors that enabled the Ningaloo Reef to largely escape the 1997-98 La Nina mass bleaching that devastated many of the world's coral reefs.

Another major study site is the Houtman-Abrolhos Islands, where Delphine Dissard together with Tim Cooper and Janice Lough from AIMS collected a number of cores from long-lived *Porites* corals. This site should be especially sensitive to the effects of ocean acidification and the collected cores will be examined using the boron isotopic proxy for seawater pH, a method pioneered by McCulloch. Other approaches, including boron isotopic systematics, will also be used to study the effects of ocean acidification. The data will be used to determine how specific processes such as global warming, reduced levels of carbonate ions due to ocean acidification, and rising sea levels, are influencing coral reef growth without the confounding influence of direct land-based (human) impacts. The research will provide a long-term baseline response for climate change and help ensure the preservation of reefs in this region in the face of the massive expansion of marine infrastructure from the rapidly expanding natural gas and mining industry.

Pandolfi and collaborators published two landmark papers during 2010. Their *Science* paper provides new evidence that the evolutionary action on coral reefs is not in their 'hot spots' – but out on the fringes, where corals struggle to survive. These studies underscore the importance of including evolutionary processes in conservation prioritization. The second paper, in *Ecology*, is the world's first study of what happened to coral reefs when ocean levels sank to their lowest recorded level – over 120 metres below today's levels (see opposite). The fossil record shows that reefs have been remarkably successful in surviving large environmental disturbances. However, the combination of environmental changes that we are seeing today, such as degraded water quality, depleted fish stocks, coral bleaching, ocean acidification and loss of habitat are unprecedented in the history of coral reefs. This study clearly highlights the resilience of reef ecosystems and informs management responses to the challenges that reefs are currently facing.

MEDIA RELEASE – 1 March 2010

Ancient corals hold new hope for reefs

Fossil corals, up to half a million years old, are providing fresh hope that coral reefs may be able to withstand the huge stresses imposed on them by today's human activity.

If reefs could persist through the massive changes imposed by sharply falling sea levels during the last ice age, they may equally be able to endure human impacts causing equivalent stresses, an international scientific team has found.

In the world's first study of what happened to coral reefs when ocean levels sank to their lowest recorded level – over 120 metres below today's levels – a study carried out on eight fossil reefs in Papua New Guinea's Huon Gulf region has concluded that a rich diversity of corals managed to survive, although they were different in composition to the corals under more benign conditions.

"Of course, sea levels then were falling – and today they are rising. But if we want to know how corals cope with hostile conditions, then we have to study what happens under all circumstances," explains Professor John Pandolfi of the ARC Centre of Excellence for Coral Reef Studies and The University of Queensland. "We've seen what happens to corals in the past when sea levels rose and conditions were favourable to coral growth: we wanted to see what happened when they fell and conditions were adverse."

"When sea levels drop you get a catastrophic reduction in coral habitat and a loss of connectivity between reefs. Well, those circumstances are in some respects similar to what corals are experiencing today due to human impacts – so there are useful parallels."

"Although it is little asked, the question of where reef species go when faced with extreme environmental situations is highly relevant for understanding their prospects of survival in the future – and what we need to do to give them the best chance," Prof. Pandolfi suggests.

In the Huon region, the team found coral reefs survived the hard times low of sea levels with as much richness of species – but with a different composition to what they had during the good times. "As a rule the coral colonies during the period of low sea levels were lower and slower-growing in comparison with times of high sea levels."

In other words, Pandolfi says, today's rising sea levels – provided they do not rise too fast and 'drown' the reefs – offer what would otherwise be ideal growing conditions for corals, were it not for all the other human impacts, such as polluted runoff and sediment from the land, overfishing, coral bleaching and ocean acidification.

"We somehow have to find ways of preventing or offsetting each of these impacts if we expect our reefs to ride out the major climatic changes of the 21st century in as good condition as they have in the past."

Prof. Pandolfi says the submerged fossil reefs in the Huon Gulf region provide greater confidence that coral reefs will not be wiped out worldwide by climate change – as some researchers fear – provided other impacts can be kept in check.

Tager, D, Webster, JM, Potts, DC, Renema, W, Braga, JC and Pandolfi, JM (2010). Community dynamics of Pleistocene coral reefs during alternative climatic regimes. *Ecology* 91(1): 191-200.

Photo Terry Hughes

RESEARCH PROGRAM 2

Understanding and Managing Coral Reef Biodiversity

Researchers

- **Sean Connolly** *Program Leader*
- **Glenn Almany** *Research Fellow*
- **Andrew Baird** *Research Fellow*
- **David Bellwood**
- **Joana Figueiredo** *Visiting Research Fellow*
- **Chris Fulton**
- **Nick Graham** *Research Fellow*
- **Terry Hughes** *Research Fellow*
- **Geoffrey Jones**
- **Ronald Karlson**
- **Laurence McCook**
- **David Mouillot** *Visiting Research Fellow*
- **Peter Mumby** *Research Fellow*
- **Philip Munday** *Research Fellow*
- **John Pandolfi**
- **Lucie Penin** *Visiting Research Fellow*
- **Morgan Pratchett** *Research Fellow*
- **Robert Steneck**

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 aims to understand the mechanisms and processes that maintain coral reef biodiversity, using a combination of mathematical modelling and field studies. This multi-disciplinary approach informs knowledge-based management of biodiversity resulting in environmental, social, and economic benefits to tropical maritime nations.

Program 2 research in 2010 provided several key breakthroughs in understanding how biodiversity is maintained on coral reefs, on how reefs are likely to respond to ongoing human impacts, and importantly how management can mediate those responses.

David Bellwood and colleagues, examining the co-evolution of reef organisms, in a paper in *Journal of Evolutionary Biology*, identified a 12 million-year dependency of butterflyfishes on corals, underscoring their high vulnerability to climate change. Mathematical modelling by Sean Connolly and co-workers, published in the journal *Ecology Letters*, identified a role for complex patterns of dispersal to the maintenance of reefs' high biodiversity. This revealed that habitat loss and changes to ocean currents associated with climate change may have more profound consequences than previously recognised. Peter Mumby, working in the Caribbean with Alistair Harborne, documented reductions in seaweed domination on reefs where large reef herbivores were protected from fishing. In a paper in *Frontiers in Ecology and the Environment*, John Pandolfi and colleagues revealed the historical role of Moreton Bay as a refuge for coral reefs in the past, highlighting the critical importance of managing local impacts in the Bay to restore its potential to provide a buffer against climate change. A paper led by Mumby and published in *Ecology Letters* identified novel ways of designing networks of marine reserves to hedge against the effects of climate change, and found that some reefs can be prioritised for protection based on their ubiquitously important role across a broad range of scenarios.

Researchers in Program 2 also made numerous important contributions in 2010 to coral reef policy issues at State, Commonwealth, and international levels. For example, Morgan Pratchett, Philip Munday, and Nick Graham, along with several international colleagues, were commissioned by the Secretariat for the Pacific Community to assess the effects of climate change on fisheries and food security in Pacific island nations. Pandolfi and Munday participated in an ongoing series of IPCC workshops in ocean acidification, which will inform the production of the IPCC's next Assessment Report. Pandolfi also coordinated the Coffs Harbour Subtropical Reefs Declaration, which called on Australian governments at all levels to manage marginal reefs in subtropical areas of Queensland and Western Australia, because these areas may become critical refuge areas as climate change proceeds.

In 2010, members of Program 2 were once more the recipients of numerous awards and honours. For example, Mumby received a Fellowship in Marine Conservation from the Pew Foundation, and the Marsh Award for Marine Conservation from the Zoological Society of London. Graham was made a Fellow of the UK's prestigious Linnean Society. In addition, David Mouillot joined the Centre as a visiting research fellow, supported by a European Union Marie Curie Fellowship, and Joana Figueiredo joined the Centre as a visiting researcher, supported by the Portuguese *Fundação para a Ciência e a Tecnologia*.

MEDIA RELEASE – 3 February 2010

New theory could help save biodiversity

Australian scientists have announced a major new finding that helps explain how natural systems like coral reefs and forests maintain the richness of their mix of species.

Their findings have important implications for understanding how humans can better protect biodiversity during one of the worst episodes of species extinction in the Earth's history.

The research also may help to explain why, in habitats fragmented by human activity, the loss of species can be especially high – despite our best attempts at conservation.

Mathematical modelling by a team from the ARC Centre of Excellence for Coral Reef Studies and James Cook University, published today in the prestigious journal *Ecology Letters*, identifies the way species disperse across fragmented habitats as one of the keys to biodiversity – and how to preserve it.

"One of the great unanswered questions in ecology for the past 80 years is how species-rich communities like reefs and rainforests maintain their diversity. When resources are limited, you'd expect that the most competitive species would eventually dominate and the others be wiped out," says lead author Yacov Salomon, now a PhD candidate at the University of Melbourne.

Till now, explanations have focused on what goes on in the habitats themselves. However, in their latest paper, the team argues that the answer lies also in how corals and rainforests spread their offspring across surrounding fragments of available habitat. By dispersing offspring unevenly – on winds, current or carried by other creatures – across patchworks of reefs or forest fragments, the richness of biodiversity is perpetuated.

"We're basically proposing a novel mechanism by which biodiversity can be maintained, which helps to explain how some of our most marvellous natural systems retain their richness."

"For example, for every reef that receives plenty of offspring from dominant coral types floating in on the current, there will be other reefs that receive fewer offspring from those corals – giving the less competitive species an opportunity to thrive."

"There is a practical angle to this idea," says Professor Sean Connolly, a co-author of the study. "The take-home message from a conservation standpoint is that losing fragmented habitats is likely to result in greater loss of species than you might otherwise expect."

"The models that scientists currently use to predict biodiversity loss focus on the overall reduction in dispersal between increasingly far-flung habitats. Our study shows that fragmentation also reduces the opportunities for different species to have different dispersal patterns."

"That can mean a double whammy for species that aren't good competitors: less success dispersing offspring into suitable habitat, and fewer habitats that offer some respite from competitively dominant species."

"On the flip side, though, it also means that restoring degraded patches of habitat may have greater beneficial effects on biodiversity than we previously thought."

"The bottom line is that, if your aim is to maintain a rich community of species, like on coral reefs or in rainforests, real-world complexities in dispersal need to be considered."

Salomon, Y, Connolly, SR and Bode, L (2010). Effects of asymmetric dispersal on the coexistence of competing species. *Ecology Letters* 13(4): 432-441.

Photo Nick Graham

RESEARCH PROGRAM 3

Marine Reserves and Reef Connectivity

Researchers

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

Networks of marine reserves (no-take areas) are used to manage biodiversity and fisheries. Zoning for multiple levels of use and protection, including no-take areas, has become one of the principal mechanisms for management of marine resources in Australia and around the world. Program 3 focuses on how marine reserves enhance biodiversity and fisheries management. A major issue is the level of larval dispersal and connectivity within and between marine reserve networks. Program 3 focuses on the optimal design of reserve networks for coral reef conservation and fisheries management; and on the consequences of shifts in connectivity, due to climate change and other processes that affect stock-recruitment relationships.

In 2010, members of Program 3 contributed three invited papers to a Special issue of the *Proceedings of the National Academy of Sciences (USA)* entitled "Networking Marine Resources, Marine Reserves Special Feature". One of these papers, senior authored by Laurence McCook, entitled "Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves", reviewed the evidence for biodiversity conservation and fisheries benefits of the 2004 re-zoning of the Great Barrier Reef Marine Park (GBRMP) (see National Benefit Case Study p.54).

Program 3 continues to lead the world in development and application of techniques to tag and track marine larvae. Larval tracking, combined with detailed larval dispersal modeling, have now been applied successfully to the Great Barrier Reef Marine Park. Extensive DNA sampling of commercially and recreationally important species of reef fish in the Keppel Islands was completed in 2010. Groundbreaking research by Geoff Jones and colleagues has, for the first time, demonstrated substantial larval connections between the no-take marine reserves ("Green Zones") and the fished ("Blue") zones of the Keppel Islands. More significantly, the research demonstrated that the green zones were delivering substantially more recruits to fisheries than their area would suggest. The important finding is that green zones not only "produce more fish and bigger fish", but also export substantial amounts of recruits to fished areas. The management implications of this finding to the GBRMP are substantial. These novel results are almost unique, globally. They herald a new era in the design and implementation of marine reserve networks. In future, managers will be able to place, size and space green zones to meet objectives.

Program 3 continues to make breakthroughs in understanding critical aspects of larval biology. Mark McCormick and colleagues continue with novel research showing that successful recruitment to the next generation of breeding reef fish is strongly influenced by parental condition. In a paper in the *Proceedings of the National Academy of Sciences,* Philip Munday and colleagues found that ocean acidification disrupts the sensory system of reef fishes, increasing their vulnerability to predators nearly tenfold. This has implications for the prioritization of conservation and management efforts. Impairment of recruitment will reduce population sustainability of many marine fish species, with potentially profound consequences for marine biodiversity, fisheries sustainability and connectivity patterns of populations and networks of marine reserves.

Garry Russ and colleagues made a national-scale assessment of the current extent, conservation efficacy and gaps in coverage of marine protected areas in the Philippines. This research, carried out by PhD student Rebecca Weeks, also showed how spatial zoning software can be used to consider local marine tenure explicitly in the design of marine protected area (MPA) networks. Weeks and colleagues were able to design MPA networks that impacted local resource users more equitably, and were therefore more likely to be socio-economically viable.

In Papua New Guinea and the Solomon Islands, Glenn Almany and colleagues work closely with marine scientists and conservation planners at The Nature Conservancy to test and design new MPA networks. The latest insights gained from Program 3 research activities on MPAs and connectivity are incorporated into these network designs to improve their resilience to threats from climate change and overfishing.

MEDIA RELEASE – 7 July 2010

Carbon emissions threaten fish populations

Humanity's rising CO_2 emissions could have a significant impact on the world's fish populations according to groundbreaking new research carried out in Australia.

Baby fish may become easy meat for predators as the world's oceans become more acidic due to CO_2 fallout from human activity, an international team of researchers has discovered.

In a series of experiments reported in the latest issue of the *Proceedings of the National Academy of Sciences*, the team found that as carbon levels rise and ocean water acidifies, the behaviour of baby fish changes dramatically – in ways that decrease their chances of survival by 50 to 80 per cent.

"As CO_2 increases in the atmosphere and dissolves into the oceans, the water becomes slightly more acidic. Eventually this reaches a point where it significantly changes the sense of smell and behaviour of larval fish," says team leader Professor Philip Munday of the ARC Centre of Excellence for Coral Reef Studies.

"Instead of avoiding predators, they become attracted to them. They appear to lose their natural caution and start taking big risks, such as swimming out in the open - with lethal consequences."

Dr Mark Meekan from the Australian Institute of Marine Science, a co-author on the paper, says the change in fish behaviour could have serious implications for the sustainability of fish populations because fewer baby fish will survive to replenish adult populations.

"Every time we start a car or turn on the light, part of the resulting CO_2 is absorbed by the oceans, turning them slightly more acidic. Ocean pH has already declined by 0.1 unit and could fall a further 0.3.-0.4 of a unit if we continue to emit CO_2 at our present increasing rate.

"We already know this will have an adverse effect on corals, shellfish, plankton and other organisms with calcified skeletons. Now we are starting to find it could affect other marine life, such as fish."

Earlier research by Professor Munday and colleagues found that baby 'Nemo' clownfish were unable to find their way back to their home reef under more acidic conditions. The latest experiments cover a wider range of fish species and show that acidified sea water produces dangerous changes in fish behaviour.

"If humanity keeps on burning coal and oil at current rates, atmospheric CO_2 levels will be 750-1000 parts per million by the end of the century. This will acidify the seas much faster than has happened at any stage in the last 650,000 years.

"In our experiments we created the kind of sea water we will have in the latter part of this century if we do nothing to reduce emissions. We exposed baby fish to it, in an aquarium and then returned some to the sea to see how they behaved.

"When we released them on the reef, we found that they swam further away from shelter and their mortality rates were five to eight times higher than those of normal baby fish," Professor Munday says.

He adds it should be clearly understood that this impact is likely to happen independent of global warming, and is a direct consequence of human carbon emissions.

The research team concludes "Our results demonstrate that additional CO_2 absorbed into the ocean will reduce recruitment success and have far-reaching consequences for the sustainability of fish populations."

Munday, PL, Dixson, DL, McCormick, MI, Meekan, M, Ferrari, MCO and Chivers, DP (2010). Replenishment of fish populations is threatened by ocean acidification. *Proceedings of the National Academy of Sciences* 107(29): 12930-12934.

RESEARCH PROGRAM 4

Genetic, Molecular and Physiological Processes

Researchers

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

Reef-building corals and their symbionts are fundamental elements of tropical coastal ecosystems. Researchers from Program 4 continued their investigation of the intricate relationships between corals and their holobiont partners, including dinoflagellates and bacteria, particularly in how they respond to environmental stressors. These issues are important in light of the rapid rates of environmental change occuring at both local and global scales. Research results generated by Program 4 scientists have important implications for the future and management of coral reefs.

Research continued on the disease agents affecting corals. Ove Hoegh-Guldberg and colleagues expanded their work on white syndrome in collaboration with Michael Kuhl from the University of Copenhagen, on how acute tissue death during white syndrome affects the microenvironments associated with tabular *Acropora*. Bette Willis collaborated with scientists from the National Oceanic and Atmospheric Administration (NOAA) to produce a model that explained how inter-annual seasonal differences can drive the appearance of white syndrome in corals. Willis also investigated skeletal eroding band on the Great Barrier Reef and the role of injury in the initiation of this widespread coral disease. Her team continued to investigate how particular elements of the immunity system of corals underpinned their susceptibility to bleaching and disease. These studies are producing an integrated picture of how environmental drivers influence the susceptibility and potential outcome of an increased abundance of coral diseases. This project has direct application to management of the Great Barrier Reef through a better understanding of the drivers of disease.

Sophie Dove and others continued their work on the stress biology of corals, focusing on the tolerance of corals to stress at a physiological level. Working at both Heron Island and Lizard Island, Dove has begun to explore the latitudinal differences in physiological tolerance across the Great Barrier Reef. Simon Dunn has been improving our understanding of the interactions between coral host and symbiotic dinoflagellate and developed a method based on the incorporation of stable isotope and HPLC-MS lipidomic studies of anemones and corals. This work is providing an important insight into the fate of photosynthate metabolites, which can now be tracked over time to specific synthetic and metabolic pathways. In a similar vein, Mathieu Pernice has been using nanosim technology to successfully visualize the incorporation of ^{15}N into metabolites and its subsequent transport and utilization between symbiotic partners. These provide valuable insight into the metabolic interactions between partners, the functions of the symbiosis, and will lead to the development of markers for monitoring health and changes in the status of the symbiotic partnership under different climate change scenarios.

Madeleine van Oppen has continued to explore the genetic structure of coral populations on the Great Barrier Reef. Together with Program 4 postdoctoral fellows and students, van Oppen is developing some of the first data on the genetic variability of corals with respect to heat tolerance. In a series of experiments moving corals between warm and cooler areas of the Great Barrier Reef, van Oppen's team is providing important information on the potential for coral populations to adapt to rapid changes in sea temperature and ocean acidity. Smart State Fellow, Line Bay, has been collaborating with van Oppen to develop a number of important techniques and insights into gene expression responses to environmental stress. These types of studies will provide important insight into how corals are likely to respond to the rapid changes in sea temperature and ocean acidity that are projected to occur on the Great Barrier Reef over the coming decades.

Bill Leggat, David Yellowlees and Tracy Ainsworth have investigated the effect of sub-bleaching temperatures on the expression of basic metabolic genes in both the coral host and *Symbiodinium* and how these sub-lethal temperatures modify the expression of genes involved in apoptosis. These results show that at temperatures 2-3 degrees below the bleaching threshold there are significant changes in the gene expression in the coral host. This has important implications for how corals will respond to future increases in temperature.

MEDIA RELEASE – 17 August 2010

How corals fight back

Australian researchers are a step closer to understanding the rapid decline of our coral reefs, thanks to a breakthrough study linking coral immunity with its susceptibility to bleaching and disease.

The discovery was made by Caroline Palmer, Bette Willis and John Bythell, scientists from the Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University (Queensland) and Newcastle University (UK).

"Understanding the immune system of reef-building corals will help to reduce the impact of coral diseases and environmental stresses," says Caroline Palmer, lead author of the publication. "Potentially, this will enable us to more accurately predict the vulnerability of coral reefs to disease and bleaching, before there are obvious signs of stress."

"This unique study broadens the limited knowledge we have about the defence systems of corals, which is one of the main challenges facing scientists aiming to protect corals" says Professor Bette Willis, a chief investigator in the ARC Centre. "Identifying and measuring the immune functions of several different corals allows us to predict which ones are particularly susceptible to stress."

"Variation in levels of immune function among different species is likely dependent on the energy they assign to it. Corals that utilise energy to grow and reproduce rapidly have less to spare for their immune response as energy is vital for this process," says Caroline Palmer. "These corals, like the staghorns, are the colonies most vulnerable when challenged by temperature stress or disease."

The study of coral immunity will enable scientists to better pre-empt the effects of different stresses on corals. This is important, as by the time physical symptoms become apparent, strategies to mitigate stress effects will be far less valuable.

"Our increased understanding of coral immune systems may therefore be used to address the causes rather than the symptoms of coral declines", says Caroline Palmer. Bette Willis adds: "This approach is necessary particularly given that coral bleaching is similar to having a fever – it's a common sign for many different stresses so it's often difficult to point to any one cause in particular".

Two of the main factors that cause corals to bleach are attacks by disease-causing microbes and temperature stress. It is currently estimated that between three and six per cent of corals on the Great Barrier Reef are affected by coral diseases, and up to a third of corals at a given location can be affected by temperature stress in a warm year. Temperature stress is a growing concern due to global warming.

Researchers and reef managers are currently working on strategies to protect vulnerable coral sites. The preventive measures envisioned involve minimising human impacts which might further injure the coral, such as dredging, building construction, pollution, land runoff or damaging corals by boat activity or fishing.

Palmer CV, Bythell JC, Willis BL (2010). Levels of immunity parameters underpin bleaching and disease susceptibility of reef corals. *FASEB Journal* 24:1935-1946

Photo Ernesto Weil

RESEARCH PROGRAM 5

Resilience of Linked Social-Ecological Systems

Researchers

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

Program 5 focuses on the interface between people, economies and coral reef ecosystems. Our objective is to undertake research and develop new tools that improve the governance and management of natural systems and enhance their capacity to sustain human and natural capital. Program 5's multi-disciplinary research combines expertise on coral reef biology, management, governance, economics and the social sciences.

In January, Centre Director Terry Hughes travelled to Paris for a meeting of the inaugural Science Committee responsible for developing a 10-year global research project of ICSU, the *International Council for Science*. The project, entitled *Program on Ecosystem Change and Society* (PECS) will focus on both human development and sustainability of natural resources at regional to global scales. PECS aims to link science and environmental management to society, policy and human well-being. The PECS Science Committee will meet twice a year to develop a social-ecological research agenda that is closely aligned to the ARC Centre's Programs 5, 6 and 7. PECS is co-sponsored by UNESCO, and will complement existing global environmental change programs and international partnerships.

In February, Joshua Cinner and Terry Hughes presented invited talks at the AAAS meeting in San Diego, based on two Special Feature articles on marine reserves, published in *Proceedings of the National Academy of Sciences*. Another research highlight in 2010 was the cover article in the September issue of *PNAS*, entitled "Navigating transformations in governance of Chilean marine coastal resources." Led by Stefan Gelcich from Universidad Catholica, this study is based on a 2008 workshop co-chaired by Hughes and Juan-Carlos Castilla in Santiago, Chile – one of the Centre's ongoing series of international working group meetings focussing on marine social-ecological systems.

In May, John Pandolfi and Jeremy Jackson from the Scripps Institution of Oceanography convened a workshop with 14 colleagues entitled *Incorporating Appropriate Ecological Baselines into Management of Ocean Resources*, in Washington, DC. The purpose of the meeting was to bring together a diverse group of ecologists, natural resource managers, conservation scientists, lawyers, and policy makers, to foster the incorporation of historical ecological baselines into marine environmental laws, regulations and policies. The goal is to produce several synthetic publications during 2011, including a Law Review article that reflects the relevant strategies for improving both US and Australian legislation. The workshop will provide a landmark case study for environmental law, with applications that could extend globally to a variety of ecosystems and governments. This project is funded by the ARC Centre, the Smithsonian Marine Science Network, IUCN, and the Australian Academy of Science.

In June, Program 5 leader Terry Hughes hosted an ARC Centre working group focussing on the challenges of trans-boundary governance in the sea, with a particular emphasis on the emerging Coral Triangle Initiative and the Baltic. Among the twelve participants were members of the Centre's Programs 5, 6 and 7, as well as representatives from The WorldFish Center, the Resilience Alliance, the Beijer Institute for Ecological Economics, and the Stockholm Resilience Centre.

As 2010 drew to a close, Joshua Cinner secured a prestigious 5-year Australian Research Fellowship, based at James Cook University, which will enable him to continue and expand his own work on climate change adaptation, in collaboration with Hughes and Tim McClanahan from Kenya. Their project, entitled *Linking social science and ecology to understand the vulnerability of coastal societies to changes in coral reef resources*, will be based mostly in east Africa and the Indian Ocean.

Program 5 hosted many international visitors during the year (see p.46), including Professor Hui Huang, from the Chinese Academy of Science. During her 5-month stay at James Cook University, Professor Huang wrote a review with Hughes and Matt Young on the regional status of coral reefs in the South China Sea, with recommendations for their future management.

MEDIA RELEASE – 7 October 2010

Call to heal the world's coral reefs

There is still time to save the world's ailing coral reefs, if prompt and decisive action can be taken to improve their overall health, leading marine researchers say. Writing in the journal *Trends in Ecology and Evolution*, eminent marine scientists from Australia and the USA have called for an international effort to improve the resilience of coral reefs, so they can withstand the impacts of climate change and other human activities.

"The world's coral reefs are important economic, social and environmental assets, and they are in deep trouble. How much trouble, and why, are critical research questions that have obvious implications for formulating policy and improving the governance and management of these tropical maritime resources," explains Jeremy Jackson from the Scripps Institution of Oceanography.

The key to saving the reefs lies in understanding why some reefs degenerate into a mass of weeds and never recover – an event known as a 'phase shift' – while on other reefs the corals manage to bounce back successfully, showing a quality known as resilience. This underlines the importance of managing reefs in ways that promote their resilience, the researchers say.

"We have a very good scientific understanding of what causes reefs to decline – what we now need is a clearer picture of how to help them back onto the reverse trajectory," says lead author Professor Terry Hughes from the ARC Centre of Excellence for Coral Reef Studies at James Cook University.

Taking an optimistic view, the researchers argue there is compelling evidence from sites in Hawaii, Australia's Great Barrier Reef, the Caribbean, Bahamas and Philippines that the degradation and disappearance of corals can be arrested and reversed with the right management: The team has formulated the scientific lessons from resilient reefs into a set of management advice which governments can adopt to give coral reefs a fighting chance:

- Empower and educate local people to look after their own reefs
- Change land uses that cause damaging runoff and sediment
- Control not only fishing, but also fish markets to protect herbivorous fish
- Integrate resilience science with reef management and support for local communities in restoring their reefs
- Improve laws that protect coral reefs globally
- Confront climate change as the single most important issue for coral reef management and conservation by sharply reducing greenhouse gas emissions.

On climate change they caution: "Without urgent action, unchecked global warming and ocean acidification promise to be the ultimate policy failures for coral reefs. Although it is possible to promote the recovery of reefs following bouts of bleaching via local actions such as improving water-quality and protecting herbivores, these interventions alone cannot climate-proof reefs."

"The clear message from our research, and that of other marine scientists, is that the world's coral reefs can still be saved… if we try harder," Hughes says.

Hughes, TP, Graham N, Jackson JBC, Mumby PJ, and Steneck RS (2010). Rising to the challenge of sustaining coral reef resilience. *Trends Ecol. Evol*. 25: 633-642

RESEARCH PROGRAM 6

Conservation Planning for a Sustainable Future

Researchers

- **Bob Pressey** *Program Leader*
- **Glenn Almany** *Research Fellow*
- **Natalie Ban** *Research Fellow*
- **Debora de Freitas** *Research Associate*
- **Mariana Fuentes** *Research Fellow*
- **Tatjana Good** *Visiting Research Fellow*
- **Alana Grech** *Research Fellow*
- **Johnathan Kool** *Research Fellow*
- **Laurence McCook**

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

The Great Barrier Reef, the Coral Sea and the Coral Triangle remain major geographical focal regions of Program 6. Collaborations are now well established with government agencies and non-profit organisations in several countries. In the Great Barrier Reef region, Bob Pressey and colleagues are engaging with the Great Barrier Reef Marine Park Authority, Queensland Parks and Wildlife Service, the Great Barrier Reef Foundation, and Natural Resource Management Boards in northern Queensland. For example, in 2010 Pressey partnered with Derek Ball in the Mackay-Whitsunday Natural Resource Management (NRM) region on a long-term project investigating island biosecurity. Pressey is also engaging actively in the Coral Triangle Initiative. In 2010, he attended the Asia-Pacific Coral Reef Symposium in Phuket and an associated workshop on marine protected areas in the Coral Triangle. He also presented at the Association for Tropical Biology meeting in Bali and visited Jakarta for discussions with the Coral Triangle Support Partnership.

Two new research fellows joined Program 6 in 2010, Alana Grech and Mariana Fuentes. Mariana Fuentes is an ARC Super Science Fellow whose project is developing systematic priorities for the management of marine mega-fauna to increase their resilience to climate change, focusing on the northern Great Barrier Reef and Torres Strait. Mariana has a strong network of collaborators among managers and scientists in agencies and universities in Queensland and is working closely with island managers in the Queensland Parks and Wildlife Service. Alana's research focuses on bringing together traditional knowledge and western science to support a systematic approach to designing marine conservation strategies in the Torres Strait. She works closely with multiple State and Federal government agencies.

In 2010, Program 6 helped the Solomon Islands achieve its reporting commitments under the Convention on Biological Diversity (CBD). Johnathan Kool led the project, in collaboration with The Nature Conservancy, which identified gaps in coverage of ecosystems by terrestrial and marine protected areas. The Solomon Islands government, approved the report in parliament and endorsed it as their submission to the CBD.

In Fiji, Pressey and his students partnered with the Wildlife Conservation Society and the national Protected Area Committee to investigate:

- opportunity costs to local communities of establishing marine protected areas
- differential effectiveness of several types of management actions
- achievement of Fiji's national conservation goals through community-based resource management actions.

Results of this collaboration have been presented in a national workshop for Fijian provincial governments to implement additional management actions within their provinces. This research also contributed towards Fiji's reporting requirements to the Convention on Biological Diversity.

In the Great Barrier Reef and adjacent Coral Sea, Program 6 is involved in several projects. Pressey and Natalie Ban collaborated with the University of Queensland to analyse sea surface temperature trends using satellite imagery to incorporate rising temperatures into conservation planning. Work is also underway to examine the impact of interacting stressors on coral bleaching and disease. Pressey and Ban's work on estimating management costs of complete no-take and partial no-take scenarios for the proposal Coral Sea Marine Reserve is generating interest, resulting in an invited presentation to the Marine Biodiversity Research Hub's workshop on strategic research needs in managing the Commonwealth marine estate.

Program 6 has been active in numerous additional collaborations and meetings. With funding from the Canadian government, Ban and colleagues launched a new collaboration with the University of British Columbia on social considerations in conservation planning. Pressey and Ban became partners in the Global Ocean Biodiversity Initiative, an international partnership for advancing the scientific basis for conserving and managing the deep seas and open oceans. In 2010, Ban also served as an invited member on the organising committee of the Royal Society's and Australian Academy of Science's *Frontiers in Marine Sciences* meeting in Western Australia.

MEDIA RELEASE – 22 February 2010

Participation important for healthy marine parks

The involvement of locals is a key ingredient in the success of marine parks which protect coral reefs and fish stocks.

The largest-scale study to date of how coastal communities influence successful outcomes in marine reserves has found that human population pressure was a critical factor in whether or not a reserve succeeded in protecting marine resources – but so too was local involvement in research and management.

The team looked at how successful coral reef marine reserves were at conserving fish stocks. They studied 56 marine reserves from 19 different countries throughout Asia, the Indian Ocean, and the Caribbean.

"About ¾ of the marine reserves we studied showed a positive difference in the amount of fish inside compared to outside – so most reserves we studied were working" says Dr Josh Cinner of the ARC Centre of Excellence for Coral Reef Studies.

"However, the differences weren't always large. The most successful reserves showed really big differences - 14 times the amount of fish inside compared to outside - but that wasn't always the case.

"What we were most interested in was understanding what made some reserves more successful than others. One of the best predictors of how 'successful' a marine reserve was, is actually the size of the human communities around the reserve – but interestingly, this varied in different regions.

"In the Indian Ocean, for example, where reserves are government-controlled and moderate in size (around six square kilometres on average), having lots of people nearby had a positive effect."

"In the Caribbean, we found the opposite. Large human populations near reserves led to poor performance of the reserve," Dr Cinner said.

The other key ingredient for a successful marine reserve was the level of poaching in the reserve. But importantly, the team found that compliance with reserve rules was not just related to the level of enforcement, but also to a range of social, political, and economic factors which enabled people to co-operate better in protecting their marine resources. Reserves worked best where there was a formal consultation processes about reserve rules, where local people were able to participate in monitoring the reserve, and when ongoing training for community members was provided so that they could better understand the science and policy.

"It was clear that this type of local involvement was a very important factor in building the local support necessary to make reserves successful. Park agencies need to foster conditions that enable people to work together to protect their local environment, voluntarily, rather than focusing purely on regulations and patrols.

"Enforcement will almost always be an important part of a successful reserve, but there is a lot of ocean out there to patrol and many of the places we studied were poor, developing countries which don't have the luxury of being able to invest in lots of patrol boats.

Pollnac R, Christie P, Cinner JE, Dalton T, Daw TM, Forrester GE, Graham NAJ, McClanahan TR (2009) Marine reserves as linked social–ecological systems *Proceedings of the National Academy of Sciences* 107(43): 18262-18265

Photo Rebecca Weeks

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*
- **Pedro Fidelman** *Research Fellow*
- **Terry Hughes** *Research Fellow*
- **John Pandolfi**

Program 7, launched in mid-2009 and led by Simon Foale, 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 includes a focus on the Great Barrier Reef, its activities are global in scope, with emphasis on the rapidly evolving coastal resource management and governance challenges in countries throughout the Indo-Pacific region, particularly in Melanesia and the Coral Triangle. Program 7 addresses the global, political and economic drivers of resource-use at several scales, and aims to understand the cultural, social and political dimensions of coral reef tenure systems and resource use, both contemporary and historical. Program 7 is already involved in capacity-building activities in many countries, working with NGOs and national governments.

Post-doctoral fellows, Louisa Evans and Mike Fabinyi, were recruited to the ARC Centre in the first half of 2010, and have each made significant progress in the short time they have been with the Program. Evans worked for The WorldFish Center prior to her arrival, and her ongoing collaborations with WorldFish contribute to the Centre's growing alliance with this group. Evan's expertise in resilience theory, combined with her solid grounding in applied fisheries governance research, makes her a particularly valuable asset to the Program. She has already secured funding from the National Climate Change Adaptation Research Facility. Fabinyi comes to us from the ANU, and his anthropological expertise is also highly valued by Program 7, particularly in relation to our goal of developing constructive collaborations between ecologists, economists and social scientists.

Program 7 members led and participated in two working groups in 2010 (in addition to those described earlier for Program 5). Foale led one in Cairns in September entitled *Conserving Biodiversity for Food Security: Putting People at the Heart of the Coral Triangle*. In December, Visiting Research Fellow, Per Olsson, from the Stockholm Resilience Centre led a related working group entitled *Working towards Regional Ocean Governance: The Coral Triangle Initiative* in which Hughes, Foale and Evans participated.

Other Program 7 work includes a stakeholder analysis led by Pedro Fidelman aimed at describing institutional interplay within the Coral Triangle Initiative (CTI), and the governance landscape of the Coral Triangle region – a particularly relevant study given the importance of the CTI to our work, and the pressing need to understand the complex and problematic governance issues that the CTI presents. Fabinyi is leading an investigation of commodity fishery market chains (e.g. live reef fish, bêche-de-mer and shark fin) from the Asia-Pacific region into China – a fundamentally important yet widely neglected aspect of commercial, reef-based fisheries in the region.

In 2010, Foale led a joint JCU-ANU field trip to the remote and densely populated island of Tikopia as part of his research project on traditional knowledge in subsistence fisheries. This work focuses on local understandings of the impacts of fishing on artisanal fisheries in the Melanesian countries of Solomon Islands and Papua New Guinea.

Tikopia is a well-known name in anthropological and archaeological circles, and was singled out by Jared Diamond in his recent, book 'Collapse', as an example of a 'success story', in striking contrast to another remote Pacific Island, Rapanui (Easter Island). In part due to its isolation, Tikopia has one of the strongest traditional cultures in the Pacific. Intriguingly, Foale's team substantiated earlier claims that the Tikopians appear to lack any effective traditional fisheries management institutions, such as customary marine tenure, or regular serial closures (taboos). The team's findings call into question some widely cited and popular dogmas about the extent to which subsistence fisheries were in fact ecologically limiting for pre-colonial human populations on Pacific Islands, and related hypotheses about the existence of a traditional conservation ethic in Pacific Island societies. The policy implications of this work are important, because if people did not 'traditionally' conserve subsistence fisheries out of necessity, then a 'renaissance' or 'strengthening' of tradition or custom is unlikely to achieve fishery management objectives in modern contexts. Other policy initiatives, including the development of locally-relevant science education programs, appear to be more useful, and this approach is being tested in Foale's work.

MEDIA RELEASE – 10 June 2010

Fishers caught between degradation and development

The livelihoods of tens of millions of fishers in the world's richest coral reef region, the Coral Triangle, are at risk from the combined impact of collapsing fish stocks, environmental decline and coastal development.

A new study focusing on a group of islands in the Philippines by Dr Michael Fabinyi of the ARC Centre of Excellence for Coral Reef Studies and James Cook University has highlighted the pressures being experienced by tens of millions of subsistence fishers in the region bounded by Australia, the Pacific and Southeast Asia.

"The Calamianes islands in the Philippines are fairly typical of what is happening throughout the region," Michael explains.

"Until recently they had relatively pristine coral reefs and healthy levels of fish stocks – but the impact of overfishing, including dynamite fishing and cyanide fishing, to feed the hungry markets of China and Asia have caused extensive degradation to the reefs and declines in the fish that depend on them.

"In Southeast Asia it is commonly assumed that tourism development will provide some of the answers by employing people who can no longer fish for a living – but in my study I did not find that.

"Instead it became clear that what was spoken of as eco-tourism was, in reality, often coastal resort development – and it was pushing many coastal families off their land as well as squeezing them out of their fishing areas.

"It has certainly created jobs for some former fishers – but by no means for all, and this wider social impact needs to be taken into account when thinking about the future livelihoods of the tens of millions who have, until now, drawn their living from the sea."

Dr Fabinyi says that the creation of marine protected areas in some parts of the Philippines and Coral Triangle has proved beneficial both for fishers and genuine ecotourism, although it has also restricted the area that fishers rely on for their livelihood.

"In the Calamianes, for example, I found that most fishers were working longer hours, over greater distances, for fewer fish caught – which is a clear sign that the fishery is continuing to decline.

"At the same time resort developers were pressuring them to give up their land on the coast, without creating sufficient livelihoods to compensate for the loss on land and at sea."

Tourism development is often seen as a 'silver bullet' solution to poverty in underdeveloped regions, he says, but studies on the ground indicate the picture is more mixed – while some livelihoods are created, others are being destroyed. Also tourism is less reliable than fishing, being subject to booms and busts and the cost of world air travel.

"The people who are affected by these forces of environmental degradation, fish stock decline and coastal development are so numerous throughout the region that this is emerging as a very serious social issue for all the countries in the Coral Triangle as well as those which border it – like Australia," Fabinyi says.

Fabinyi M (2010), The Intensification of fishing and the rise of tourism: Competing coastal livelihoods in the Calamianes Islands, Philippines. *Human Ecology* 38, 415–427.

Photo Simon Foale

RESEARCH PROGRAM 8

Genomics and Metagenomics of Coral Reefs

Researchers

- **David Miller** *Program Leader*
- **Tracy Ainsworth** *Research Fellow*
- **Line Bay** *Research Fellow*
- **Simon Dunn** *Research Fellow*
- **Sylvain Forêt** *Research Fellow*
- **Lauretta Grasso** *Research Associate*
- **Ove Hoegh-Guldberg** *Research Fellow*
- **Bill Leggat**
- **Aurélie Moya** *Visiting Research Fellow*
- **Susanne Sprungala** *Research Associate*
- **Madeleine van Oppen**

Program 8 was established in 2009 in recognition of the growing importance of genomics in coral reef research and the Centre's growing expertise and leadership in this field. The Program is based around the structure and function of the genomes of corals, their dinoflagellate symbionts and associated bacterial and viral communities, known as the "holobiome". The long-term aim of Program 8, in association with Program 4, is to understand how the "holobiome" functions under normal and stressed conditions.

Major research highlights of 2010 included a comparative study, published in *Trends in Genetics*, highlighting the importance of "old" genes in enabling the evolution of new traits. The assumption has been that the evolution of new traits, such as building the coral skeleton, is enabled primarily by the evolution of new genes, whereas what we have shown is that old genes – many of which have been lost from many animals – are at least as important as "new" genes in this respect.

Substantial progress has been made in determining the whole genome sequence of the coral *Acropora millepora* - the first animal to undergo whole genome sequencing and assembly by an all-Australian team. This ground-breaking project is exclusively based on short-read "next-gen" sequencing methods, and is a partnership between the ARC Centre, The Australian Genome Research Facility and Illumina Inc. In combination with the genome sequence, the availability of the large volumes of transcriptome data accumulated by the combined efforts of David Miller (JCU), Eldon Ball (ANU) and collaborators have led to *Acropora millepora* becoming the coral of choice for molecular and cell biology research by most scientists in the international coral research community.

Significant progress has also been made on the genomics of the dinoflagellate symbionts (*Symbiodinium* sp.). The major focus is on the use of high-throughput sequencing to characterise the transcriptome of *Symbiodinium*. This work is supported by a number of postgraduate student projects that are examining quantitative changes in gene expression of these unicellular algae under a variety of stress conditions, including increased temperatures, CO_2 and nutrient levels.

In September, Miller, with Thomas Bosch, co-organized and co-chaired a joint symposium on coral genomics which was held in Kiel (Germany) with the *Kiel Cluster of Excellence – "The Future Ocean"*. Sylvain Forêt and Marcelo Kitahara were also participants as was Terry Hughes who delivered a plenary. Program 8 also hosted Allen Chen of Academia Sinica (Taiwan), who spent a sabbatical in the ARC Centre in 2010, and Jaap Kaandorp (University of Amsterdam). Two members of Kaandorp's group, Muriel de Boer and MSc student Lotte Huisman, are supported by a Dutch Science Foundation grant on which Miller is a Chief Investigator and are long-term visitors to the Centre.

Other research highlights in 2010 included major advances in understanding coral evolution. Marcelo Kitahara's PhD project has shown that two deep-sea coral families, the gardeneriids and micrabaciids, are the earliest diverging of all extant corals, pushing coral origins back in time to the Paleozoic. Zoe Richards moved to the Australian Museum, where she is the first recipient of the Virginia Chadwick Post-doctoral Fellowship. Sylvain Forêt, a postdoctoral bioinformatician in the Program, was a member of the team that analysed the methylome of the honeybee, resulting in a very highly cited *PLoS Biology* paper. This research has been invaluable in guiding the analysis of the coral genome in which Forêt is playing a leading role. Tracy Ainsworth, an ARC postdoctoral fellow, published a number of studies in 2010, including an invited review in *Trends in Ecology and Evolution* which examined the future of coral reefs from a microbial perspective, and the role these organisms play in coral reef resilience.

RESEARCHER PROFILE

PROFESSOR MADELEINE VAN OPPEN

Madeleine van Oppen was awarded a prestigious Level 3 ARC Future Fellowship in 2010. Her achievement follows on the success of ARC Centre researchers, Andrew Baird and Glenn Almany, who were both awarded Level 1 Fellowships in the inaugural Future Fellowship round. Madeleine is based at the Australian Institute of Marine Science (AIMS) in Townsville and is a Partner Investigator and adjunct Professor in the ARC Centre.

Madeleine originally trained as a marine (molecular) ecologist in the Netherlands, studied herbivorous coral reef fish and zooplankton for her masters, cold-water seaweeds for her doctorate and African cichlid fishes for her first postdoctoral work in the UK. She began researching reef corals in 1997 on a James Cook University postdoctoral research fellowship in David Miller's laboratory, followed by an ARC Australian Research Fellowship. In 2001 she moved to AIMS, where she developed and now leads a highly successful research program on the genetics of adaptation/ acclimatisation of corals to climate change. Madeleine is the co-editor of the first major book on coral bleaching. She collaborates extensively with other scientists in the ARC Centre, particularly Bette Willis, and she is on the supervisory panel of several postgraduate students enrolled in the Centre.

Over the past few years, Madeleine has expanded her research program to include quantitative genetics and (functional) genomics approaches. In addition, she is developing genetic tools and assessing the impacts and likely success of management strategies (for example, the introduction of beneficial alleles into threatened populations through translocation of corals).

Madeleine is the Director of the Centre for Marine Microbiology and Genetics at AIMS which was funded by a major grant from the Queensland Government's Smart State Research Facilities Fund. Her Future Fellowship project is to explore a new and exciting aspect of coral research - the viruses associated with corals. Her aim is to characterise these viruses and obtain a detailed understanding of the critical roles they play in coral health, coral bleaching and adaptation of corals to climate change.

'Despite the popular misconception, not all viruses are bad,' says Madeleine, who regularly leads and participates in field research on the Great Barrier Reef. It is an astonishing fact that ~28,000 viral types are associated with a single coral colony, yet viruses are the least studied of the biota living on or in corals. The research results of her fellowship will provide major insights into how corals are likely to respond to climate change, and as such will substantially contribute to management strategies which aim to maximise reef resilience.

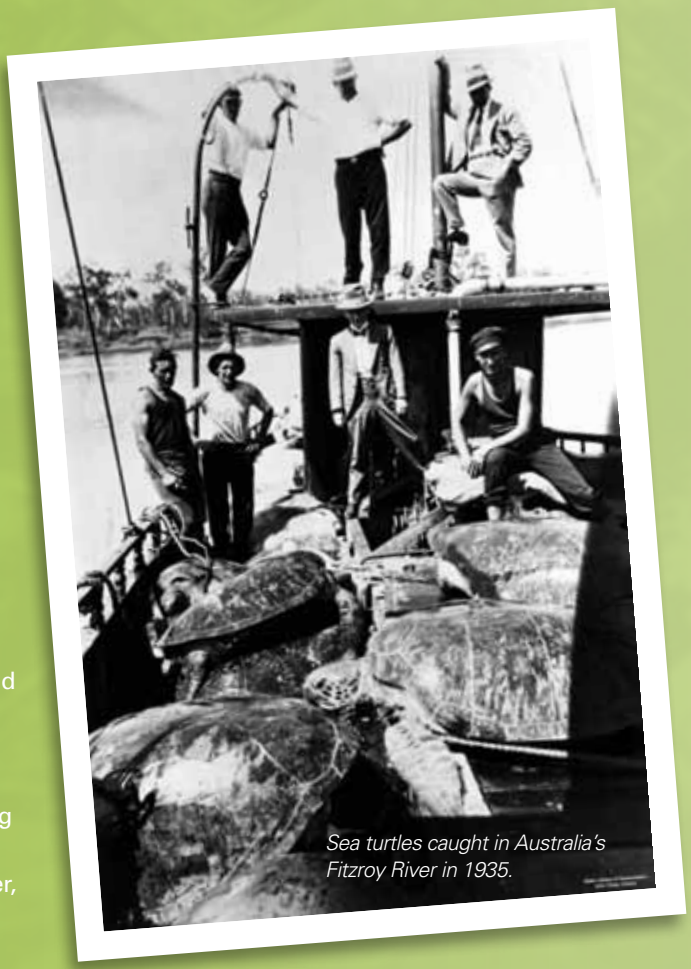
The Future of Marine Governance

By Terry Hughes

A remarkably simple lesson has emerged from recent research into preserving marine resources around the world: concerted human planning and effort are effective in preventing further decline of marine ecosystems. Fundamentally, the deterioration of marine ecosystems signals a crisis of governance, and the widespread degradation of our environment is a symptom of inadequate, dysfunctional, or missing institutions.[1] Currently, most coastal and almost all oceanic fisheries lack effective property rights, leading to widespread depletion of stocks, while globalized markets pressure people to fish even harder. However, management of common-pool resources within the nearshore territorial waters of some countries has markedly improved in recent years, and some improvement has also been achieved at larger scales within the Exclusive Economic Zones (generally up to 200 nautical miles from the coast) of progressive nations. The major challenge globally, to overcome rampant free riding on the high seas, is to design new international agreements that reward cooperation and sanction violations.

On land, most human societies long ago made the transition from roaming hunter-gatherer to farmer or city dweller. Societal rules and norms have changed over many centuries to reflect this increased attachment to place. In particular, many human activities on land revolve around systems of property rights and restricted access to resources. Governance of the sea lags far behind terrestrial systems. Increasingly, however, many nation states are experimenting with new legal frameworks and institutional arrangements to confront overfishing and the degradation of marine ecosystems.

Open access to coastal resources changed nearshore ecosystems surprisingly early in human history.[2] For example, archaeological middens around the world show a rapid depletion of megafauna, often followed by sequential fishing down the food chain from larger to smaller species. Even the relatively intact Great Barrier Reef has seen rapid declines in sharks, turtles, and dugongs due to hunting and accidental bycatch. In contrast, many of the great fisheries of the world, such as the Atlantic cod, were persistent for centuries because there was always somewhere too far offshore, too deep, too dangerous, or too expensive to fish. On the other hand, global positioning technology has greatly enhanced the capacity to divide the ocean into patches with different management regimes. We can artificially restore refuges from overfishing by establishing appropriately scaled no-take reserves.



Sea turtles caught in Australia's Fitzroy River in 1935.

In the last four years, global ocean protection has made significant strides. Offshore locations still have reasonably intact ecosystems because of their relative isolation, and the paucity of people there simplifies the social costs of establishing no-take marine reserves. In 2006, former U.S. president George W. Bush established Papahanaumokuakea Marine National Monument (360,000 km^2) in the northwestern Hawaiian Islands. In the same year, the president of the Republic of Kiribati announced the Phoenix Islands Protected Area (184,700 km^2). In 2010, former UK foreign secretary David Miliband established the Chagos Marine Reserve in the tropical Indian Ocean (covering 545,000 km^2). The Chagos Reserve alone doubled the area of the world's oceans that are under protection.

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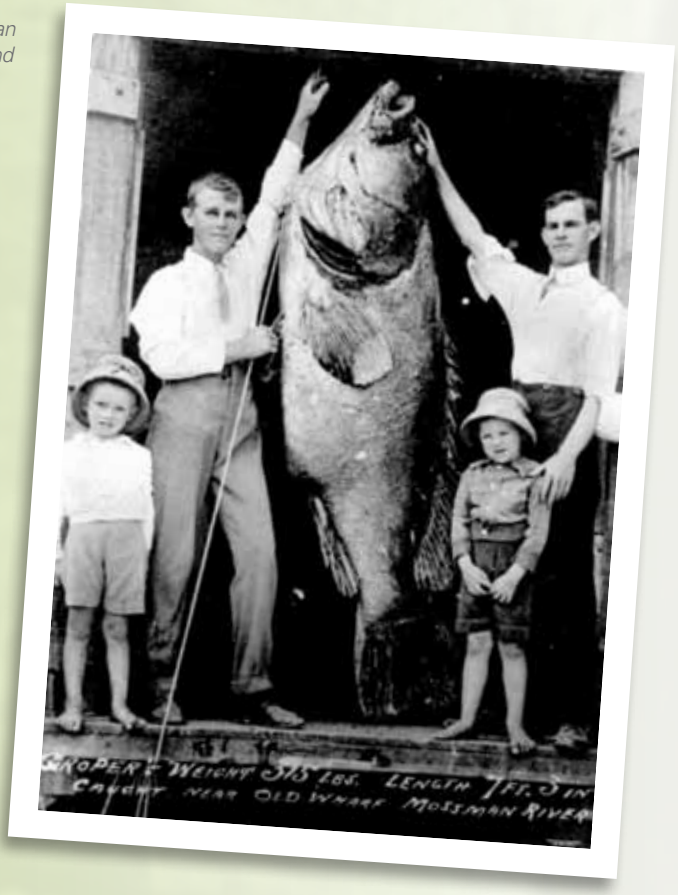


This grouper caught circa 1917 in the Mossman River in Australia weighed in at 315 pounds and was 7 feet and 3 inches long.

Nearshore governance has also improved in many countries. For example, in the Philippines, legal frameworks have emerged that encourage partnerships between local fisher communities, local municipalities, and NGOs, leading to co-management of coastal coral reefs.[3] This emerging system devolves marine management responsibility from the central government to coastal communities, with greater authority allocated to local governments up to 15 kilometers from shore. Similarly, in Chile, a new property-rights system has allocated exclusive use of areas of the coastal seafloor to cooperatives of artisanal fishers, requiring commercial operators to work offshore.[4] Each cooperative that chooses to join the system pays rent and is allocated a catch quota for up to four species each year, based on an annual stock assessment. Other commercial species are left unharvested, creating an effective system of no-take zones for most of the ecosystem.

The Great Barrier Reef Marine Park is another hopeful example of adaptive governance in the face of human impacts such as overfishing, pollution, and climate change.[5,6] The park is divided into seven color-coded zones that allow for different activities by different users. For example, fishing and collecting is prohibited in green zones, but tourism and research are allowed. There is clear evidence for widespread recovery of fish stocks in newly created green (no-fishing) zones. However, zones are ineffective for coping with land-based pollution runoff or depletion of highly mobile megafauna. These issues remain major challenges.

These examples of transformative governance from the Philippines, Chile, and Australia all illustrate the importance of new scientific information and of testing policy options prior to full-scale implementation.[3,4,6] In each case, small groups of researchers worked with local fishers to explore the feasibility of different management regimes, and local support and communication among multiple stakeholders was critical in gaining political support for new initiatives. In a rapidly changing world, static governance is doomed to failure, and learning how to adapt to new information and shifting circumstances is key to achieving desirable outcomes.

1. Walker, B et al. Looming global-scale failures and missing institutions. *Science* 325, 1345–1346 (2009).
2. Jackson, J et al. Historical overfishing and the recent collapse of coastal ecosystems. *Science,* 293: 629-638 (2001).
3. Alcala, CA and Russ, GR. No-take marine reserves and reef fisheries management in the Philippines: A new people power revolution. *Ambio* 35, 245-254 (2006).
4. Gelcich, S et al. Navigating transformations in governance of Chilean marine coastal resources. *Proceedings of the National Academy of Sciences* 107(39), 16751–17060 (2010).
5. Day, J. An overview of the Representative Area Program and its role in protecting the biodiversity of the Great Barrier Reef**.** *Solutions 2, 56–66 (2011).*
6. McCook, LJ et al. 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(43), 18278-18285 (2010).

GRADUATE TRAINING

In 2010, the ARC Centre supervised and funded 192 postgraduate and honours students representing a 3 fold increase over the past 5 years. This represents the world's largest postgraduate program in coral reef research. Apart from support for the student research costs, the Centre also provides targeted professional development for the students and financial assistance to attend conferences, Centre Symposia and, to visit other nodes of the Centre. The total investment in student activities is >25% of the Centre's annual budget.

In September, the ARC Centre again held a National Student Mentoring Day immediately prior to the annual Australian Coral Reef Society conference at the National Marine Science Centre in Coffs Harbour, NSW. The program focused on developing the students' research and publication skills as well as preparing them for careers in either research or management agencies. A range of speakers from the Centre, including Bill Leggat, John Pandolfi, Tracy Ainsworth, and Jenny Lappin provided an informative day for attendees. The 33 graduate students came from 8 universities across the country as well as from overseas.

A professional writing workshop, held at the Australian National University was arranged for students on 6th October 2010. A total of 30 students from the Centre attended. This workshop provided an opportunity for students with all levels of writing ability to hone their writing skills, with activities including cover letters, abstracts, and manuscript structure. Students also exchanged draft manuscripts to gain editing experience.

Following discussions at the Students' Canberra retreat, the students instituted a series of cross-nodal "labs", videoconferenced weekly. Topics covered various aspects of interest including statistics and strategies for writing and publishing research. The forum has evolved into a session where students can exchange statistical skills, ask relevant pressing questions, and through which they can invite experts to give presentations on topics of interest.

On the JCU campus, the Student Committee have also been increasing the Centre's green credentials through their involvement with the *Greening the University* initiative. In collaboration with the student body and the University's Environment Manager, they have begun to take steps towards greening the Centre office through energy efficiency measures, and an improved recycling program.

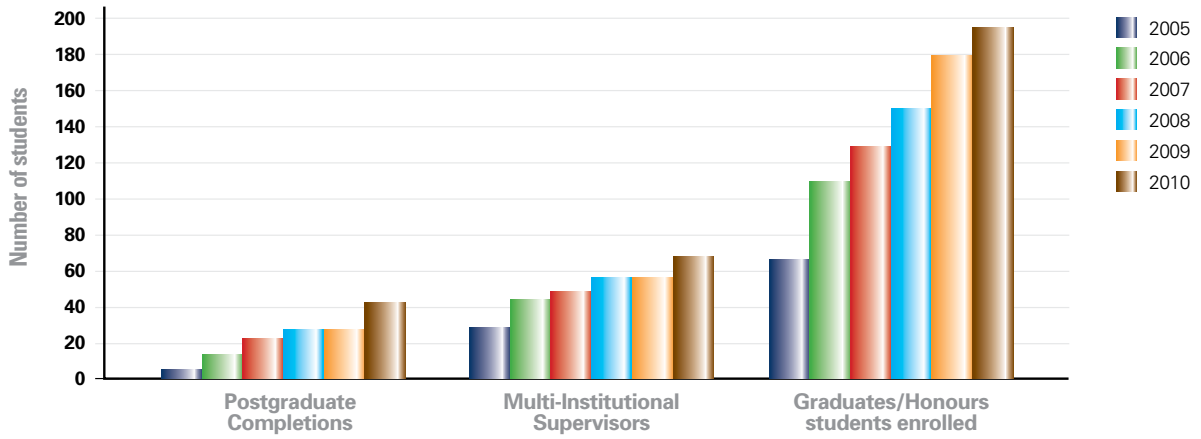
Awards to Centre students in 2010 include:

- Four of the five GBRMPA Science for Management Awards for 2010 were awarded to students in the ARC Centre. These were to Rohan Brooker, Christopher Goatley, Brynn Devine and Jennifer Donelson, who was also a winner in 2009. ARC Centre winners of the 2009 awards delivered lectures to a GBRMPA audience during the year.
- James Fang was the 2010 winner of the International Society for Reef Studies (ISRS) Graduate Fellowship for Coral Reef Ecosystem Research.
- Chia-Miin Chua, Naomi Gardiner, Rebecca Lawton and Joe Pollock all received travel grants from the Australian Coral Reef Society to attend their annual meeting in Coffs Harbour, NSW.
- Rebecca Lawton was presented with the Quicksilver Award for the outstanding oral presentation at the Australian Coral Reef Society meeting in Coffs Harbour.
- Renata Legorreta received a grant from the Conservation Leadership Program to attend the ISRS European meeting in The Netherlands.
- Danielle Dixson won the Australian Society for Fish Biology International Travel Scholarship for her paper on ocean acidification, published in *Ecology Letters.*
- Brynn Devine won the *Best oral presentation by a senior student* at the annual meeting of the Australian Society for Fish Biology.
- Yui Sato was awarded *the Best student oral presentation* prize at the 2nd Asia Pacific Coral Reef Symposium in Phuket, Thailand.
- Christopher Doropoulos received funding from both the Australian Coral Reef Society (*Danielle Simmons Award*) and the Winifred Violet Scott Foundation (*Research Award*) for his PhD research.
- Claire Reymond received a *Student Travel Award* from the Cushman Foundation to attend the International Symposium on Foraminifera in Bonn, Germany.
- Joe Pollock was awarded a *Sir Keith Murdoch Fellowship* by the Australian American Association. He was also the recipient of a Rottnest Island Authority Research Grant for his work on coral diseases.
- The Virginia Chadwick Awards are awarded to five ARC Centre of Excellence graduate students for

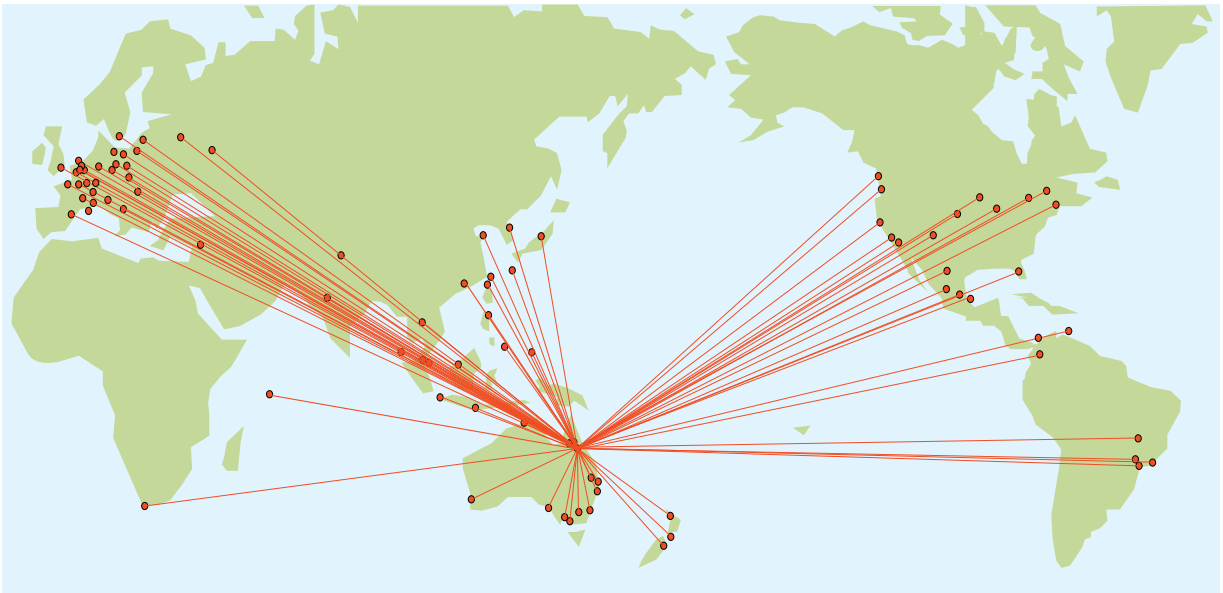
the most outstanding publications in peer-reviewed international journals. The research must be published in Excellence in Research Australia (ERA) A* or A ranked journals and each attracts a prize of $1,000. The winners for 2010 were Vanessa Adams, Pim Bongaerts, Alicia Crawley, Joe Pollock and Yui Sato.

The ARC Centre would like to acknowledge the Student Committee for their valuable contribution during 2010. Along with Olga Bazaka, our graduate student co-ordinator, they make an invaluable contribution to the success of the ARC Centre. Members of the committee during the year were Tom Brewer (Chair), JCU; Alicia Crawley, UQ; Anne Leitch, CSIRO/JCU; Juan Pablo D'Olivo, ANU; Christina Hicks, JCU; Ian McLeod, JCU; Chun (James) Hong Tan, JCU.

Trends in the ARC Centre's training activities 2005 to 2010



The ARC Centre's international network of graduate students. In 2010, 120 overseas students came from 42 countries



2010 Student members of the ARC Centre of Excellence for Coral Reef Studies

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Rene Abesamis	JCU, Silliman University	Philippines	Demographic connectivity of reef fish populations in the Philippines. (PhD)	Prof G Russ, Prof G Jones
Vanessa Adams	JCU	USA	Incorporating economic factors into systematic conservation planning. (PhD)	Prof R Pressey, Prof T Hughes
Siham Afatta	UQ	Indonesia	Resilience studies of Indonesian coral reefs: ecological and social assessments in Karimunjawa National Park. (MPhil)	Dr K Anthony, Prof O Hoegh-Guldberg
Bridie Allan	JCU	New Zealand	Predator-prey interactions under a CO_2 rich environment. (MAppSc)	Dr M McCormick, Prof P Munday
Campbell Allen	UQ	Australia	Australia eco-informatic tools for coral reef ecology. (MSc awarded)	Prof O Hoegh-Guldberg
Jorge Alvarez-Romero	JCU	Mexico	Cross-system threats and competing values in coastal and marine conservation planning: an integrated land-sea approach to prioritize conservation actions in the Gulf of California. (PhD)	Prof R Pressey, Dr N Ban, Dr J Kool
Shelley Anthony	JCU, AIMS	USA	White Syndrome Disease and colony mortality in captive Indo-Pacific corals. (PhD)	Prof B Willis
Stephen Ban	JCU	Canada	Spatial responses of coral reef ecosystems to climate change and associated stressors. (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
Christopher Bartlett	JCU	USA	Emergence, evolution and outcomes of marine protected areas in Vanuatu - implications for social-ecological governance. (PhD awarded)	Dr J Cinner
Andrew Bauman	JCU	USA	The ecology and dynamics of coral reef communities in marginal reef environments. (PhD)	Dr M Pratchett, Dr A Baird
Brian Beck	UQ, JCU	USA	Palaeoecological dynamics of coral communities in the South Pacific. (PhD)	Prof J Pandolfi, Prof S Connolly
Roger Beeden	JCU	New Zealand	How healthy is the Great Barrier Reef in a warming world? (PhD)	Prof B Willis
Victor Beltran-Ramirez	JCU	Mexico	Molecular aspects of the fluorescent protein homologues in *Acropora millepora*. (PhD awarded)	Prof D Miller, Prof D Yellowlees, Prof M van Oppen
Dorothea Bender	UQ	Germany	Impacts of climate change and ocean acidification on coral reef turf algae (PhD)	A/Prof S Dove, Dr G Diaz-Pulido
Duan Biggs	JCU, CSIR South Africa, Emory University USA, University of Canterbury NZ	South Africa	Resilience of reef-based tourism to climate change and disturbance. (PhD)	Prof T Hughes, Dr J Cinner
Sandra Binning	ANU	Canada	Phenotypic plasticity in coral reef fish ecomorphology. (PhD)	Dr C Fulton
Shane Blowes	JCU	Australia	Territoriality, competition, and coexistence of butterflyfishes. (PhD)	Prof S Connolly, Dr M Pratchett
Teressa Bobeszko	JCU	Australia	The role of carbonic anhydrase in the coral-dinoflagellate symbiosis. (PhD)	Dr W Leggat, Prof D Yellowlees
Lynda Boldt	JCU	Australia	*Symbiodinium* photosynthetic genes and the effect of varying environmental conditions on photosynthetic processes. (PhD)	Dr W Leggat, Prof D Yellowlees
Roberta Bonaldo	JCU	Brazil	The ecosystem role of parrotfishes on coral reefs. (PhD awarded)	Prof D Bellwood, Prof S Connolly
Pim Bongaerts	UQ	Netherlands	Bathymetric patterns of genetic variation in the coral-algal symbiosis. (PhD awarded)	Prof O Hoegh-Guldberg

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Mary Bonin	JCU	USA	Causes and consequences of habitat specialization in coral reef fish communities. (PhD)	Prof G Jones, Dr G Almany
Madeleine Bottrill	UQ, JCU	United Kingdom	Evaluating the effectiveness of conservation planning: when do plans work. (PhD)	Prof R Pressey
Tom Brewer	JCU, UQ	Australia	A multi-scale analysis of the social causes of coral reef resource decline, and management response, in Solomon Islands. (PhD)	Prof T Hughes, Prof R Pressey, Dr J Cinner, Dr S Foale, Prof J Pandolfi
Rohan Brooker	JCU	New Zealand	Habitat specialisation and its consequences for a corallivorous filefish. (PhD)	Prof G Jones, Prof P Munday
Michael Cappo	JCU, AIMS	Australia	Development of a baited video technique and spatial models to explain patterns of fish biodiversity in inter-reef waters. (PhD awarded)	Prof M Kingsford
Alexandra Carter	JCU	Australia	The effects of no-take zoning, region and year on reproductive output of the common coral trout, *Plectropomus leopardus*. (PhD)	Dr M McCormick, Prof G Russ
Jordan Casey	JCU	USA	Modelling the effects of apex predator declines on coral reef trophodynamics. (PhD)	Prof S Connolly
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, Dr K Anthony
Rowan Chick	JCU	Australia	Stock enhancement of local populations of blacklip abalone (*Haliotis rubra* leach) in New South Wales, Australia. (PhD awarded)	Prof M Kingsford
Karen Chong-Seng	JCU	Seychelles	The mechanistics of regeneration in coral reef ecosystems. (PhD)	Dr N Graham, Prof D Bellwood, Dr M Pratchett
Chia-Miin Chua	JCU	Malaysia	Effects of elevated temperature and increased acidity on the early life history of coral. (PhD)	Dr A Baird, Dr W Leggat, Prof T Hughes
Tara Clark	UQ	Australia	Dating and mapping historical changes in Great Barrier Reef coral communities. (PhD)	Prof J Pandolfi
Philippa Cohen	JCU	Australia	The contribution of locally-managed marine areas to food security of Solomon Islands. (PhD)	Dr S Foale, Prof T Hughes
Darren Coker	JCU, DEC in WA, AIMS	New Zealand	The role of live coral in moderating key ecological processes for coral reef fishes. (PhD)	Dr M Pratchett, Dr N Graham
Andrew Cole	JCU, DEC in WA	Australia	The effect of chronic fish predation on scleractinian corals. (PhD)	Dr M Pratchett, Prof G Jones
Amy Coppock	JCU	United Kingdom	Experimental evaluation of olfactory cues in the settlement of coral reef fishes. (MAppSc)	Prof G Jones
Melissa Cowlishaw	JCU	Australia	Determinants of home range and territorial behaviour in coral fishes: roles of body size, habitat structure and population density. (PhD)	Prof G Jones, Dr M McCormick
Peter Cowman	JCU	Ireland	Dating the evolutionary origins of trophic novelty in coral reef fishes. (PhD)	Prof D Bellwood
Alicia Crawley	UQ	Australia	The synergistic effect of rising ocean temperature and acidification on coral reef ecosystems. (PhD)	A/Prof S Dove, Dr S Dunn

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Vivian Cumbo	JCU, AIMS	Australia	Thermal tolerance in corals: the role of the symbiont. (PhD)	Dr A Baird, Prof M van Oppen, Prof T Hughes
Christopher Cvitanovic	ANU	Australia	Ecological energetics of coral reef butterflyfishes. (PhD)	Dr C Fulton, Dr M Pratchett
Kathryn Danaher	JCU	Australia	Oceanography and the condition of plankton. (PhD)	Prof M Kingsford
Sana Dandan	UWA	Denmark	Resilience of coral reef communities and coral metabolism in extreme environmental conditions. (PhD)	Prof M McCulloch
Jaclyn Davies	JCU	USA	Influence of topography on use of sensory modes in risk assessment. (MAppSc)	Dr M McCormick
Thalia de Haas	JCU	Netherlands	Genetic structures and patterns of *Amphiprion melanopus* within the central, south-eastern part of the Indo-Australian archipelago. (MAppSc)	Prof G Jones
Andrea de Leon	ANU	Australia	Palaeoceanographic records of the Southern Ocean: insights from the boron composition of biogenic silica. (PhD)	Prof M McCulloch
Brynn Devine	JCU	USA	Effects of ocean acidification on habitat selection in fish. (MSc)	Prof P Munday, Prof G Jones
Ayax Diaz-Ruiz	UQ	Mexico	The use of coral associated fauna as indicators of coral health. (PhD)	Prof O Hoegh-Guldberg, Prof J Pandolfi
Danielle Dixson	JCU	USA	Use of olfactory cues for settlement site selection in coral reef fishes. (PhD)	Prof P Munday, Prof G Jones, Dr M Pratchett
Jennifer Donelson	JCU, CSIRO	Australia	Climate change and the future for coral reef fishes: potential for acclimation and adaptation. (PhD)	Prof P Munday, Dr M McCormick
Christopher Doropoulos	UQ	Australia	Climate change effects on the recruitment and succession of algae and corals from the Great Barrier Reef. (PhD)	Dr Guillermo Diaz-Pulido
Maxi Eckes	UQ	Germany	How do coral reef fish protect themselves from solar ultraviolet radiation? (PhD awarded)	A/Prof S Dove
Udo Engelhardt	UQ	Australia	Community-level ecological responses of coral reef biota to mass coral bleaching events. (PhD)	Prof O Hoegh-Guldberg
Kar-Hei (James) Fang	UQ , UWA	Hong Kong, China	Effects of climate change and eutrophication on the Indo-Pacific excavating sponge *Cliona orientalis* Thiele (PhD)	A/Prof S Dove, Prof O Hoegh-Guldberg
Pepito (Sonny) Fernandez	ANU, JCU	Philippines	Political engagements in marine protected area governance in northeastern Liloilo, Philippines. (PhD)	Dr S Foale
Rebecca Fox	JCU	United Kingdom	Ecosystem function of rabbitfishes (F:Siganidae) on the Great Barrier Reef, Australia. (PhD)	Prof D Bellwood
Matthew Fraser	JCU	Australia	Egg predation at tropical reef fish spawning aggregation sites: trade-offs for fitness. (PhD awarded)	Dr M McCormick, Prof G Jones
Naomi Gardiner	JCU	Australia	Habitat specialisation niche overlap and site fidelity in a vulnerable family of coral reef fishes - the cardinal fish (Apogonidae). (PhD awarded)	Prof G Jones
Chris Goatley	JCU	United Kingdom	The ecological role of sediments on coral reefs. (PhD)	Prof D Bellwood
Luis Gonzalez Reynoso	JCU, Griffith University	Mexico	Mechanisms of stress inhibition of reproduction in fish. (PhD)	Dr M McCormick
Alonso Gonzalez-Cabello	JCU	Mexico	Cryptobenthic reef fish ecology in the Great Barrier Reef, Australia. (PhD)	Prof D Bellwood

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Benjamin Gordon	JCU, AIMS	Australia	The metabolome of *Symbiodinium* phylotypes and their coral hosts. (PhD).	Dr W Leggat
Erin Graham	JCU	USA	Energetics of coral larvae and its implications for dispersal. (PhD)	Prof B Willis, Prof S Connolly, Dr A Baird
Jessica Haapkyla	JCU, AIMS	Finland	Impacts and drivers of coral disease in Indo-Pacific reefs. (PhD)	Prof B Willis
Andrew Halford	JCU	Australia	Disturbance effects on tropical reef fish assemblages at large spatial and temporal scales. (PhD awarded)	Prof G Jones
David Harris	UQ	Australia	Ecology of high latitude populations of *Pomacentrus coelestis*. (PhD)	Prof O Hoegh-Guldberg
Hugo Harrison	JCU, University of Perpignan	France	Larval recruitment dynamics and the genetic structure of coral reef fish populations in marine protected networks. (PhD)	Prof G Jones, Prof G Russ, Dr S Planes
Tom Heintz	JCU	France	The impact of growth anomalies on growth and reproduction of corals. (MAppSc)	Prof B Willis
Christina Chemtai Hicks	JCU	United Kingdom	The interplay between economic values and societal settings in coral reef governance. (PhD)	Prof T Hughes, Prof R Pressey, Dr J Cinner
Jean-Paul Hobbs	JCU	Australia	Reef fishes on isolated islands: community structure, endemism and extinction. (PhD awarded)	Prof G Jones, Prof P Munday
Jennifer Hodge	JCU	USA	Evolution and speciation processes in coral reef fishes. (PhD)	Prof D Bellwood
Andrew Hoey	JCU	Australia	The ecosystem role of macroalgal browsing fishes on coral reefs. (PhD awarded)	Prof D Bellwood, Prof G Russ
Thomas Holmes	JCU	Australia	Processes and mechanisms of predatory interactions on newly settled reef fish. (PhD awarded)	Dr M McCormick
Vera Horigue	JCU, University of the 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	Genetic resilience of *Symbiodinium* populations: the role of coral endosymbionts in reef adaptation to climate change. (PhD)	Prof B Willis, Dr L Bay, Prof M van Oppen
Lotte Huisman	JCU, University of Amsterdam	Netherlands	Combined effect of warming and ocean acidification on early life stages of corals. (MSc)	Dr A Moya, Prof D Miller
Matthew Jankowski	JCU	United Kingdom	Influence of reef aspect and depth on the distribution of coral reef fishes. (MAppSc)	Prof G Jones
Stephanie Januchowski	JCU	USA	Systematic conservation planning for fresh waters in the Wet Tropics bioregion Queensland Australia (PhD)	Prof R Pressey
Fraser Januchowski-Hartley	JCU	United Kingdom	Biological mechanisms of customary management of Melanesian coral reefs and their consequences for the reef fish community. (PhD)	Prof G Russ, Dr N Graham , Dr J Cinner
Jacob Johansen	JCU	Denmark	Energetics of habitat choice in planktivorous coral reef fishes. (PhD)	Prof G Jones, Prof D Bellwood
Charlotte Johansson	JCU, AIMS	Sweden	Managing coral reefs: the importance of working with functional groups to conserve ecosystem resilience. (PhD)	Prof D Bellwood
Jung Ok Kang	ANU	Korea	Anthropogenic increase of atmospheric carbon dioxide, ocean acidification and global warming: implications for long-term changes in the calcification rate of coral reefs. (PhD)	Prof M McCulloch

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
James Kerry	JCU	England	Functional role of corals on coral reefs. (MAppSc)	Prof D Bellwood
Brent Knack	JCU	Australia	Cell adhesion factors in Cnidarians. (PhD)	Prof D Miller, Dr W Leggat
Narinratana Kongjandtre	UQ	Thailand	The taxonomy and systematics of the coral genus *Favia* from Thai waters. (PhD awarded)	Prof O Hoegh-Guldberg
Joleah Lamb	JCU, AIMS	USA	Identifying and managing impacts and drivers of coral disease associated with reef-based recreational activities. (PhD)	Prof B Willis, Prof G Russ
Angela Lawton	UQ	USA	The effects of micro-scale variation on the photosynthetic productivity of the symbiotic algae of reef building corals. (PhD)	Prof O Hoegh-Guldberg, A/Prof S Dove
Rebecca Lawton	JCU, KAUST	New Zealand	Geographic variation in the ecology of butterflyfishes and resilience to large scale disturbances. (PhD)	Dr M Pratchett, Dr L Bay, Prof T Hughes
Carine Lefèvre	JCU	France	Ecological aspects of small cryptic fish 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)	Dr M McCormick, Prof G Jones
Raechel Littman	JCU, AIMS	USA	The dynamics of bacterial populations associated with corals and the role of bacterial pathogens in coral bleaching. (PhD)	Prof B Willis
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, Prof M van Oppen
Matt Lybolt	UQ	USA	Causes of change in coastal ecosystems: past, present and future. (PhD)	Prof J Pandolfi
Jeffrey Maynard	University of Melbourne, UQ	USA	Climate change processes affecting coral reef ecology. (PhD awarded)	Dr K Anthony
Dominique McCowan	JCU	USA	Bleaching susceptibility of corals: a hierarchy of causes and consequences. (PhD)	Dr M Pratchett, Dr A Baird, Prof T Hughes
Ian McLeod	JCU	New Zealand	Influence of temperature on the early life history of coral reef fishes. (PhD)	Prof G Jones, Dr M McCormick
Amelie Menchenin	JCU	France	Early life history of *Epinephelus quoyanus* (MAppSc)	Prof G Jones, Prof G Russ
Luiz-Felipe Mendes-de-Gusmao	JCU, AIMS	Brazil	Trophic controls on development and nucleic acid indices in tropical planktonic copepods. (PhD awarded)	Prof M Kingsford
Vanessa Messmer	JCU	France	From genes to ecosystems: patterns, processes and consequences of declining biodiversity in coral reef fish communities. (PhD awarded)	Prof G Jones, Prof P Munday, Dr S Planes
Rachael Middlebrook	UQ	Australia	Determining thermal threshold dynamics and variability in reef building corals. (PhD)	A/Prof S Dove, Dr K Anthony, Prof O Hoegh-Guldberg
Gabrielle Miller	JCU	Australia	The interacting effects of ocean acidification and increasing temperature on a coral reef fish. (PhD)	Prof P Munday, Dr M McCormick
Morena Mills	JCU	Brazil	Implementation opportunity in systematic conservation planning. (PhD)	Prof R Pressey, Dr N Ban, Dr S Foale

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Matthew Mitchell	JCU	United Kingdom	Antipredator defence through chemical alarm cues - how common amongst tropical marine fishes? (PhD)	Dr M McCormick
Roshni Narayan	UQ	Canada	Holocene to recent changes in the benthic foraminifera communities of subtropical Moreton Bay, Queensland and potential indicators for monitoring sediment/water quality in estuarine environments. (PhD)	Prof J Pandolfi
Crystal Neligh	JCU	USA	Links between metabolism, growth and performance. (MAppSc)	Dr M McCormick
Jessica Nowicki	JCU	USA	Interactive effects of increased temperature and carbon dioxide concentrations on foraging behaviours of juvenile coral reef fishes. (MAppSc)	Prof P Munday
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
Juan Carlos Ortiz	UQ	Venezuela	Eco-physical dynamics of the Heron Island coral reef. (PhD awarded)	Prof O Hoegh-Guldberg
Juan Pablo D'Olivo	ANU	Mexico	Environmental and climate variability in seawater pH reconstructed from Boron isotopes in corals from the Pacific Ocean. (PhD)	Prof M McCulloch
Allison Paley	JCU, AIMS	USA	Colour polymorphism and thermal resilience in the coral *Acropora millepora* on the Great Barrier Reef. (PhD)	Prof B Willis, Prof M van Oppen, Dr L Bay
Caroline Palmer	JCU, Newcastle University	United Kingdom	Biological mechanisms of coral immunity. (PhD)	Prof B Willis
Christine Pam	JCU	Australia	The global discourse of climate change and small island states. (PhD)	Dr S Foale
F. Joseph Pollock	JCU, AIMS, College of Charleston (SC, USA)	USA	Phylogeny of the coral pathogen *Vibrio coralliilyticus* and the development of a qPCR-based diagnostic assay for its detection. (MSc)	Prof B Willis
Mary Portwood	JCU	USA	Influence of marine protected areas on invertebrate communities. (MAppSc)	Prof G Jones
Eneour Puill-Stephan	JCU, AIMS	France	Chimerism and allorecognition in the broadcast spawning coral *Acropora millepora* on the Great Barrier Reef. (PhD)	Prof B Willis, Prof M van Oppen
Paola G Rachello-Dolmen	UQ	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
Ana Redondo-Rodriguez	UQ	Spain	Implications of climate change for the oceanography of the Great Barrier Reef ecosystem. (PhD awarded)	Prof O Hoegh-Guldberg
Alejandro Reyes	JCU	Colombia	Cellular mechanisms of coral calcification. (PhD awarded)	Prof D Miller
Maria Catalina Reyes-Nivia	UQ	Colombia	The role of climate change on carbonate dissolution processes by microborers. (PhD)	A/Prof S Dove, Dr G Diaz-Pulido, Prof O Hoegh-Guldberg
Claire Reymond	UQ, AIMS	Australia	Historical ecology and experimental biology of foraminifera from the inshore Great Barrier Reef, Australia. (PhD)	Prof J Pandolfi
Zoe Richards	JCU, AIMS	Australia	Rarity in the coral genus *Acropora*: implications for biodiversity conservation. (PhD awarded)	Prof D Miller, Prof B Willis, Prof M van Oppen
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

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Jairo Rivera Posada	JCU	Colombia	Pathogenesis in crown-of-thorns starfish (*Acanthaster planci*). (PhD)	Dr M Pratchett, Prof T Hughes, Dr T Ainsworth
Dominique Roche	ANU	Canada	Bio-physical coupling of predator-prey interactions in coral reef fishes (PhD)	Dr C Fulton
George Roff	UQ	United Kingdom	Historical ecology of coral communities from the inshore Great Barrier Reef, Australia. (PhD awarded)	Prof J Pandolfi, Prof O Hoegh-Guldberg
Agnes Rouchon	JCU	Reunion	Experimental evaluation of olfactory cues in the clownfish *Amphiprion polymnus*. (MAppSc)	Prof G Jones
Pablo Saenz-Agudelo	JCU, University of Perpignan	Colombia	Estimating connectivity in coral reef fish populations: a tool for understanding stability and resilience of marine ecosystems. (PhD)	Prof G Jones, Dr S Planes
Yui Sato	JCU, AIMS	Japan	Ecology and biology of black band disease in the scleractinian coral, *Montipora*. (PhD)	Prof B Willis
Shio Segi	ANU, JCU	Japan	'Pinning our hope on the seas': conservation, resource depletion and livelihood in a Philippine fishing village. (PhD)	Dr S Foale
Francois Seneca	JCU, AIMS, ANU	Monaco	The molecular stress response in the Indo-Pacific model scleractinian coral, *Acropora millepora*. (PhD awarded)	Prof D Miller, Prof M van Oppen
Michael Short	JCU	Australia	The recovery of coral reefs following ship grounding disturbances. (MSc)	Prof B Willis, Prof G Jones
Dylan Simonson	JCU	USA	An alternative method for estimating fishing effort: assessing derelict fishing gear in the Palm Islands, Australia. (MAppSc)	Prof G Russ, Dr D Williamson
Jennifer Smith	JCU	Canada	Influence of patch dynamics on coral reef fishes on the southern Great Barrier Reef. (PhD)	Prof G Jones, Dr M McCormick
Brigitte Sommer	UQ	Australia	Dynamics and conservation of subtropical coral communities of eastern Australia under climate change. (PhD)	Prof J Pandolfi
Jessica Stella	JCU	USA	Climate impacts on coral-associated invertebrates. (PhD)	Prof G Jones, Dr M Pratchett, Prof P Munday
Jill Sutton	ANU	Canada	Southern ocean nutrients and climate change: insights from isotopic and elemental signatures of diatoms and sponges. (PhD)	Prof M McCulloch
Chun Hong Tan	JCU	Malaysia	Environmental controls and evolutionary constraints on growth and reproduction in corals. (PhD)	Dr A Baird, Dr M Pratchett, Dr L Bay
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
Michelle Templeman	JCU	Australia	The role of jellyfish in cycling contaminants in the marine environment and their utility as biomonitors. (PhD)	Prof M Kingsford
Loic Thibaut	JCU, Université Pierre et Marie Curie	France	Resilience in coral reef and model ecosystems. (PhD)	Prof S Connolly, Prof T Hughes
Gergely Torda	JCU, AIMS	Hungary	Assessment of ecological connectivity in corals: implications for their recovery from major perturbations and their potential to adapt to climate change. (PhD)	Prof M van Oppen, Prof B Willis
Melanie Trapon	JCU	France	Variation in population dynamics of reef-building corals along the Great Barrier Reef. (PhD)	Dr M Pratchett, Dr A Baird

Student	University	Country of Origin	Thesis Title	ARC Centre Supervisor/s
Lubna Ukani	JCU	India	Characterisation of DNA methylation systems in *Acropora* and other lower animals. (PhD)	Dr W Leggat
Svetlana Ukolova	JCU	Russia	Characterisation of the Wnt signalling system in *Acropora*. (PhD)	Prof D Miller, Dr W Leggat
Annamieke Van Den Heuvel	UQ	Australia	Characterisations of genes, proteins, and the regulatory pathways involved in nitrogen uptake and the assimilation in *Acropora aspera* and its symbiont *Symbiodinium* sp. (PhD)	A/Prof S Dove, Dr W Leggat, Prof D Yellowlees
Cameron Veal	UQ	Australia	Meso-and micro-scale light fields around shallow coral reefs. (PhD awarded)	Prof O Hoegh-Guldberg, Dr K Anthony, A/Prof S Dove
Ana Cecilia Villacorta Rath	JCU	Peru	Determinants of selective mortality during the early life history of *Spratelloides delicatulus* in the northern Great Barrier Reef. (MSc)	Dr M McCormick, Dr M Meekan
Piero Visconti	JCU, University La Sapienza, Rome, Italy	Italy	Addressing new challenges in dynamic conservation planning. (PhD)	Prof R Pressey, Dr N Ban
Marcelo Visentini Kitahara	JCU, Smithsonian Institute	Brazil	Morphological and molecular systematics of scleractinian corals (Cnidaria, Anthozoa), with emphasis on deep-water species. (PhD)	Prof D Miller
Stefan Walker	JCU	Australia	Phenotypic plasticity across natural-and sexual-selection gradients in a reef fish. (PhD awarded)	Dr M McCormick, Prof P Munday
Patricia Warner	JCU, AIMS	USA	Reproductive ecology and population genetic approaches to assessing connectivity of the brooding coral, *Seriatopora hystrix*. (PhD)	Prof B Willis, Prof M van Oppen
Rebecca Weeks	JCU	United Kingdom	Developing marine protected area networks in the Philippines: reconciling regional-scale planning with community-based implementation. (PhD awarded)	Prof G Russ, Prof G Jones
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
Colin Wen	JCU	Taiwan	Recruitment hotspots and their role in the ecology and management of large exploited predatory fishes. (PhD)	Prof G Jones, Dr M Pratchett, Dr G Almany
Amelia Wenger	JCU	USA	Effects of sedimentation and turbidity on planktivorous fishes. (MSc)	Prof G Jones, Dr M McCormick
Laura Woodings	JCU	Australia	Variation in gene expression, growth, and lipid content between colour morphs of *Acropora millepora*. (MAppSc)	Prof B Willis, Dr L Bay
Erika Woolsey	JCU	USA	Reefs on the edge: coral biogeography and larval ecology in a warming ocean. (PhD)	Dr A Baird
Huibin Zou	JCU	China	The characterisation of selenium containing protein families in coral *Acropora millepora*. (PhD)	Prof D Miller, Dr T Ainsworth

Pip Cohen

MEDIA ARTICLE – Postgrad: The Weekend Australian – 4-5 September 2010

Saving the Seas

Researchers have learned to act local to save coral reefs, reports Cheryl Jones.

Traditional practices such as taboos on the harvesting of some species are among methods being assessed by James Cook University researcher Pip Cohen in a study on the conservation of Solomon Islands fisheries.

Cohen is one of several PhD candidates at the Australian Research Council Centre of Excellence for Coral Reef Studies working at the boundary of the ecological and social sciences. Her work is aimed at helping marine ecosystems in the "Coral Triangle" and the societies that depend on them withstand environmental shocks.

The Coral Triangle is a region of high biodiversity and conservation value spanning the Solomon Islands, Papua New Guinea, East Timor, Indonesia, Malaysia and the Philippines. Coral reefs are big sources of food and income in the developing countries.

Reefs will be hit hard by global warming as rising ocean temperatures increase coral bleaching. They also face "the other carbon dioxide problem". Ocean acidification due to rising atmospheric carbon dioxide levels is expected to send ocean chemistry awry.

Organisms such as coral, which use calcium carbonate in seawater to build their exoskeletons, are expected to be affected, with impacts rippling through marine ecosystems.

Overfishing and coral disease are other threats. And the run-off of nutrients and sediments is a mounting problem in the Solomons as forestry and mining intensify and the islands become increasingly urbanised amid fast population growth, Cohen says.

"There are associated problems and opportunities to do with reef governance and stewardship over resources," she says.

Cohen is investigating the role of locally managed marine areas in the food security of the Solomons. The work, which will have implications for the entire Coral Triangle, is focusing on policy, institutions and governance.

"I'm looking at advances that local communities have made in managing their reefs," she says.

"I'm interested in the interplay of locally driven human impacts and the global drivers that affect the marine system, things that may be beyond the control of local communities on the ground, such as potential impacts of climate change.

"I'm not just interested in the threats that cause biological damage, but also how changes in demography, culture and society can affect the way people manage or use the resources, particularly the fisheries."

Cohen wants to find out the best way to integrate local fisheries management with national conservation policy.

Halfway through her three-year program, she has been interviewing residents, government officials and aid workers to assess the effectiveness of local management initiatives.

"Many governments in the Coral Triangle have recognised that local action with strong community involvement is critical, especially in the conservation of subsistence fisheries," she says.

One strategy has been the reinforcement of traditional Melanesian conservation practices. "In some cases, the harvesting of species is banned," Cohen says. "In others, a certain area is closed or a fishery is closed at certain times."

One success story is the back-up of the traditional management of the slow-growing giant clam with a community education campaign on the life cycle of the species.

Article reproduced with thanks to The Weekend Australian newspaper and Cheryl Jones.

Photo Aurélie Moya

SYMPOSIUM 2010

In October this year, the ARC Centre undertook 3 major events: a 2-day symposium, a public forum and an exhibition at the National Museum of Australia.

Our annual symposium was held in association with the Australian Academy of Science and The Royal Society as part of its 350th anniversary celebrations. Over 150 researchers, students, natural resource managers, policy makers and politicians attended the symposium, *Coral Reefs in a Changing Environment* at the Shine Dome in Canberra on 7th and 8th October. The Canberra symposium incorporated presentations by members of both national academies, the ARC Centre of Excellence for Coral Reef Studies, and other invited presenters.

Speakers at the symposium addressed a number of the issues critical to coral reefs in the 21st century including:

- The past, current and future development of coral reef research in Australia
- Understanding and managing coral reef biodiversity
- Climate change adaptation and acclimatisation
- Ocean acidification
- Coral reef fishes: ecology, conservation and management
- Conservation planning for sustainable futures.

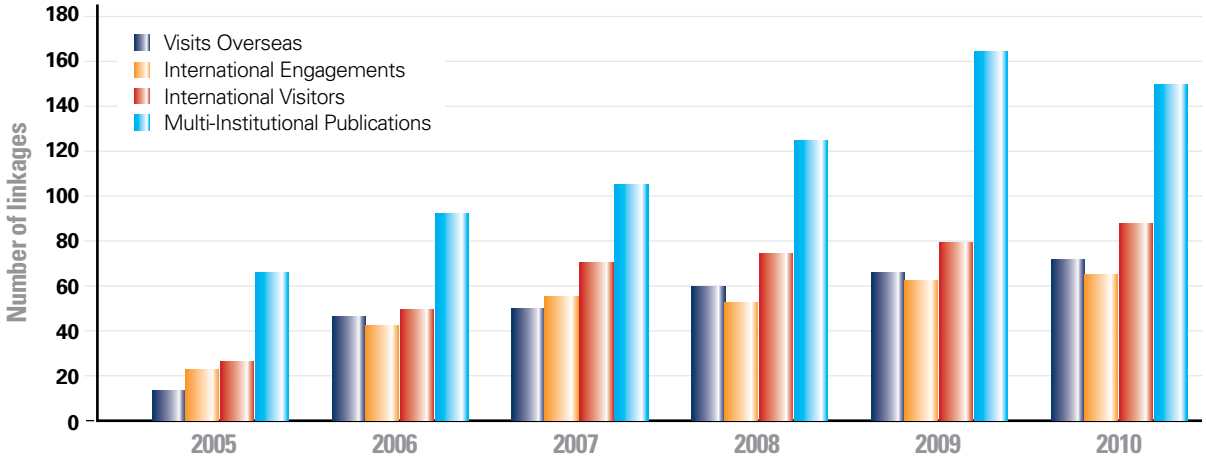
2010 was also the International Year of Biodiversity. Coral reef biodiversity underpins the important functions and services performed by reef ecosystems. Biodiversity is, for instance, critical in sustaining the productivity of the fish stocks which many tropical nations depend on for their food security and future development. The latest science on understanding and managing coral reef biodiversity was a feature of the symposium.

Robyn Williams, presenter of ABC's Science Show, hosted a highly successful Public Forum in the National Museum of Australia on the evening of 7th October. A general audience of about 250 people enjoyed a series of short talks by members of the ARC Centre. They are available online at http://www.coralcoe.org.au/events/symposium2010/public.html. Attendees had the added benefit of entrance to the exhibition *Exploration and Endeavour: The Royal Society of London and the South Seas* celebrating the 350th anniversary of the founding of the Royal Society of London and its early involvement in exploration and science.

Following the Canberra events, a UK-Australia *Frontiers of Science* meeting sponsored by The Royal Society and the Australian Academy of Science was held in Perth, from 9th-12th October. Seventy future leaders in marine science (35 early career researchers from each of Australia and the United Kingdom) presented the latest advances in their fields, learned from each other about research developments in other marine science disciplines, and explored opportunities for collaboration. Two of the Centre's early career researchers, Australian Postdoctoral Fellows Tracy Ainsworth and Natalie Ban, were selected by the Australian Academy of Science to represent Australia on the organising committee for this international meeting. Nick Graham, another Centre-based ARC Australian Postdoctoral Fellow, was selected by the joint organising committee as a speaker in the Macrobiology session on *The effects of ocean acidification on marine ecosystems*.

NATIONAL AND INTERNATIONAL LINKAGES

The Centre's international linkages in 2005 to 2010
All four metrics have shown strong growth



Since its establishment in 2005 there has been a steady growth in the engagement of the Centre's researchers with their international colleagues (see graph). This is exemplified by multi-institutional publications, visits to overseas institutions and visitors to all four nodes of the Centre. The Centre's profile is increasingly attracting overseas postgraduate students who in 2010 come from 42 different countries around the world (see Graduate training, p34). Centre personnel are also actively involved in many international research consortia and activities such as consultancies and end-user engagement. The International Society for Reef Studies has appointed the ARC Centre Director, Terry Hughes, as the Convener of the next International Coral Reef Symposium, which will be held in Australia in 2012 (see p.49).

In 2010, the ARC Centre produced 151 publications with cross-institutional co-authorship (compared to 88 in 2006), involving researchers from 391 institutions in 75 countries. The ARC Centre hosted 91 international visitors from 21 countries, and Centre personnel traveled to 25 countries.

The ARC Centre participated in or hosted 24 international working groups during 2010. This year ARC Centre personnel were members of editorial boards for 13 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 International Council for Science (ICSU).

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

International Programme on Ecosystem Change and Society (PECS)

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

- DIVERSITAS (www.diversitas-international.org) projects such as BioSustainability
- International Geosphere-Biosphere Programme, www.igbp.net/page.php?pid=113) projects such as Analysis, Integration and Modeling of the Earth System
- International Human Dimensions Programme (IHDP, www.ihdp.unu.edu) projects such as Earth System Governance and Urbanization and Global Environmental Change
- Observation programs such of GEOSS (www.earthobservations.org/geoss.shtml)

- Existing global research networks such as UNESCO's Man and Biosphere Programme, the CGIAR network of partners and research projects on agriculture food production and natural resource management.

The Nature Conservancy (TNC)

The Nature Conservancy, the world's largest non-profit conservation Organisation, and the ARC Centre, signed a Memorandum of Understanding in 2008. It cements a growing level of engagement between the two organisations involving projects in numerous countries. The TNC depends on sound scientific knowledge to accomplish its mission, and works closely with the Centre on many fronts. For example in 2010, Future Fellow Glenn Almany was seconded from the Centre's JCU node to TNC's Brisbane office, to work - with TNC researcher Alison Green and her teams in Melanesia - on reef connectivity and the design of networks of coral reef marine protected areas in the Coral Triangle region. The TNC and Program 6 Leader, Bob Pressey, also undertook ongoing collaborations in 2010, focusing on conservation planning and seascape approaches to coastal management in the Bismark Sea and elsewhere in the Coral Triangle.

The Stockholm Resilience Centre

In 2007, the ARC Centre of Excellence for Coral Reef Studies signed a Memorandum of Understanding with the newly established Stockholm Resilience Centre (SRC) to cooperate and collaborate in areas of mutual interest in research. This new international centre advances trans-disciplinary research for governance of social-ecological systems with a special

emphasis on resilience - the ability to deal with change and continue to develop. The SRC is a joint initiative between Stockholm University, the Stockholm Environment Institute and the Beijer International Institute of Ecological Economics at The Royal Swedish Academy of Sciences. The ARC Centre Director, Terry Hughes, is a Fellow and Board member of the Beijer Institute. As part of the agreement, Orjan Bodin, Albert Norström, Magnus Nyström and Per Olsen visited the ARC Centre's node in Townsville in 2010, while Terry Hughes, Natalie Ban, Joshua Cinner, Louisa Evans, Nick Graham and Christina Hicks also worked in Stockholm during the year. The ARC Centre and SRC held a joint working group meeting on trans-boundary governance in the sea, in the Baltic Sea in June. Led by Terry Hughes, the working group included members from the Australian and Swedish Centres, The WorldFish Center in Penang, and six international organisations in the USA, Canada and Europe. Results from an earlier joint working group on adaptive management of fisheries, in Santiago, Chile, were published in 2010 as the cover article in *Proceedings of the National Academy of Sciences.*

The WorldFish Center

Established in 1977 as the International Center for Living Aquatic Resources Management (ICLARM), The WorldFish Center re-named and established its new headquarters in Penang, Malaysia in 2000. WorldFish have regional or country offices in Bangladesh, Cambodia, Egypt, Malawi, Malaysia, the Philippines, Solomon Islands, and Zambia. In 2009, James Cook University and The WorldFish Center established a Memorandum of Understanding to build new collaborative links. In 2010, WorldFish researchers Dedi Adhuri, Eddy Allison, Neil Andrews, and Nireka Weeratunge visited the ARC Centre and engaged in multiple workshops and working groups. David Mills, a senior researcher at WorldFish will be in residence at the ARC Centre from the end of 2010, and Neil Andrew has joined the Centre's Advisory Board. Several of the ARC Centre's researchers, notably Louisa Evans, Bob Pressey and Simon Foale have begun new collaborative projects with WorldFish in the Solomon Islands and elsewhere in the Coral Triangle region.

Overseas Visiting Researchers

In 2010, more than 90 international visitors were hosted by one or more nodes of the ARC Centre, or attended working group meetings organized by the Centre.

Visitors to the Centre of Excellence for Coral Reef Studies in 2010

Visitor	Organisation	Country
Dr Dedi Adhuri	The WorldFish Center	Malaysia
Ms Rebecca Albright	University of Miami	USA
Prof Perry Alino	University of Philippines	Philippines
Dr Edward Allison	The WorldFish Center	Malaysia
Dr Matar Hamed Al-Neyadi	United Arab Emirates Boundary Affairs	United Arab Emirates
Dr Neil Andrew	The WorldFish Center	Malaysia
Dr Derek Armitage	University of Waterloo	Canada
Prof Jelle Atema	Boston University	USA
Mr Scott Atkinson	Conservation International	Indonesia
Ms Rhona Barr	London School of Economics	United Kingdom

Visitor	Organisation	Country
Prof Tom Baumiller	University of Michigan	USA
Dr Örjan Bodin	Stockholm Resilience Centre	Sweden
Dr Bertrand Cazalet	University of Perpignan	France
Prof Allen Chen	Biodiversity Research Centre	Taiwan
Prof Douglas Chivers	University of Saskachewan	Canada
Dr Beatrice Crona	Stockholm Resilience Centre	Sweden
Mr Vasilis Dakos	Wageningen University	Netherlands
Dr Muriel de Boar	University of Amsterdam	Netherlands
Dr Jennifer DeBose	Smithsonian Marine Station, Fort Pierce	USA

Visitor	Organisation	Country
Dr Paolo Domenici	Istituto per l'Ambiente Marino Costiero	Italy
Mr Jonathan Kua	Singapore Economic Development Board	Singapore
Ms Priyanka Jain	Singapore Economic Development Board	Singapore
Ms Emily Peh	Singapore Economic Development Board	Singapore
Dr Maud Ferrari	University of California-Davis	USA
Dr Joana Figueiredo	Foundation for Science and Technology	Portugal
Prof Carl Folke	Beijer Institute of Ecological Economics	Sweden
Dr Samuel Gameda	Agriculture and Agri-Food	Canada
Dr Claire Garrigue	Operation Cetaces	New Caledonia
Prof Gabi Gerlach	Oldenburg University	Germany
Dr Mario Giordano	Università Politecnica delle Marche	Italy
Prof Marion Glaser	Bremen University	Germany
Dr Tatjana Good	Swiss National Science Foundation	Sweden
Dr Chris Gregory	University of Manchester	United Kingdom
Prof Lance Gunderson	Emory University	USA
Prof Hui Huang	South China Sea Institute of Oceanology	China
Ms Chantal Huijbers	Radboud University	Netherlands
Ms Lotte Huisman	University of Amsterdam	Netherlands
Ms Sabine Jessen	Canadian Parks and Wilderness Society and Simon Fraser University	Canada
Dr Jaap Kaandorp	University of Amsterdam	Netherlands
Dr Sally Keith	Bournemouth University	United Kingdom
Prof Chris Langdon	University of Miami	USA
Dr Pierre Leenhardt	University of Perpignan	France
Dr Jen-Sheng Lian	South China Sea Institute of Oceanology	China
Mr Roger Longhorn	Global Spatial Data Infrastructure Association, Legal and Socioeconomic Committee and Information Policy Advisor to EUCC	United Kingdom
Prof Yossi Loya	Tel Aviv University	Israel
Mr Alexander Makini	Solomon Islands Ministry of Environment, Conservation and Meteorology	Solomon Islands
Dr Wayne Mapp	Minister of Research Science and Technology	New Zealand
Ms Paula Marris	Small Steps Big Ideas	United Kingdom
Mr Tia Masolo	Solomon Islands Ministry of Environment, Conservation and Meteorology	Solomon Islands
Dr Mikhail Matz	University of Texas	USA

Visitor	Organisation	Country
Dr Nova Mieszkowska	Marine Biological Association	United Kingdom
Prof David Mouillot	University of Montpellier II	France
Dr Aurélie Moya	European Fellowship from the Marie Curie	France
Dr Albert Norström	Stockholm University	Sweden
Dr Magnus Nyström	Stockholm University	Sweden
Ms Elise Olivieri	New York science fellow	USA
Dr Per Olssen	Stockholm Resilience Centre	Sweden
Dr Henrik Österblom	Stockholm Resilience Centre	Sweden
Dr Lucie Penin	Perpignan University	France
Prof Robert Pomeroy	University of Connecticut	USA
Ms Julie Pouliquen	Biovision 2010 project	France
Dr Kaddour Raissi	French Embassy	France
Dr J Murray Roberts	Heriot-Watt University	United Kingdom
Ms Franciska Rosen	Stockholm Resilience Centre	Sweden
Dr Jodie Rummer	City University of Hong Kong, University of British Columbia	Hong Kong British Columbia
Prof Marten Scheffer	Wageningen University	Netherlands
Dr Stephen Simpson	Bristol University	United Kingdom
Mr Jointly Sisiolo	Ministry of Environment, Conservation and Meteorology	Solomon Islands
Dr Michael Stat	Hawaii Institute of Marine Biology	USA
Prof John Steffensen	University of Copenhagen	Denmark
Dr Michael Steinke	University of Essex	United Kingdom
Prof Bob Steneck	University of Maine	USA
Prof Noreen Tuross	Harvard University	USA
Ms Ingrid van de Leemput	Wageningen University	Netherlands
Dr Egbert van Nes	Wageningen University	Netherlands
Dr Shang-Yin Vanson Liu	National Taiwan University, Institute of Oceanography	Taiwan
Dr Tonny Wagey	University of Pattimura, Ambon and Agency for Marine and Fisheries Research	Indonesia
Prof Robert Warner	University of California	USA
Dr Nireka Weeratunge	The WorldFish Center	Philippines
Dr Gangjian Wei	Guangzhou Institute of Geochemistry	China
Dr Joerg Wiedenmann	University of Southampton	United Kingdom
Dr Marian Wong	Boston University	USA

Photo © Giles Winstanley / pelagicon.com

INTERNATIONAL CORAL REEF SYMPOSIUM 2012

The ARC Centre and James Cook University are proud to **host the 12th International Coral Reef Symposium (ICRS 2012) in Cairns, Australia from 9 – 13 July 2012.** The ICRS is the world's largest and most important coral reef meeting. Held every 4 years, it brings together coral reef scientists, educators, graduate students, resource managers and policy makers. The 12th ICRS is expected to attract approximately 2,500 delegates from 80 countries to the Cairns Convention Centre, an award-winning venue.

ICRS 2012 will provide the international science community with a platform to increase global knowledge and interest in coral reefs, as well as the opportunity to showcase innovative science, and the latest developments in coral reef conservation and management. Activities at ICRS 2012 will include a comprehensive science program, a trade exhibition, and field trips both before and after the Symposium to the Great Barrier Reef, utilising Heron Island, Lizard Island and Orpheus Island Research Stations. Exciting and culturally significant Australian social events and the Symposium banquet will provide additional networking opportunities for delegates to develop collaborations and partnerships to increase international capacity in coral reef research, education and environmental management. ICRS 2012 will attract an extensive international media contingent, and the ARC Centre expects to host some 60 journalists, whose stories will increase awareness of coral reef science across the world.

The ARC Centre established an Executive Committee for the Symposium in 2009 (chaired by the Symposium Convenor, Terry Hughes), linked to sub-committees responsible for fundraising (led by David Yellowlees), and for developing the scientific program (chaired by Terry Done). The committee membership for organising the Symposium includes representatives from 10 countries. We sincerely thank everyone who has volunteered their expertise and support so far.

In 2010, the Symposium's website at www.icrs2012.com was further developed to receive >120 submissions for mini-symposia, and to announce the Symposium's plenary speakers and other developments. This year was also a busy one for fundraising – we are very grateful for major sponsorship received so far from the Australian Institute for Marine Science, the King Abdullah University of Science and Technology, National Oceanic and Atmospheric Administration, and the Queensland Government.

The plenary speakers and their talk titles were announced at the end of 2010:

- **Denis Allemand**
  Centre Scientifique de Monaco
  Coral calcification: from cell physiology to ocean acidification
- **Ove Hoegh-Guldberg**
  University of Queensland
  Coral reefs and global change: where do the solutions lie?
- **Jamaluddin Jompa**
  Hasanuddin University
  Scientific and management challenges in conserving the reefs in the Coral Triangle region
- **Geoff Jones**
  James Cook University
  Marine reserves: importance of local connectivity for fish, fishers and fisheries
- **Peter Kareiva**
  The Nature Conservancy
  Just how fragile are coral reefs? – it depends
- **Jane Lubchenco**
  National Oceanic and Atmospheric Administration
  From science to policy: using science to inform coral reef conservation and management
- **Helene Marsh**
  James Cook University
  Conserving coral reef megafauna
- **Madeleine van Oppen**
  Australian Institute of Marine Science,
  Can old corals learn new tricks?

The Symposia program will be announced before July 2011, when the call for talk and poster abstracts will commence. Registration will be open from July 2011.

For further information on the Symposium, contact:
Eliza Glasson, Conference Coordinator
ARC Centre of Excellence for Coral Reef Studies
James Cook University, Townsville, Qld 4811, Australia
Ph: 61-747-814844
Fax: 61-747-813015
email: eliza.glasson@jcu.edu.au

MEDIA AND PUBLIC OUTREACH

The ARC Centre engages with the wider community through the media and through a diverse array of public awareness activities. As part of our communications strategy, the Centre has developed a robust media presence in consultation with Julian Cribb and Associates, our media advisor.

In 2010, Centre personnel participated in more than 40 public outreach events and programs, reaching audiences locally, nationally and internationally. The Centre held its 2-day national symposium *Coral Reefs in a Changing Environment* in Canberra on 7th – 8th October. Events included a sold-out and highly successful public forum at the National Museum of Australia, hosted by Robyn Williams, presenter of ABC's *Science Show* (see p.45).

The Centre's website caters for multiple audiences, providing information, access to resources, research services, and downloads of research, teaching and educational materials and tools. The site received 5.7 million web hits in 2010, a three-fold increase over the past 3 years. The ARC Centre has also developed a new website for the upcoming 12th International Coral Reef Symposium, which we will convene in Cairns in July 2012 (see p.49). The symposium website was launched in March, and generated 400,000 web hits before the close of the year. We have also branched out into social media to promote the symposium, with information on the symposium also available through Twitter and Facebook.

The Centre's highly popular webinar series continued in 2010 with the addition of 35 new talks under the theme, *Coral Reefs in a Changing Environment*. These videos range from short, highly topical presentations on issues of interest to the general public to longer videos showcasing the latest, leading-edge science for a scientifically informed audience.

Examples of other outreach activities include:

- More than twenty public talks were delivered by Centre researchers in Australia and overseas in 2010. For instance, Philip Munday spoke at the Victoria Museum, Mike Kingsford at the Townsville Maritime Museum, and Sean Connolly at the Southbank Convention Centre, Townsville. Malcolm McCulloch contributed to a public forum *Climate Change and Skepticism*, and presented two other talks as part of the University of Western Australia's public lecture series, while Terry Hughes presented at a community forum on Aland Island, Finland.
- Joshua Cinner and Terry Hughes presented invited talks at the American Association for the Advancement of Science (AAAS) Symposium, in San Diego, which generated significant media coverage, including *Science, Nature* and on the *BBC World Service*.
- Activities aimed at school children were held throughout the year. Among these was an address by Ove Hoegh-Guldberg in January to the National Youth Science Forum in Canberra, while Mariana Fuentes presented her insights on turtle biology to primary school children on Murray Island in the Torres Strait Islands. Centre researchers continue their involvement with the Queensland *Scientists in Schools* program, including Nick Graham who delivered an interactive talk to students of Hermit Park State School, in Townsville during April. As part of the same scheme, Line Bay designed and operated an information booth on reef science for students and parents at Mundingburra State School, in Townsville during September. In April, Mike Kingsford contributed to the Melbourne Careers Expo. In May, Glenn Almany presented to year 11 and 12 students at Papitolai State School, Manus Island, Papua New Guinea. John Pandolfi spoke to students and teachers at Ironside State School, Brisbane in August.
- At the invitation of the *Virginia Chadwick Memorial Foundation*, in August, Janice Lough, Garry Russ and Terry Hughes presented talks to concert-goers at the annual *Australian Festival of Chamber Music*.
- Australian business leaders were briefed by Ove Hoegh-Guldberg at the Great Barrier Reef Foundation's weekend retreat on Lizard Island in May. In June, recreational fishers were presented with research findings by David Williamson in Cairns, Mossman and Tully, while Kenyan fishermen were consulted in a series of community meetings convened by Joshua Cinner in August.
- In Papua New Guinea, Glenn Almany led a series of discussions with local communities that own, manage and depend on coral reefs about the vulnerability of spawning fish aggregations to over-fishing, and the value of marine protected area networks for sustainable fisheries.

Examples of the Centre's 2426 media stories in 2010.

In 2010, the ARC Centre produced 27 media releases, generating 2426 media stories that reached local, national and international audiences. Examples include:

Telegraph.co.uk, *Fishing ban regenerates Australia's Great Barrier Reef*, 22/2/10, L McCook

Sun Herald, *Marine reserves 'a success' – scientists*, 22/2/10, L McCook, J Cinner

ABC News, *Public education seen as key to marine parks' success*, 23/2/10, J Cinner

BBC World Service, *Marine reserves restore fish stocks on the Great Barrier Reef*, 23/2/10, T Hughes

Science Show, *GBR fish respond to fishing ban*, 27/2/10, T Hughes

R&D Magazine, *Ancient corals hold new hope for reefs*, 2/3/10, J Pandolfi

The Sydney Morning Herald, *Sharks, rays like a bit of pampering*, 8/3/10, M Kingsford

Townsville Bulletin, *Climate of scepticism*, 10/4/10, M McCulloch

The Australian, *Triumph in the tropics*, 21/4/10, T Hughes, V Horique

Climate IMC International, *Ocean Acidification is threatening marine ecosystems*, 4/5/10, O Hoegh-Guldberg

Sun Herald, *Report: Oceans' deteriorating health nearing irreversible'*, 4/7/10, O Hoegh-Guldberg

News Track India, *Global warming could lead small fish to engage in 'risky' business*, 5/7/10, P Munday, G Jones

Los Angeles Times, *Oceans' growing carbon dioxide levels may threaten coral reef fish*, 6/7/10, P Munday

7.30 Report, ABC TV, *Reef predictions add impetus to parks plan*, 9/7/10, O Hoegh-Guldberg

Bio Medicine, *Turtle, dugongs 'at risk under climate change'*, 10/7/2010, M Fuentes

Japan Herald, *Oz scientist discovers world's rarest coral in Pacific*, 31/7/10, Z Richards

The Sydney Morning Herald, *Iconic coral species the most vulnerable*, 17/8/10, C Palmer

Reuters, *Soaring temps cause mass coral killing in Indonesia: study*, 17/8/10, A Baird

Science Daily, *How Corals Fight Back*, 19/8/10, C Palmer, B Willis

ABC Online, *Infant coral mortality as high as 90pc: researchers*, 25/8/10, L Penin

Weekend Australian, *Fishing for answers*, 4/9/10, P Cohen

Phys.Org.com, *Call to heal the world's coral reefs,* 8/10/10, T Hughes, P Mumby

China Daily, *Scientists say Asia's corals hit by die-out*, 20/10/10, A Baird

The Australian, *Marine 'dead zones' on the rise*, 1/12/10, O Hoegh-Guldberg, M McCormick

Australian Maritime Digest, *Call to curb reef runoff*, 1/12/10, M McCulloch.

Confronting global threats to marine mega-fauna

in Northern Australia

Juvenile Green Turtle swimming on the reef at Bonegi in the Solomon Islands. Photo courtesy Simon Foale.

The Australian Research Council's (ARC) *Super Science Fellowship* scheme is assisting world-first research that will lead to the identification of priorities for managing the conservation of marine mega-fauna in Northern Australia.

Twenty Australian institutions are currently recruiting the best and brightest young researchers to work on exciting and important science projects under the ARC's *Super Science Fellowship* scheme. These young researchers will play an important role in boosting Australia's research efforts in areas of significant science endeavour. At James Cook University, five new Super Science Fellows will be focused on marine and climate science.

The northern Great Barrier Reef and Torres Strait region is the dugong and turtle "capital of the world". Nowhere else on the planet is there such large populations of these important species, which are globally threatened. The response of these iconic mega-fauna species to climate change and other human influences is the subject of a new ARC *Super Science Fellowship* by Dr Mariana Fuentes in the ARC Centre of Excellence for Coral Reef Studies, headquartered at James Cook University.

Dr Fuentes, who has moved to Australia from Brazil, said that the northern Great Barrier Reef and Torres Strait are home to three turtle populations; the green, hawksbill and the flatback turtles.

"The resilience of these species to climate change is already compromised by reductions in their population sizes due to impacts such as bycatch in nets, hunting, and pollution.

"Now reef managers responsible for stewardship of marine resources face the added challenge of coping with the effects of climate change."

Dr Fuentes' research includes undertaking a risk assessment of how climate change will affect green turtles.

"Sea turtles are particularly vulnerable to climate change because they lay their eggs on beaches that are prone to increasing sea levels, storm surges and cyclonic activity," she said.

"One of the major effects of climate change will be on the gender balance of the turtle population. The sex ratio of hatchlings is sensitive to temperature, and a warmer climate will increase the number of females in the population. There is the potential for low-cost strategies to minimise increasing temperatures at the nesting sites, and my research will focus on developing ways to protect eggs and nesting sites.

"One of the predicted features of climate change is an increase in sea level and the severity of tropical storms in the northern Great Barrier Reef—these have the potential to destroy nesting sites and to adversely influence annual nesting which overlaps with the cyclone season.

"Extreme weather events also damage the seagrass habitats where dugong feed, causing the animals to move away or delay breeding, neither of which is good for the local indigenous peoples," Dr Fuentes said.

Dugongs and turtles have spiritual and social importance to Australia's indigenous peoples. The Super Science Fellowship will build on Dr Fuentes' extensive experience working with

At James Cook University, five new Super Science Fellows will be focused on marine and climate science.

"Sea turtles are particularly vulnerable to climate change because they lay their eggs on beaches that are prone to increasing sea levels, storm surges and cyclonic activity."

– Dr Mariana Fuentes

Dr Fuentes measuring and tagging a green turtle with the help of a Torres Strait Islander on Bramble Cay in the Torres Strait. Photo courtesy Dr Mariana Fuentes.

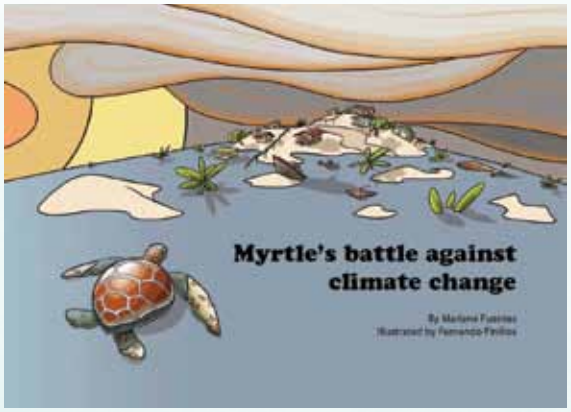
Torres Strait Islanders to help them conserve their culturally important megafauna.

Dr Fuentes recently wrote a book for Torres Strait children *Myrtle's battle against climate change*. Myrtle is, of course, a turtle! This book has been distributed to Grade 7 children in the local school campuses of the Torres Strait where it will be used as an educational tool for teachers.

Director of the ARC Centre of Excellence for Coral Reef Studies, Professor Terry Hughes, said the Centre was delighted to have Dr Fuentes as a Super Science Fellow.

"Her research project will be critical to managing population of mega-fauna in the northern Great Barrier Reef and Torres Strait."

The Fellowship will be undertaken in collaboration with Professors Helene Marsh and Bob Pressey, who have extensive experience with marine megafauna and conservation planning.



The cover to Dr Fuentes' school book on turtles targeted at Torres Strait school children.

The research is a world first, and will lead to the identification of priorities for management for the conservation of turtles and dugongs. In particular, it will develop a vulnerability assessment framework for multiple species to investigate the cumulative impact of climate on sea turtle nesting rookeries and dugong feeding grounds. It will focus on which cost-effective strategies can be used to minimise the impact of climate change.

One strategy to combat increasing temperature at nesting sites might be the erection of shelters on nesting beaches, to shade the sand and ensure the hatching eggs include enough males to sustain the turtle population.

Professor Marsh said this research will help place Australia at the forefront of understanding and responding to the regional scale impacts of global-warming on tropical societies and economies.

"Knowledge-based management of biodiversity will result in environmental, social and economic benefit to Australia and other tropical maritime nations."

This project is one of five Super Science Fellowships awarded to the ARC Centre of Excellence for Coral Reef Studies at James Cook University. The others focus on commercially important reef fishes on the Great Barrier Reef; the capacity of both corals and fish to acclimatise and adapt to climate change; and, using genomic studies to investigate the short and long-term response of corals to climate change.

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RESEARCH *in the national interest – enabling the future*

NATIONAL BENEFIT CASE STUDY 1

Adaptive Management of the Great Barrier Reef

Australia's coral reefs are highly profitable resources. Tourism and fisheries on the Great Barrier Reef World Heritage Area alone contribute $5.9 billion annually to the nation's economy, and provide employment for 63,000 people (www.accesseconomics.com.au/reports/gbrmp.pdf). Globally, the welfare of 500 million people is closely linked to the goods and services provided by coral reef biodiversity. The ARC Centre undertakes cutting edge research and the development of technological tools that are highly relevant for conservation, management and development of coral reef resources world-wide.

Zoning for multiple levels of usage and protection has become the principal mechanism of management of Australia's maritime resources. An improved understanding of marine connectivity (the flux of organisms, genes, nutrients, pollutants etc between locations) and of barriers to dispersal is central to this endeavour. The Great Barrier Reef Marine Park was re-zoned in 2004 to create a new network of marine reserves, providing the opportunity to rigorously test the environmental consequences of these new management approaches. The ARC Centre's research informs tourism and fisheries industries, governments and NGOs, and domestic and overseas development and environmental agencies, on how to manage, sustain and benefit from coral reefs. Managing corals reefs proactively, in anticipation of future uncertainty is a key unifying theme in all of the Centre's research programs. This research places Australia in the forefront of understanding and responding to the regional-scale impacts of overfishing, pollution and global warming on tropical societies and economies.

Many critical management issues are broad-scale phenomena (e.g. depleted fish stocks, habitat fragmentation, global warming) that cannot be fully understood at small scales. The Centre continues to develop innovative approaches to "scaling up" studies, and to making research more relevant for managing sustainable resources. With knowledge of the mechanisms operating at regional to global scales, restoration and effective maintenance of biodiversity across national borders is an achievable goal. For example, knowledge-based management of biodiversity that takes better account of the diversity of ecological roles played by coral reef species will result in environmental, social and economic benefit to Australia and other tropical maritime nations.

A key output in 2010 for several research programs within the ARC Centre has been completion of an invited synthesis paper published in the *Proceedings of the National Academy of Sciences*. This study, led by Laurence McCook, summarizes the ecological, social and economic effects and effectiveness of the marine reserve network on the Great Barrier Reef. A large collaborative effort, with 21 co-authors including 9 ARC Centre scientists, this paper compiled a very broad range of information, including a large amount of new results. The analysis shows that there are more, bigger fish inside marine reserves, with probable benefits for fisheries due to larval spill-over. The zoning provides some protection to groups like sharks and dugongs, although they still urgently need other, complementary protection. Social surveys demonstrate that a large majority of people, including fishers, understand the need to protect the reef environment with measures like this. Finally, but importantly, the paper provides one of the first economic analyses for the GBR marine reserve network, and finds that a healthy Great Barrier Reef generates far more economic benefit to Australia than the cost of protecting it.

Sample 2010 publications:

Babcock, RC, Shears, NT, Alcala, AC, Barrett, NS, Edgar, GJ, Lafferty, KD, McClanahan, TR and Russ, GR (2010). Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proceedings of the National Academy of Sciences* 107(43): 18256-18261.

Edwards, HJ, Elliott, IA, Pressey, RL and Mumby, PJ (2010). Incorporating ontogenetic dispersal, ecological processes and conservation zoning into reserve design. *Biological Conservation* 143(2): 457-470.

Hughes, TP, Graham, NAJ, Jackson, JBC, Mumby, PJ and Steneck, RS (2010). Rising to the challenge of sustaining coral reef resilience. *Trends in Ecology & Evolution* 25(11): 633-642.

McCook, LJ, Ayling, T, Cappo, M, Choat, JH, Evans, RD, De Freitas, DM, Heupel, M, Hughes, TP, Jones, GP, Mapstone, B, Marsh, H, Mills, M, Molloy, FJ, Pitcher, CR, Pressey, RL, Russ, GR, Sutton, S, Sweatman, H, Tobin, R, Wachenfeld, DR and Williamson, DH (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(43): 18278-18285.

Pollnac, R, Christie, P, Cinner, JE, Dalton, T, Daw, TM, Forrester, GE, Graham, NAJ and McClanahan, TR (2010). Marine reserves as linked social-ecological systems. *Proceedings of the National Academy of Sciences* 107(43): 18262-18265.

Visconti, P, Pressey, RL, Segan, DB and Wintle, BA (2010). Conservation planning with dynamic threats: the role of spatial design and priority setting for species' persistence. *Biological Conservation* 143(3): 756-767.

MEDIA ARTICLE – 21 February 2010

Marine Reserves Help Fish Recover

by Erik Stokstad

SAN DIEGO—When fisheries have plummeted or collapsed, one approach to fix the situation is to set up a marine reserve where fishing is banned. The idea is to provide relief to stressed fish stocks by providing safe habitat where fish can reproduce, and then spread out. But banning fishing when a fishing industry is already struggling can be controversial. Yesterday and tomorrow, at two sessions here at the annual meeting of the American Association for the Advancement of Science (which publishes *Science*NOW), researchers presented new data that marine reserves help fish recover.

Jennifer Caselle, a biologist from University of California, Santa Barbara, provided a local example of success. In 2003, the state of California set up a network of 12 marine reserves near Los Angeles and banned fishing in more than 488 square kilometers. By monitoring the area before and after, Caselle and her colleagues found that over 5 years there were 50% more blue rockfish and other species targeted by fishing inside reserves than outside, and that their biomass was 80% higher. There was no change in species that people don't eat, suggesting that fishing restrictions were responsible for the recovery.

Another success story comes from Australia, which created the first large marine reserve in the Great Barrier Reef Marine Park in 1975. After a major die-off of coral, the government decided in 2003 to rezone the park and increased the proportion of no-take areas from less than 5% to 32%. Many fish species quickly doubled in size and numbers. Biomass of coral trout, for example, doubled within 2 years, after fishing was banned on heavily fished reefs. Fears of a collapse of recreational fishing in the park proved unfounded. The researchers, led by Laurence McCook of the Great Barrier Reef Marine Park Authority, in Townsville, found that the number of fishing licenses continued to rise after the rezoning.

But not everything is rosy, especially for large animals such as turtles and dugongs, whose populations continue to drop. "The biggest failure of the Great Barrier Reef park is the decline of megafauna," said co-author Terry Hughes, a coral reef biologist at James Cook University, Townsville. These species migrate in and out of the park boundaries, so there is a proposal to extend the park east into the Coral Sea.

What makes a marine reserve successful? Taking a broad look at 56 marine reserves around the world, Joshua Cinner of James Cook University in Australia examined the social and economic factors. The number of people living near the reserves played a big role in some cases. In the Caribbean, reserves near large populations tended to have less fish relative to unprotected areas than did reserves that were more remote. But the opposite was true in the Western Indian Ocean. It's not clear why, but one reason could be that people tend to move to places with healthy marine reserves so that they can fish nearby.

Another factor related to successful marine reserves was, as expected, compliance with fishing restrictions. And that tended to be associated not just with enforcement, but more complicated social dynamics such as how well people work together and participate in research and management. "In areas where people work together to invest in their resources, we saw less poaching inside marine reserves," Cinner said in a statement. "To get high levels of compliance with reserve rules, managers need to foster the conditions that enable participation in reserve activities, rather than just focusing on patrols."

The results of these and related papers also appear tomorrow in a special issue of the *Proceedings of the National Academy of Sciences*.

From Stokstad, E (2010) Marine Reserves Help Fish Recover. *Science* Now. http://news.sciencemag.org/sciencenow/2010/02/marine-reserves-help-fish-recover.html

Science NOW

Photo Simon Foale

NATIONAL BENEFIT CASE STUDY 2

Climate Change

The impacts of climate change on coral reefs have been documented for over 25 years beginning with the observation that elevated sea water temperatures contribute to the increased incidence of coral bleaching. While the science behind bleaching remains a major focus of research, interest has expanded dramatically to other aspects of climate change on coral reefs and the associated goods and services they provide. The ARC Centre has been at the global forefront of this research.

ISI Essential Science Indicators recently analysed 28,000 publications on Climate Change Research, ranking institutions, scientists and journal articles over the decade ending June 2009. Four of the ARC Centre's researchers figure prominently in this analysis: Ove Hoegh-Guldberg, Terry Hughes, John Pandolfi and Janice Lough. James Cook University, primarily due to members of the ARC Centre, ranked 2nd in the world on the basis of citations per paper. Three of the most cited papers of the past decade were authored by one or more Centre members.

All Research Programs of the ARC Centre include climate change in their research profile. Understanding how coral reefs are responding to the ongoing effects of both climate and other environmental changes is a major objective being addressed by Program 1. A multi-faceted approach is being followed, not only using direct observations from modern reefs but also examining how reefs have evolved and changed over timescales ranging from a few decades and years to many thousands of years. This research is of growing importance because it is now becoming increasingly clear that contemporary changes are occurring at a faster pace than anticipated due to the combination of local environmental impacts and changes in climate and ocean chemistry, the latter from rapidly rising levels of atmospheric CO_2.

Program 2 research has contributed to several key breakthroughs in understanding how coral reefs respond to climate change, and importantly how management can mediate those responses. For example, Philip Munday, Geoff Jones and their graduate students have detailed the effects of ocean acidification on coral reef fish larvae and juveniles, including impairment of their abilities to home in on reef habitat, and to identify and avoid predators.

Climate change is a crucial consideration in management and conservation planning decisions. Therefore, a major focus of Program 6 is investigating options for incorporating climate change into conservation planning research. For example, future management actions need to anticipate dynamic threats such as species migrations and climate shocks associated with climate change (Visconti et al. 2010).

Programs 5 and 7 have contributed significantly to our understanding of the socio-economic consequences of climate change on coral reefs. In dealing with these issues, a more productive way forward is to harness new theoretical insights and empirical information on why some reefs degrade and others do not (Hughes et al. 2010). This approach contributes to our understanding of how to avoid undesirable phase-shifts, and how to reverse them when they occur resulting in the reform of scientific approaches, policies, governance structures and coral reef management.

Achieving a deeper understanding of the impact of climate change on corals at a physiological and molecular level is also central to Programs 4 and 8. For example, the incidence of coral diseases has been shown to increase as a result of climate change. Bette Willis and her group pioneered this research on the Great Barrier Reef and have shown for the first time that base-line immunity underlies the vulnerability to thermal bleaching and disease. On a different tack, research undertaken by Ove Hoegh-Guldberg and colleagues has demonstrated that ocean acidification, resulting from higher atmospheric CO_2 concentrations, affects photorespiration and the metabolic productivity of corals.

The ARC Centre's expertise in climate change was recognised with the award of 9 ARC Super Science Fellowships to the Centre's nodes at James Cook University (5), the University of Queensland (2) and the University of Western Australia (2). This will ensure that climate change and its effect on coral reefs will continue to be a major focus for research within the ARC Centre.

Sample 2010 publications:

Munday, PL, Dixson, DL, McCormick, MI, Meekan, M, Ferrari, MCO and Chivers, DP (2010). Replenishment of fish populations is threatened by ocean acidification. *Proceedings of the National Academy of Sciences* 107(29): 12930-12934.

Hoegh-Guldberg, O and Bruno, JF (2010). The impact of climate change on the world's marine ecosystems. *Science* 328(5985): 1523-1528.

Dixson, DL, Munday, PL and Jones, GP (2010). Ocean acidification disrupts the innate ability of fish to detect predator olfactory cues. *Ecology Letters* 13(1): 68-75.

Hughes, TP, Graham, NAJ, Jackson, JBC, Mumby, PJ and Steneck, RS (2010). Rising to the challenge of sustaining coral reef resilience. *Trends in Ecology & Evolution* 25(11): 633-642.

Palmer, CV, Bythell, JC and Willis, BL (2010). Levels of immunity parameters underpin bleaching and disease susceptibility of reef corals. *FASEB Journal* 24(6): 1935-1946.

Visconti, P, Pressey, RL, Segan, DB and Wintle, BA (2010). Conservation planning with dynamic threats: the role of spatial design and priority setting for species' persistence. *Biological Conservation* 143(3): 756-767.

MEDIA RELEASE – 9 October 2010

Call to curb reef run-off

A leading earth scientist is calling for intensified efforts to curb the runoff of sediment and nutrients onto Australia's Great Barrier Reef and other coral assets, to protect them through a period of unavoidable climate change.

Professor Malcolm McCulloch of the ARC Centre of Excellence for Coral Reef Studies and University of Western Australia, says that while Australia's efforts to limit human impacts on the GBR have been outstanding on a world scale, recent scientific measurements indicate large amounts of sediment and nutrients from the land are still being dumped on inshore reefs.

"Climate change is inexorable, due to the large amount of CO_2 we have already loaded into the atmosphere – so the one area we can really take effective action to try to protect our coral reefs from the effects of global warming is in how we manage the land to influence water quality over the reef," he will tell a major international scientific symposium in Canberra tomorrow.

Professor McCulloch says the GBR is now far better protected than at any previous time in Australian history – but water quality measurements indicate there is still a way to go in controlling the impact of terrestrial runoff on the reef, especially its inshore corals.

"We also need to take account of the fact that climate change means heavier dumps of rain in the catchments that border the GBR and unless our land and river management, farming methods and engineering works are first class, these more intense rain events will lead to poorer water quality inshore and in the GBR lagoon," he explains.

Prof. McCulloch said that while much had been done to control runoff, scientific measurements of water quality were not showing any significant decline in sediment or nutrient loads reaching the GBR – and this was a sign that land management had to go much further.

"It has been well established by scientists at the ARC Centre that the resilience of GBR corals can be improved by reducing the impacts of human activity, such as runoff and overfishing – and the corals are going to need all the resilience they can get, to cope with the impacts of higher ocean temperatures and acidification.

"There is not much we can do in the short run to reverse either global warming or ocean acidification: one thing we can do something really positive about is water quality."

Professor McCulloch says there is a need for everyone who lives in the GBR's catchments to think about what they do to the soils and waterways, and to consciously try to reduce to load of material entering the GBR lagoon.

"It's not only about reducing farm and grazing runoff and soil loss – it's also about how we engineer our roads, stormwater drains, waterways, buildings and urban areas. It's about thinking of the downstream consequences whenever we dig up or move soil for whatever reason – and understanding the negative effects these can have on the corals of the reef."

"If communities up and down the length of the GBR were to compete with one another to radically improve runoff and water quality locally, it will give the GBR a much better fighting chance of coping with climate change," Prof. McCulloch says.

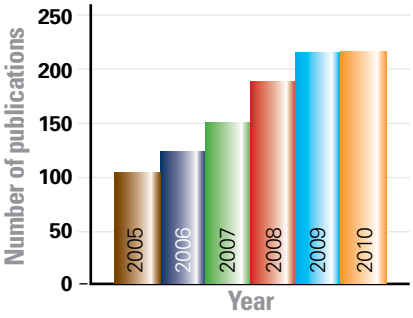
Photo Simon Foale

PUBLICATIONS

The ARC Centre of Excellence for Coral Reef Studies produced 229 publications in 2010, continuing the growth in output exhibited since 2005. According to *ISI Web of Science*, the ARC Centre is the first-ranked institution in the world for both the number of journal publications and citations in coral reef science. A Thomson Reuters ScienceWatch analysis of climate change research from 1999-2009 (http://sciencewatch.com/ana/st/climate/authors/) also indicates that James Cook University is ranked second globally for citations per paper in climate change science (see p.56, Climate change case study).

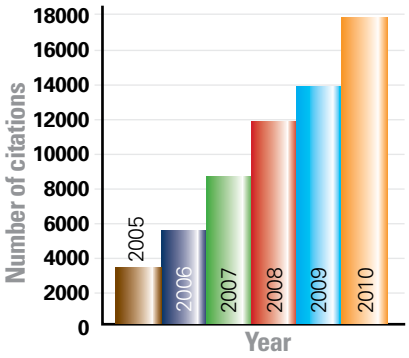
The average Impact Factor for all 197 journal articles published in 2010 was 4.12. Fifty-eight of the 2010 articles are in journals with Impact Factors greater than four, including top-tier journals such as *Science, Proceedings of the National Academy of Sciences* and *Current Biology*. Research outputs in 2010 were published in a total of 80 journals, illustrating the broad focus of the Centre's research programs.

Number of peer-reviewed publications by members of the ARC Centre of Excellence each year for 2005-2010



Two high-profile clusters of outputs in 2010, involved a dozen Centre members: Centre Fellow Maria Dornelas was co-editor with Anne Magurran (University of St. Andrews) of a 187-page Special Issue of the *Philosophical Transactions of the Royal Society (B)*, volume 365, entitled *Biological diversity in a changing world*. The Centre also contributed three papers to a 74–page Special Feature section in *Proceedings of the National Academy of Sciences*, volume 107, entitled *Marine Reserves* (see p.54, GBR National Benefit Case Study).

Summed citations to members of the ARC Centre of Excellence each year for 2005-2010



Citations of the Centre's publications continue to grow, increasing nearly 3-fold since 2005. Twenty-six researchers were each cited >200 times in 2010, 11 of the Centre members had >500 citations, and 3 had >1000 citations in the 12-month reporting period.

League table achievements in 2010 include:

- Four Program Leaders in the Centre are recognized by ISI as *Highly Cited Researchers;* in Earth Sciences (Malcolm McCulloch), Ecology/Environment (Bob Pressey, Terry Hughes), and now also in Plant and Animal Science (Ove Hoegh-Guldberg).
- The *Faculty of 1000 Biology* highlighted ten of the ARC Centre's publications for review in 2010.
- *ISI Essential Science Indicators* identified one of the Centre's recent *Nature* articles, on planetary boundaries and earth system dynamics, as a 2010 *Hot Paper*. The paper is led by Johan Rockstrom from the Stockholm Resilience Centre, and co-authored by Terry Hughes, Carl Folke and 26 other colleagues from around the world.
- *ISI Essential Science Indicators* identified five *Research Fronts* in 2010 that highlight the Centre's research. A Research Front is a group of Highly Cited papers, referred to as core papers, in an emerging topic defined by a cluster analysis. Twenty core papers in these *Research Fronts,* including eleven in *Science, Nature* and *PNAS,* were co-authored by ARC Centre members Glenn Almany, Ken Anthony, David Bellwood, Joshua Cinner, Sophie Dove, Carl Folke, Nick Graham, Ove Hoegh-Guldberg, Terry Hughes, Geoff Jones, Mike Kingsford, Laurence McCook, Mark McCormick, Peter Mumby, Serge Planes, Morgan Pratchett, Bob Pressey, Robert Steneck, Shaun Wilson, and Bette Willis. The five Research Fronts are:
  - Global biodiversity conservation
  - Ocean acidification
  - Connectivity and larval dispersal
  - Coral bleaching and disease
  - Social-ecological resilience and adaptive capacity.

PUBLICATIONS LIST

Book Sections (8)

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RECOGNITION OF EXCELLENCE BY CENTRE MEMBERS

2010 has again been marked by the recognition of many of ARC Centre members' achievements. In particular, we were delighted to see that two of our Program Leaders were elected members of prestigious national academies. Malcolm McCulloch was elected Fellow of the Royal Society, adding to his membership of a number of other prestigious societies. Bob Pressey was elected a Fellow of the Australian Academy of Science for his contributions to the field of systematic conservation planning, including the dynamics of biodiversity and human activities.

Other examples of awards and peer-recognition include:

- Peter Mumby was awarded a Pew Fellowship in Marine Conservation. These are awarded to outstanding scientists who are working to preserve and protect the world's oceans and marine species. He was also the recipient of the Marsh Award for Marine and Freshwater Conservation of the Zoological Society of London for contributions of fundamental science and its application to conservation in marine and/or freshwater ecosystems.
- Nick Graham was elected a Fellow of the Linnean Society of London, the leading society in the United Kingdom for studies of taxonomy and biodiversity.
- Joshua Cinner was the subject of a "career profile" in the prestigious journal *Science* (http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2010_06_18/caredit.a1000061)
- Tracy Ainsworth and Line Bay were awarded Australian Academy of Science Travelling Fellowships while Tracy also received a *Journal of Experimental Biology* Travel Fellowship to support her collaboration with Ruth Gates in Hawaii.
- Several research papers from the Centre were recognised, including:
  - Garry Russ and his long-time collaborator Angel Alcala received the Philippines Commission on Higher Education Award for the best paper in the Natural Science Category for "No-take marine reserves and reef fisheries management in the Philippines: a new people power revolution". The award was made at the Republica Symposium in Quezon City, The Philippines, in May.
  - The Editors, staff and Editorial Board of *Coral Reefs* announced that the winner of the best paper published in 2009 was awarded to SK Wilson, AM Dolman, AJ Cheal, MJ Emslie, MS Pratchett, and HPA Sweatman for the paper: "Maintenance of fish diversity on disturbed coral reefs" published in *Coral Reefs* 28: 3 - 14 (2009).
  - The 2010 paper by Philip Munday and collaborators in the *Proceedings of the National Academy of Sciences* entitled "Replenishment of fish populations is threatened by ocean acidification" was judged as "exceptional new research" by the Faculty of 1000 and was also the Editor's Choice in *Science* and reported in Research Highlights in *Nature*.
- At James Cook University, several of the ARC Centre's researchers were recognised within the University:
  - Chris Fulton from the Australian National University node was recognised in James Cook University's 40th Anniversary celebrations with an "Outstanding Early Career Alumni Award" for his achievements since graduation.
  - Joshua Cinner was the recipient of the 2010 JCU Award for Excellence in the category of Research and Supervision.
  - Mark McCormick was awarded the Supervisor of the Year Award 2010 in the Established Supervisory Category while Bill Leggat was successful in the Early Career Supervisor Category.
  - Sylvain Forêt was the winner of the People's Choice Award in the "My Research in 3 Minutes" competition during the annual Celebrating Research @JCU in September.

PERFORMANCE MEASURES

Research findings

Measure	Target 2010	Outcome 2010
Number of publications (p.58)	175	229
Publications in journals with an impact factor > 4	40	58
Number of citations (p.58)	10000	17497
Invitations to provide plenary addresses at international conferences	30	41
Invitations to provide review articles	36	45
Number and nature of commentaries about the Centre's achievements	1200	2426
Awards, prizes or recognition (p.66)	20	28

Research training and professional education

Measure	Target 2010	Outcome 2010
Number of postgraduates enrolled (p.34)	130 over 5 years	164 enrolled in 2010 266 enrolled over 5 years
Number of postgraduate completions	80 over 5 years	42 in 2010 123 completions over 5 years
Number of Honours students	60 over 5 years	28 enrolled in 2010 68 enrolled over 5 years
Number of professional workshops	16	21
Participation in professional workshops	20	46
Number and level of graduate student courses and workshops in the priority area(s)	10	28

International, national and regional links and networks

Measure	Target 2010	Outcome 2010
Number of international visitors (p.46)	70	91
Number of national and international working groups	16	61 researcher participations in 24 working groups
Number of visits to overseas laboratories and research facilities	55	67

Membership of national and international boards and advisory committees	45	61
Number of cross-institutional publications	95	151
Number of multi-institutional supervisory arrangements of graduate students	50	67
Number of internationally funded students **Number of consultancies and contract research**	50 over 5 years 10	65 28
Number of government, industry and business briefings	50	82
Number of Centre trained/ing personnel in knowledge/technology transfer and commercialisation	6	7
Public awareness programs Website hits Public awareness presentations	 2.5 million 20	 5.7 million 45

Organisational support

Measure	Target 2010	Outcome 2010
Annual cash contributions from collaborating organisations	$1.5m	$2.7m
Annual in-kind contributions from collaborating organisations	$3.4m	$6.4m
Number of new organisations recruited to or involved in the Centre	6	7
Level and quality of infrastructure provided to the Centre	$1.12m	$1.16m
Annual cash contributions from other organisations	$0.50m	$2.3m

Governance

Measure	Target 2010	Outcome 2010
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 p. 6
Frequency and effectiveness of Advisory Board meetings	2 Centre Advisory Board meetings p.a. 4 Scientific Management Committee meetings p.a.	See p. 6
Quality of the Centre strategic plan	The Centre's progress against the plan will be formally reported to the Advisory Board and be renewed in light of outcomes	Strategic Plan reviewed and endorsed by the Centre Advisory Board. Ongoing performance against plan reviewed at Scientific Management Committee meetings

Effectiveness of arrangements to manage Centre nodes	Meetings of the Scientific Management Committee where each node and program is represented	All research programs represented at Scientific Management Committee meetings
	Monthly nodal leader phone or video conferences	Regular nodal and program leader meetings held
	Annual rotational visits to the nodes	There were 21 cross-nodal visits in 2010. Additionally, members travelled to Canberra for the Centre's annual meeting and symposium
	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	67
	Number of multi-nodal seminar and discussion groups	39
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 2010	Outcome 2010
Measures of expansion of Australia's capability in the priority area(s)	150% increase on 2004 benchmark by 2010	2.6 times the number of publications in the 2004 benchmark 5 times the number of citations in the 2004 benchmark
	50 briefings to government, business and industry groups	82 briefings
	17 cross-nodal publications	40 cross-nodal publications
	95 cross-institutional publications	151 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	27 media releases See pp. 54–57

FINANCIAL STATEMENT

ARC Centre of Excellence for Coral Reef Studies

Statement of Operating Income and Expenditure for year ended 31 December 2010

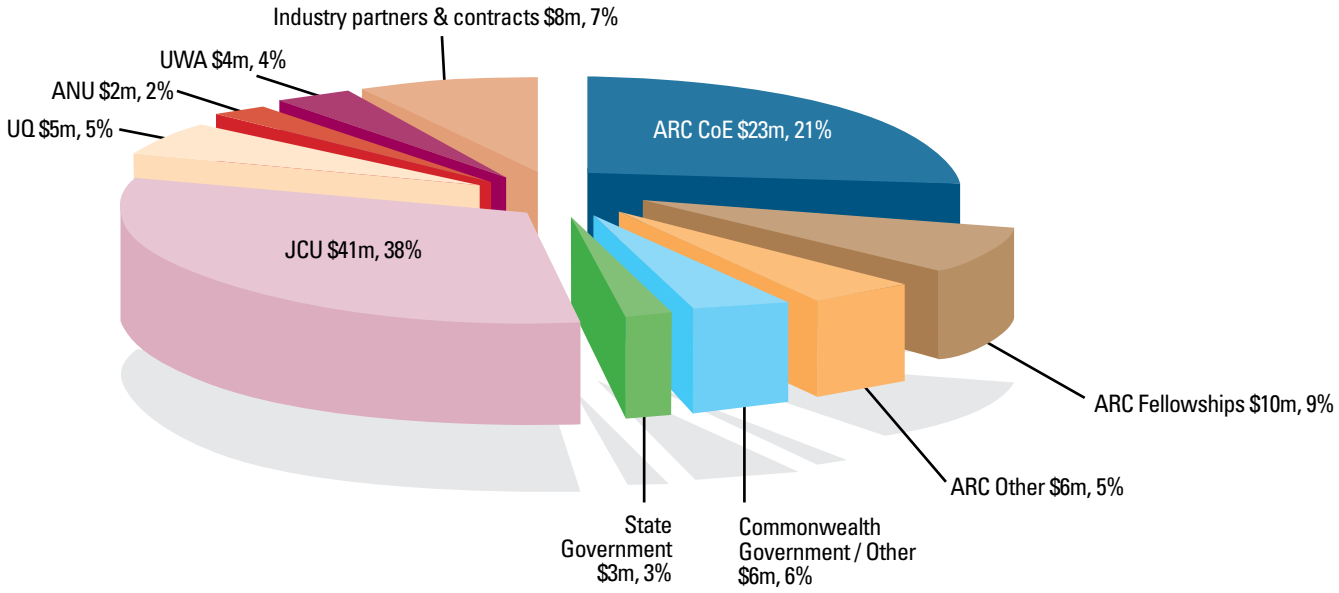
INCOME	2009 $	2010 $
ARC Centre Grant	$2,651,090	$2,811,038
ARC Fellowships	932,744	1,376,341
ARC Discovery	71,418	166,481
ARC Linkages	150,000	155,665
ARC Networks	30,000	
Host Institutions cash support	2,266,972	2,673,902
State Government	119,965	244,000
Commonwealth Government other grants	408,423	436,334
International and other contracts	571,923	570,480
Total Income	**$7,202,535**	**$8,434,241**

EXPENDITURE		
Salaries	3,829,430	4,379,076
Equipment	526,204	429,470
Travel	1,236,948	1,305,139
Research maintenance and consumables	1,087,630	1,035,491
Scholarships	153,077	92,375
Public outreach and administration	171,776	176,482
TOTAL EXPENDITURE	**$7,005,065**	**$7,418,034**
SURPLUS (DEFICIT)	**$197,470**	**$1,016,207**

Financial Status

As at 31 December 2010, the total cash and in-kind income budget for the ARC Centre of Excellence for 1 July 2005 to 31 December 2013 totals $108m, more than triple the 2005 funding outlook. The chart below indicates the budgeted level of income from the various funding sources.

ARC Centre of Excellence cash and in-kind funding outlook 2005-2013



ACKNOWLEDGEMENTS

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- Australian Institute of Nuclear Science and Engineering Inc (AINSE), New South Wales
- American-Australian Association, USA
- ARC Research Network for Earth System Science (ARCNESS), New South Wales
- Australian Academy of Science, Canberra
- Australian Genome Research Facility (AGRF), Brisbane
- Australian Institute of Marine Science, Townsville
- Australian Coral Reef Society, Australia
- Australian Marine Mammal Centre, Hobart
- Australian Museum, Sydney
- Beijer Institute for Ecological Economics, Sweden
- Centre National de la Recherche Scientifique, France
- Cairns Marine
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) Flagship
- Collaboration Fund, Australia
- Conservation International, USA
- Coral Reef Initiatives for the Pacific (CRISP), New Calendonia
- Department of Foreign Affairs and International Trade, Canada
- Commonwealth Department of Sustainability, Environment, Water, Population and Communities
- Deutsche Forschungsgemeinschaft Excellence Cluster, University of Kiel, Germany
- European Commission, Brussels
- Fisheries Research and Development Corporation, Canberra
- Fundação para a Ciência e a Tecnologia (FCT), Portugal
- GHD Pty Ltd, Australia
- Government of the Republic of Indonesia
- Great Barrier Reef Foundation, Brisbane
- Great Barrier Reef Marine Park Authority, Townsville
- Ian Potter Foundation, Melbourne
- IDP Education Australia
- Illumina Pty Ltd, Australia
- King Abdullah University of Science and Technology, Saudi Arabia
- Lizard Island Research Station, Queensland
- Marine and Tropical Sciences Research Facility (MTSRF), Canberra
- Marine Conservation Biology Institute (MCBI), USA
- National Climate Change Adaptation Research Facility (NCCARF), Brisbane
- National Coral Reef Institute, USA
- National Oceanic and Atmospheric Administration, USA
- National Parks Association of Queensland
- Project AWARE Foundation, Australia
- Queensland Department of the Premier and Cabinet
- Queensland Department of Employment, Economic Development & Innovation
- Queensland Department of Environment and Resource Management
- Reef Catchments Mackay Whitsunday Inc, Queensland
- Resilience Alliance, Sweden
- Royal Swedish Academy of Science, Sweden
- Sea World, Gold Coast
- Seychelles Fishing Authority
- Smithsonian Marine Network, USA
- Stockholm Resilience Centre, Sweden
- The CASS Foundation, Melbourne
- The Computational Biology Group, University of Amsterdam
- The Nature Conservancy, USA
- Torres Strait Regional Authority, Queensland
- University of Delaware, USA
- University of Maine, USA
- University of Montpellier 2, Sciences and Technology, France
- University of Perpignan, France
- Western Australian Department of Environment and Conservation
- Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, USA
- Wildlife Preservation Society of Australia, Sydney
- World Bank Global Environment Facility Coral Reef Targeted Research Program, USA
- World Wide Fund for Nature, Australia
- World Wildlife Fund (International), USA

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