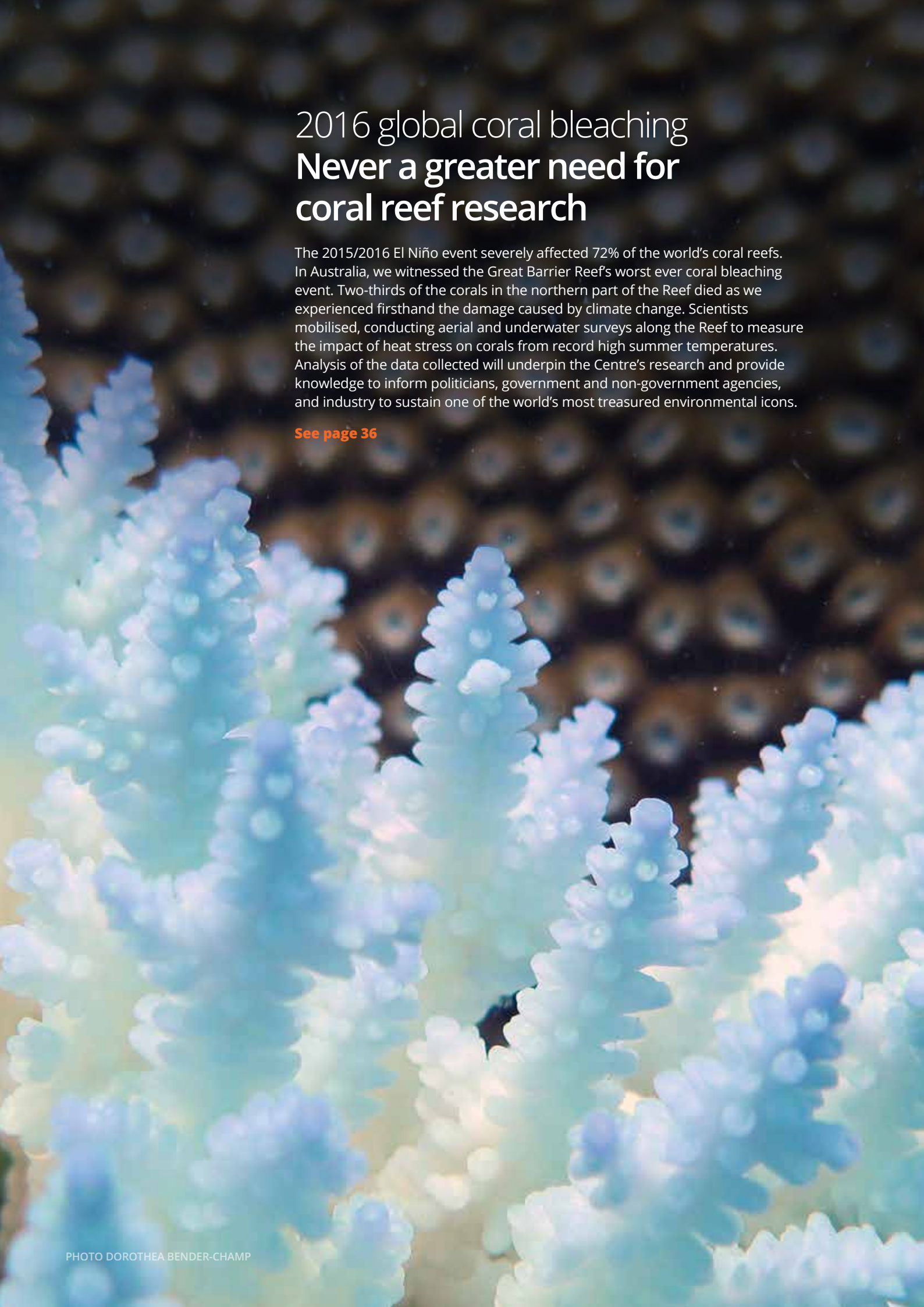
2016 global coral bleaching
Never a greater need for coral reef research

ARC CENTRE OF EXCELLENCE
Coral Reef Studies

ANNUAL REPORT **2016**



2016 global coral bleaching
Never a greater need for coral reef research

The 2015/2016 El Niño event severely affected 72% of the world's coral reefs. In Australia, we witnessed the Great Barrier Reef's worst ever coral bleaching event. Two-thirds of the corals in the northern part of the Reef died as we experienced firsthand the damage caused by climate change. Scientists mobilised, conducting aerial and underwater surveys along the Reef to measure the impact of heat stress on corals from record high summer temperatures. Analysis of the data collected will underpin the Centre's research and provide knowledge to inform politicians, government and non-government agencies, and industry to sustain one of the world's most treasured environmental icons.

See page 36

PHOTO DOROTHEA BENDER-CHAMP

ARC CENTRE OF EXCELLENCE
Coral Reef Studies

ANNUAL REPORT 2016

CONTENTS

At the ARC Centre of Excellence for Coral Reef Studies we acknowledge the Australian Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the Traditional Owners of the lands and sea where we conduct our business. We pay our respects to ancestors and Elders, past, present and future. The ARC Centre of Excellence for Coral Reef Studies is committed to honouring Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to society.

Cover Photo; Johanna Leonhardt

PHOTO JODIE RUMMER

VISION

Scientific knowledge that fosters sustainable use, adaptive governance, and effective management of the world's coral reefs to enhance human wellbeing.

MISSION

To lead the global research effort in the provision of scientific knowledge necessary for sustaining the ecosystem goods and services of the world's coral reefs during a period of unprecedented environmental change.

AIMS

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

RESEARCH
Produce research that is world-best, innovative, collaborative, multi-disciplinary and highly relevant to coral reef management, adaptive governance and policy development.

RESEARCH TRAINING AND PROFESSIONAL EDUCATION
Build human capacity and expertise in coral reef science worldwide.

NATIONAL AND INTERNATIONAL LINKAGES
Create a global hub for integrated coral reef research collaborations.

IMPACTS AND END-USER ENGAGEMENT
Exchange and transfer knowledge, technologies and research outcomes with end-users and partners.

GOVERNANCE
Continuously evolve Centre management to ensure it is co-operative, multi-institutional and communicative.

OVERVIEW

The ARC Centre of Excellence for Coral Reef Studies commenced operations in 2014 following the award of $28million from the Australian Research Council to fund the Centre for seven years. This is the Centre's second successful round of ARC Centre of Excellence funding, following its initial operations from 2005 to 2013. Headquartered at James Cook University, the ARC Centre additional nodes are the Australian National University (ANU), the University of Queensland (UQ) and the University of Western Australia (UWA). Our national and international partner institutions are the Australian Institute of Marine Science (AIMS), the Center for Ocean Solutions at Stanford University (COS, USA), Centre National de la Recherche Scientifique (CNRS, France), the Great Barrier Reef Marine Park Authority (GBRMPA), the International Union for Conservation of Nature (IUCN, Switzerland), and WorldFish (Malaysia). In 2016, the Centre has collaborative links to 280 institutions in 60 countries.

The major objective of the Centre is to achieve a better understanding of the science, both social and natural, that underpins the dynamic changes currently occurring in coral reefs worldwide. This research is both multifaceted and transdisciplinary. Improving the governance and management of natural systems and enhancing our capacity to sustain both human and natural capital is an overarching goal of our research.

DIRECTOR'S REPORT

Welcome to the 2016 annual report of the *Australian Research Council (ARC) Centre of Excellence for Coral Reef Studies*.

In 2016, coral bleaching due to global warming, affected most coral reef systems in the southern hemisphere. Australia was one of the worst affected regions, and the science and reef management community responded on an unprecedented scale. In November 2015, I convened the National Coral Bleaching Taskforce, to co-ordinate the research effort of 11 institutions and agencies in anticipation of a major bleaching event in March/April 2016. The research institutions involved in the Taskforce include all the nodes of our ARC Centre, the Australian Institute of Marine Science (AIMS), Great Barrier Reef Marine Park Authority (GBRMPA), National Oceanic and Atmospheric Administration (NOAA, USA), CSIRO, Torres Strait Regional Authority, and the Western Australian Department of Parks and Wildlife. In this report, we summarise this unprecedented response as a case study of national significance, reported on page 36. The first major results from this research will be published as the cover article in the 16th March, 2017 issue of *Nature*.

At the time of writing, in early March 2017, Centre of Excellence researchers and our collaborators are re-mobilising to respond to a new bout of coral bleaching, for the second year in a row. The ARC Centre will once more be undertaking rigorous aerial and underwater surveys of the Great Barrier Reef and Torres Strait. This information will be vital for the responses of agencies and governments responsible for reef management, and for the industries that depend on coral reefs.

During the year, the Centre has undertaken fieldwork in 25 tropical countries, particularly in Australia, the Coral Triangle (Philippines, Indonesia, Malaysia, Papua New Guinea, Timor-Leste, Solomon Islands), Fiji, French Polynesia, Micronesia, Saudi Arabia, Kenya, the Maldives, the Seychelles, Mexico, and parts of the Caribbean. Coral reefs and tropical fisheries continued to be a spotlight in 2016. Centre researchers provided hundreds of government and industry briefings, capacity-building workshops and consultancies to governments, management agencies, non-government organisations (NGOs), industry groups and businesses. The impact of these activities is international, with researchers informing policy and practice around the world (pp6–7).

In June 2016, the ARC Centre was the largest single contributor to the quadrennial International Coral Reef Symposium held in Hawaii, with researchers and students giving 148 presentations including 2 plenaries. In addition, three of the five panellists in the final day plenary discussion on climate change and its impacts on coral reefs were Centre research leaders. The Centre's three research Program summaries on pp13–34 provide an overview of our activities throughout 2016.

The Centre's researchers produced a record breaking 328 publications in 2016, including 315 peer-reviewed journal articles. More than one third of these articles were published in journals with an Impact Factor greater than 4 and twenty-six articles appeared in prestige journals such as *Nature*, *Science* and *Trends in Ecology and Evolution*. Our co-authors this year come from 280 institutions in 60 countries, reflecting the ARC Centre's continuously expanding international collaborative network.

In 2016, the Centre's membership comprised 95 researchers (including 56 Research Fellows), and 206 research students from 44 countries (p45). We farewelled two of our long-standing and inspirational colleagues who retired in 2016, Professor Bette Willis (p65) and Professor David Yellowlees (p66) and wish them every joy in their retirement. Centre researchers were once again recognised for the excellence of their achievements (p8) and the Centre continued its commitment to promoting gender equity in research leadership (p40). We welcomed Dr Alana Grech as the Centre's new Assistant Director and Dr Mia Hoogenboom as the new co-leader of Program 3.

I'd like to express my sincere gratitude to our many friends around the world for their contributions to an outstanding year, and to the Centre's Advisory Board, our research collaborators, partners and end-users from many institutions in Australia and overseas. I am especially grateful to our Chief Operations Officer Jenny Lappin, Assistant Directors Alana Grech and David Yellowlees, and our fantastic operational team, Olga Bazaka, Vivian Doherty, Kylie Simmonds, Janet Swanson, Karen van Staden and Hayley Ware for their commitment to enabling the Centre's outstanding research effort.

Terry Hughes
Director

From: Emily

Sent: Thursday, 31 March 2016

To: Hughes, Terry

Subject: Coral Bleaching :(Please Read)

Hello, my name is Emily and I'm 13. When I grow up I want to be a marine biologist!

And so when my mom went and showed me the article about the Coral bleaching from the Great Barrier Reef, I was sad 😩

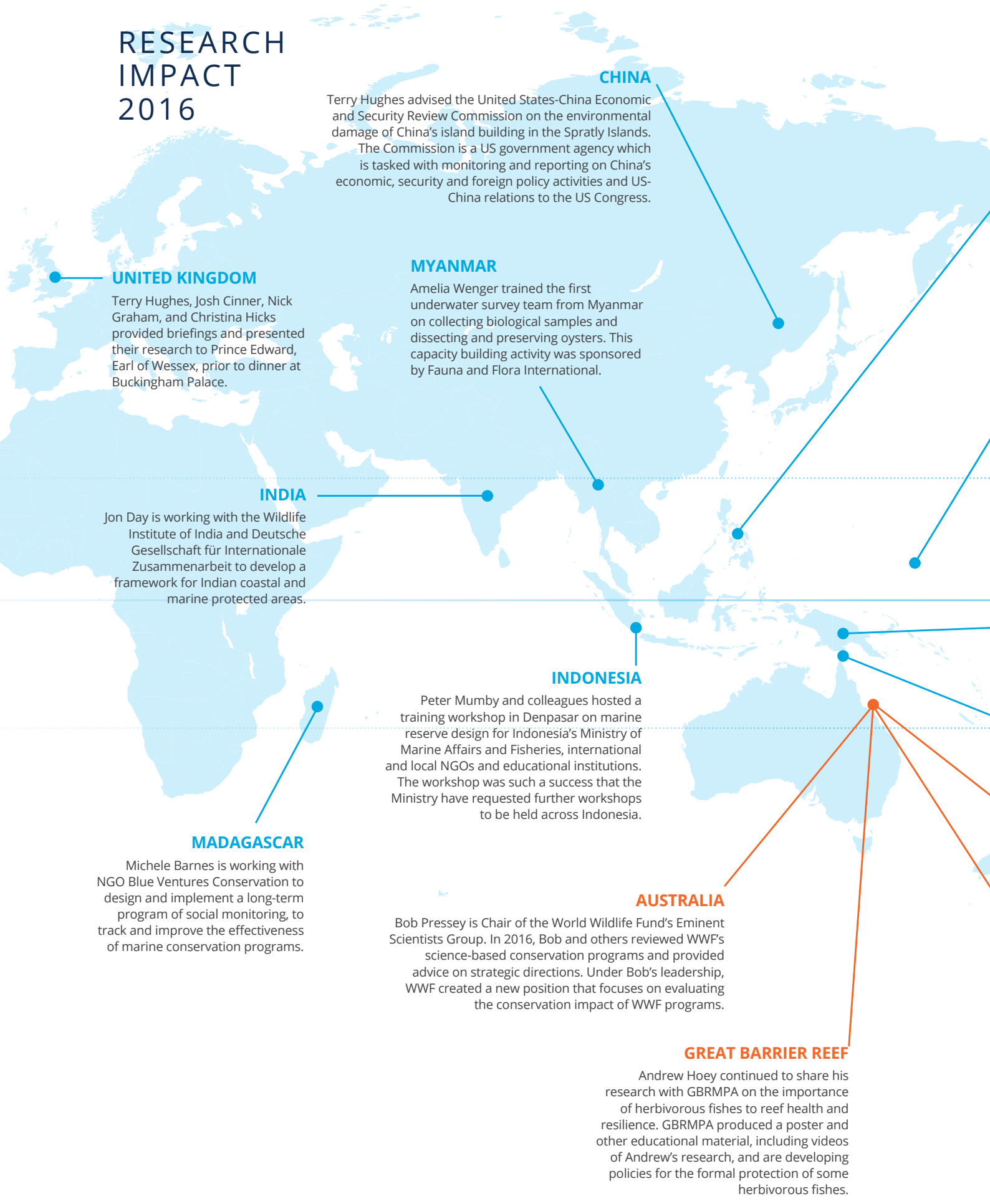
This is something that matters very dearly to me. Because one day I'm going to see it in real life and not just from pictures/videos. And live near it!

So, if there is anything I can do. (please) Plz Email me back

Thx,
Emily 〰

PHOTO MIKE MCWILLIAM

RESEARCH IMPACT 2016



CHINA

Terry Hughes advised the United States-China Economic and Security Review Commission on the environmental damage of China's island building in the Spratly Islands. The Commission is a US government agency which is tasked with monitoring and reporting on China's economic, security and foreign policy activities and US-China relations to the US Congress.

UNITED KINGDOM

Terry Hughes, Josh Cinner, Nick Graham, and Christina Hicks provided briefings and presented their research to Prince Edward, Earl of Wessex, prior to dinner at Buckingham Palace.

MYANMAR

Amelia Wenger trained the first underwater survey team from Myanmar on collecting biological samples and dissecting and preserving oysters. This capacity building activity was sponsored by Fauna and Flora International.

INDIA

Jon Day is working with the Wildlife Institute of India and Deutsche Gesellschaft für Internationale Zusammenarbeit to develop a framework for Indian coastal and marine protected areas.

INDONESIA

Peter Mumby and colleagues hosted a training workshop in Denpasar on marine reserve design for Indonesia's Ministry of Marine Affairs and Fisheries, international and local NGOs and educational institutions. The workshop was such a success that the Ministry have requested further workshops to be held across Indonesia.

MADAGASCAR

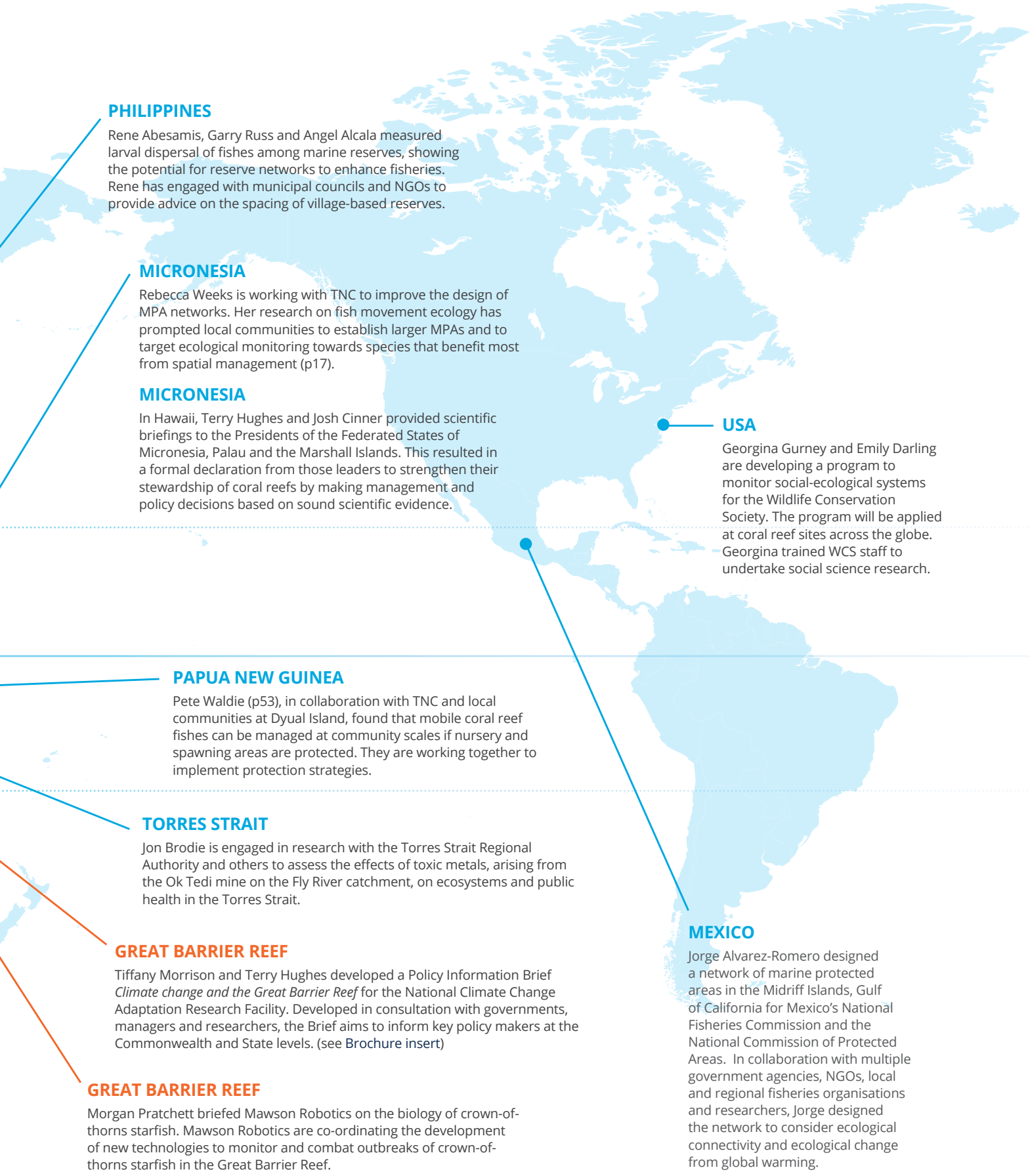
Michele Barnes is working with NGO Blue Ventures Conservation to design and implement a long-term program of social monitoring, to track and improve the effectiveness of marine conservation programs.

AUSTRALIA

Bob Pressey is Chair of the World Wildlife Fund's Eminent Scientists Group. In 2016, Bob and others reviewed WWF's science-based conservation programs and provided advice on strategic directions. Under Bob's leadership, WWF created a new position that focuses on evaluating the conservation impact of WWF programs.

GREAT BARRIER REEF

Andrew Hoey continued to share his research with GBRMPA on the importance of herbivorous fishes to reef health and resilience. GBRMPA produced a poster and other educational material, including videos of Andrew's research, and are developing policies for the formal protection of some herbivorous fishes.



PHILIPPINES

Rene Abesamis, Garry Russ and Angel Alcala measured larval dispersal of fishes among marine reserves, showing the potential for reserve networks to enhance fisheries. Rene has engaged with municipal councils and NGOs to provide advice on the spacing of village-based reserves.

MICRONESIA

Rebecca Weeks is working with TNC to improve the design of MPA networks. Her research on fish movement ecology has prompted local communities to establish larger MPAs and to target ecological monitoring towards species that benefit most from spatial management (p17).

MICRONESIA

In Hawaii, Terry Hughes and Josh Cinner provided scientific briefings to the Presidents of the Federated States of Micronesia, Palau and the Marshall Islands. This resulted in a formal declaration from those leaders to strengthen their stewardship of coral reefs by making management and policy decisions based on sound scientific evidence.

USA

Georgina Gurney and Emily Darling are developing a program to monitor social-ecological systems for the Wildlife Conservation Society. The program will be applied at coral reef sites across the globe. Georgina trained WCS staff to undertake social science research.

PAPUA NEW GUINEA

Pete Waldie (p53), in collaboration with TNC and local communities at Dyual Island, found that mobile coral reef fishes can be managed at community scales if nursery and spawning areas are protected. They are working together to implement protection strategies.

TORRES STRAIT

Jon Brodie is engaged in research with the Torres Strait Regional Authority and others to assess the effects of toxic metals, arising from the Ok Tedi mine on the Fly River catchment, on ecosystems and public health in the Torres Strait.

GREAT BARRIER REEF

Tiffany Morrison and Terry Hughes developed a Policy Information Brief *Climate change and the Great Barrier Reef* for the National Climate Change Adaptation Research Facility. Developed in consultation with governments, managers and researchers, the Brief aims to inform key policy makers at the Commonwealth and State levels. (see Brochure insert)

GREAT BARRIER REEF

Morgan Pratchett briefed Mawson Robotics on the biology of crown-of-thorns starfish. Mawson Robotics are co-ordinating the development of new technologies to monitor and combat outbreaks of crown-of-thorns starfish in the Great Barrier Reef.

MEXICO

Jorge Alvarez-Romero designed a network of marine protected areas in the Midriff Islands, Gulf of California for Mexico's National Fisheries Commission and the National Commission of Protected Areas. In collaboration with multiple government agencies, NGOs, local and regional fisheries organisations and researchers, Jorge designed the network to consider ecological connectivity and ecological change from global warming.

RECOGNITION OF EXCELLENCE BY CENTRE RESEARCHERS

The outstanding achievements of several researchers in the ARC Centre of Excellence were recognised in 2016.

David Bellwood was elected to the Fellowship of the Australian Academy of Science, Australia's most prestigious scientific body. David was honoured by the Academy for his pioneering work in understanding the evolution of coral reefs, their global ecology, and their capacity to withstand human impacts. He also received the Australian Society for Fish Biology's *K Radway Allen Award* for his outstanding contribution to fish science. (see opposite)

Terry Hughes joined the elite list of *Nature's 10* (ten people who mattered this year) as "Reef sentinel" for his leadership in establishing the National Coral Bleaching Taskforce. He was also recognised as an Honorary *Bragg Member* of The Royal Institute of Australia, which recognises excellence in scientific achievement and commitment to science communication. Terry was also the recipient of the inaugural *Australian Coral Reef Society (ACRS) Medal*, in recognition of his lifetime contribution to the research and conservation of coral reefs.

Bette Willis was awarded the *Eminence in Research Award* 2016 by the International Society for Reef Studies, for her outstanding body of research. (p65)

Ove Hoegh-Guldberg received the Banksia Foundation's *International Award* for his "truly inspiring achievements" in helping to understand the impact of climate change on oceans, particularly the Great Barrier Reef. The award recognises significant contributions to improving the environment or promoting sustainability on a global level. Ove was praised for his leadership in engaging the public and his commitment to coral reef conservation and science, which has led to major developments in data analysis, collation and storage.

The Centre's commitment to Indigenous education was recognised in 2016 by the Queensland Government. The **Aboriginals and Torres Strait Islanders in Marine Science (ATSIMS)** program won this year's *Queensland Reconciliation Award for Education*. ATSIMS, which encourages young people to take up careers in marine science and management, was founded in 2013 by Centre PhD student Joseph Pollock. Since then, the program has inspired over 150 Indigenous students from secondary schools in northern Queensland to consider tertiary education in marine science.

Eugenia Sampayo (p26) was one of 12 early to mid-career researchers who received the inaugural Thomson Reuters *Women in Research Citation Award*. She also received a University of Queensland Advancing Women Researchers Grant to attend the International Coral Reef Symposium in Hawaii.

John Pandolfi was elected as a Fellow of the Paleontological Society. John received the honour for a lifetime of achievement in research and service to paleontology.

Jenni Donelson received a Queensland *Young Tall Poppy Science Award* for her research on the ability of marine fish to cope with and adjust to ocean warming. This annual award recognises the achievements of Australia's outstanding young scientific researchers and communicators.

Jodie Rummer received the Society for Experimental Biology's *President's Medal* while Centre PhD student **Lauren Nadler** received the Society's *Young Scientist Award*. Jodie was also named as one of Australia's *Top 5 Scientists Under 40* for 2016. As part of this award, Jodie worked with the ABC and Radio National at their headquarters in Sydney as one of their 'Scientists in Residence' communicating top stories. One of the pieces she published, "The super fish challenge: Michael Phelps vs. real fish", reached >18 million people.

Andrew Baird was named James Cook University Advisor of the Year in 2016. He was applauded by his students for going "above and beyond" his duty to "transform" them into scientists.

Josh Cinner was awarded an ARC Future Fellowship Level 3 at JCU for his project Identifying and learning from 'Bright Spots' in coral reef governance (p16).

Pim Bongaerts, **Steeve Comeau** (p34) and **Hugo Harrison** received ARC Discovery Early Career Researcher Awards at the Centre's nodes in UQ, UWA, and JCU, respectively.

FELLOW OF THE AUSTRALIAN ACADEMY OF SCIENCE

PROFESSOR DAVID BELLWOOD *FAA*


PHOTO RICHARD DAVIS

"It's a wonderful feeling. I'm delighted to be part of a Fellowship that includes so many people whom I admire and respect"

Professor David Bellwood, a Chief Investigator in the ARC Centre, has been elected this year to the Fellowship of the Australian Academy of Science, in recognition of his pioneering work on coral reef ecosystem function. Australia's most prestigious scientific honour is bestowed upon scientists chosen by their peers for "outstanding research that has pushed back the frontiers of knowledge".

Joining the fellowship of 500 elite Australian scientists is a career highlight for David who is a founding member of the ARC Centre and a Distinguished Professor of Marine Biology at James Cook University. "It's a wonderful feeling. I'm delighted to be part of a Fellowship that includes so many people whom I admire and respect," he says.

David's life-long dedication to marine science has revolutionised our understanding of reef evolution and the functional role that fishes play in sustaining coral reefs. His research has had a direct impact on the way coral reefs are managed for the people who depend on them.

David's research has repeatedly shown that not all species are equal. "Protecting coral reef biodiversity, such as the number of species, may be useful, but it is what the species do that is far more important," he explains. He recently discovered that only a small number of species perform the functions required to support coral reef ecosystems. Protecting these critically important species, and their functional abilities, is vital in sustaining coral reefs for the future.

David has published over 270 peer-reviewed papers so far during his career. His other landmark findings include: discovering the exceptional swimming abilities of larval reef fishes; identifying the critical role parrotfishes play in reef ecosystem processes; documenting the world's shortest lifespan for any vertebrate; establishing the evolutionary and biogeographic foundations of global biodiversity patterns on coral reefs; uncovering fossil fish assemblages that revealed the ancient origins of modern-day reef fishes; and discovering the value of resilience-based approaches to the management of coral reefs. His outstanding contribution to fish science was further recognised in 2016 by the presentation of the *K Radway Allen Award* from the Australian Society for Fish Biology.

At the JCU node of our ARC Centre, David is highly regarded for his dedication to teaching the next generation of scientists. It is no surprise to his colleagues that he considers that passing on his knowledge is the best part of his job. "The world is changing and we face serious environmental problems; coral reefs are particularly vulnerable. What we need to do is to give the next generation the tools that they're going to need to cope with these changes," he says.

Science communication is another one of David's passions. He is a highly sought after keynote speaker who engages and entertains his audience. Former Honours student Joanna Khan says, "David has this way of captivating his audience by using weird analogies. I sometimes wondered where the lecture was heading, but it always made sense in the end. I never thought that I would learn about concepts of reef fish biogeography by hearing stories about European history, but it works".

One of David's main goals "is to give future researchers the confidence to question and to think for themselves, because we're going to need to be innovative, imaginative and bold to address the problems that we currently face".

DR SYLVAIN FORÊT

1977–2016

PHOTO AURÉLIE MOYA

On December 17, 2016, our friend and colleague Sylvain Forêt passed away in Barcelona after suffering a pulmonary embolism – a brilliant career tragically cut short at just 39 years of age. Sylvain had been the main face of the ARC Centre at the Australian National University since 2014, and previously at James Cook University when he was an ARC Centre Research Fellow from 2009-2012.

Sylvain had an eclectic education, bringing a deep interest in mathematics and statistics to his first love – invertebrate biology. A life-long fascination with the biology of social insects was stimulated by his internships in the entomology department at Cornell, and later at ANU with Ryszard Maleszka during his Masters Degree. After completing a Masters in biology and bioinformatics, he worked for the biotech start-up Alpha CSP in Paris, running training workshops on various programming languages across Europe, before being transferred to Cardif, where he worked for the insurance branch of the French banking group BNP Paribas. Inevitably, he eventually became bored by the routine of the commercial world, in 2003 returning to Ryszard's lab at the ANU to undertake a PhD on honeybee epigenetics. This relationship resulted in important publications in invertebrate epigenetics, including a paper in *Science* which showed that royal jelly altered patterns of DNA methylation in the honeybee, leading to the queen bee phenotype. This paper was voted 2008 zoology paper of the year by *Nature*.

Sylvain's scientific interest in corals was initially fostered by presentations at the annual meetings of the former ARC Centre for the Molecular Genetics of Development. In 2009, he joined the JCU node of the ARC Centre of Excellence for Coral Reef Studies as a Research Fellow in the Coral Reef Genomics program, and rapidly made his mark. As a theoretical and practical bioinformatician, his skill set was immediately recognised as essential for many of us working on coral biology. This, together with his natural gregariousness and generous nature, opened many opportunities for collaboration and he soon became irreplaceable for many coral projects. He was also a tireless and supportive mentor for many students and postdocs in the Centre.

Amongst many other feats that he accomplished during his time as a Research Fellow, Sylvain assembled the genome of the coral *Acropora millepora* – the first animal genome to be fully sequenced in Australia. Amongst the software that he developed, one program that stands out as uniquely useful for coral biologists is psytrans.py (standing for Parasite & Symbiont Transcriptome Separation), which segregates coral and *Symbiodinium* sequence data using a progressive machine learning algorithm.

Sylvain returned to ANU, accepting a faculty position in Biology in 2012, and he was awarded a DECRA in 2013. Sylvain continued to be central to coral genetics and genomics in Australia; he constantly engaged deeply with collaborators around the country. He became a Chief Investigator in the newly funded ARC Centre of Excellence for Coral Reef Studies in 2014. In this role, he was remarkably active, maintaining and developing new collaborations both within Australia and overseas. In 2016, he was the only Australian to receive funding under the *Human Frontiers Program*, for a challenging and innovative project involving German and American collaborators. He also led the coral genome sequencing effort in the *RefuGe2020* program – a bold plan to sequence not only the host genome but also associated *Symbiodinium* strains and bacteria for corals representing a range of physiological types. Only now is this project coming to fruition – too late for Sylvain to enjoy the recognition that he undoubtedly deserves.

Sylvain was a brilliant scientist, combining inventiveness and originality with hard work. As a bioinformatician, he brought to the ARC Centre a swag of skills and expertise that has enabled wet lab coral scientists to take full advantage of the revolution that has occurred in genomic technology over the last few years. Essentially, he near-singlehandedly brought experimental coral science out of the dark ages. He did so with passion, intellectual rigour and penetrating insight – the hallmarks of a genuine international leader.

He will be remembered not only for his scientific achievements, but also for the boundless optimism and energy that he brought to everything he did. Sylvain was a man with an infectious laugh and smile, around whom people naturally gravitated. Sylvain will be dearly missed by his friends and colleagues, but the greatest sense of loss will be felt by his immediate family – his wife Toop and young daughters, Hannah and Aline, and his parents, Jean-Claude and Christiane.

David Miller and Aurélie Moya

PHOTO TANE SINCLAIR-TAYLOR

RESEARCH PROGRAM 1
PEOPLE AND ECOSYSTEMS

RESEARCH PROGRAM LEADERS

PROFESSOR TERRY HUGHES *FAA*

Professor Terry Hughes is the Director of the ARC Centre of Excellence and co-leader of Research Program 1. 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 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. Terry was elected a Fellow of the Australian Academy of Science in 2001 in recognition of "a career which has significantly advanced the world's store of scientific knowledge". In 2007, he was awarded the *Sherman Eureka Prize for Environmental Research* and in 2008, he received the prestigious quadrennial Darwin Medal of the International Society for Reef Studies. From 2008–2010, he was a member of the ARC Advisory Council. Terry has been awarded three Federation/Laureate Fellowships by the ARC, from 2002–2017. In 2014, he was awarded an Einstein Professorship by the Chinese Academy of Science, and in 2016 Terry was recognised by *Nature* magazine as one of *Nature's 10* – the "ten people who mattered this year".

PROFESSOR BOB PRESSEY *FAA*

Professor Bob Pressey is a co-leader of Research Program 1. 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 considerations involved in implementing conservation. Prior to moving to James Cook University and the ARC Centre, 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 has served on the editorial boards of leading conservation biology journals. Bob was awarded *The Royal Botanic Gardens' Eureka Prize for Biodiversity Research* in 2002, and the inaugural (2008) *Australian Ecology Research Award* from the Ecological Society of Australia. In 2010, he was elected as a Fellow of the Australian Academy of Science for his contributions to the field of systematic conservation planning. His understanding of conservation applications was recognised in 2012 by his appointment to the WWF Australia's Eminent Scientists Group.

RESEARCHERS

Jorge Álvarez Romero, Neil Andrew, Michele Barnes, David Bellwood, Jessica Blythe, Jon Brodie, Jana Brotánková, Josh Cinner, Pip Cohen, Graeme Cumming, Michael Fabinyi, Georgina Gurney, Mélanie Hamel, Laurence McCook, David Mills, Tiffany Morrison, John Pandolfi, Garry Russ, Andrew Song, Rebecca Weeks, Amelia Wenger.

PHOTO ED ROBERTS TETHYS IMAGES

PHOTO GEORGINA GURNEY

Program 1 encompasses a broad evaluation of the linkages between coral reef ecosystems, the goods and services they provide to people, and the wellbeing of human societies. Our objective is to improve the governance and management of coral reefs. Critical issues include how resource use and governance systems are influenced by levels of economic development, social capital, local history and culture. Program 1 places a high value on engagement with local communities, managers and policy makers, government agencies, and non-government organisations. As in previous years, the geographic, social and ecological scope of Program 1's research was diverse in 2016, with major projects in northern, eastern, and western Australia and the Coral Sea, Brazil, Costa Rica, Fiji, Indonesia, Kenya, Micronesia, Papua New Guinea, the Philippines, and the USA.

The conservation planning group within Program 1, focusses on spatial solutions to diverse resource-management problems, involving the design of conservation areas and application of management actions within and outside protected areas. Systematic conservation planning provides a rigorous approach to decision-making that synthesises advances in biology, geography, economics, the social sciences, and spatial modelling. The overall aim of systematic planning is to minimise the loss of biodiversity and ecosystem services, while also minimising the costs and maximising the benefits to resource users. Research themes in 2016 included marine protected areas, illegal fishing, integrated catchment planning, conservation hotspots for sea turtles, cumulative impacts, and the effectiveness of conservation planning.

Josh Cinner was awarded an ARC Future Fellowship this year. His paper on 'Bright Spots' – coral reefs that are statistical outliers with more biomass of fish than expected - was the cover feature of *Nature* (p16). Georgina Gurney completed her PhD at JCU early in the year, and received a Dean's Award for 'Research Higher Degree Excellence', before taking up a 3-year postdoctoral position in the ARC Centre. Her fieldwork in 2016 was based primarily in Indonesia and Fiji, working with several local groups and non-government organisations. Among her publications in 2016, Georgina wrote a novel paper on social capital and the benefits of community-based marine protected areas, in *Conservation Biology*. Another paper led by Georgina which examined social and economic aspects of the participation of people in community-based management of marine protected areas in Indonesia, was published in *Environmental Science and Policy*. Mélanie Hamel also completed her PhD in the Centre, she too received a Dean's Award for 'Research Higher Degree Excellence'. Since then, Mélanie has been a visiting research consultant in the Centre, co-funded with Centre partner Centre National de la Recherche Scientifique, France.

Research Leader Tiffany Morrison convened a working group in the UK on *Power, authority and performance in polycentric systems*, co-chaired by Professor Kate Brown, from the University of Exeter. Tiffany and Terry Hughes produced a *Policy brief on climate change and the Great Barrier Reef*, for the National Climate Change Adaptation Research Facility and the Australian Government Department of the Environment and Energy. Tiffany published a series of papers this year on the governance of complex ecosystems in *Conservation Letters, Global Change Biology,* and elsewhere. Graeme Cumming published a synthesis paper with Tiffany and Terry, on spatial resilience of social-ecological systems, in *Ecosystems*. Research Fellow Michele Barnes published a

novel paper on how social networks influence environmental outcomes, in *Proceedings of the National Academy of Sciences*. Her work supported the Wildlife Conservation Society's Coral Reef Conservation Project, applying social network approaches to identify key players in fishing communities along the Kenyan coast.

Rebecca Weeks led the social-ecological component of a project in the Philippines that combined models of reef fish larval dispersal with new social network data, to improve local governance. Rebecca is also working with The Nature Conservancy to enhance the design of marine protected areas in the Federated States of Micronesia (p17). Three other research fellows – Jana Brotánková, Mike Fabinyi, and Amelia Wenger, – moved on to new endeavours, and all three continue to collaborate with us. Jon Brodie joined Program 1 and the ARC Centre in 2016. Jon is a highly accomplished researcher in water quality and coastal governance, with strong government and industry links.

Program 1 has a longstanding and very productive relationship with WorldFish (p54). Our relationship is recognised in our 2014-2020 funding contract with the Australian Research Council, where WorldFish is listed as one of our four formal international Partner Organisations. Four WorldFish research staff were housed in the Centre in 2016 – David Mills, Pip Cohen, Jessica Blythe and Andrew Song. Jessica and Andrew are co-funded 50:50 by our two organisations. David conducted a series of workshops in Timor-Leste throughout 2016 on sustainable livelihoods, small-scale fisheries assessment, and fisheries data collection and management for the Ministry of Agriculture and Fisheries. During the year, Pip was promoted to a new global leadership role within WorldFish as the Acting Program Leader of the Resilient Small-Scale Fisheries Research Program.

In June, Program 1 researchers were hyper-active at the 13th International Coral Reef Symposium, in Hawaii. Josh Cinner served on the Scientific Committee of the Symposium. He and Terry Hughes contributed to a high-level dialogue between Pacific Leaders, providing briefings to Presidents of Palau and the Republic of the Marshall Islands. Michele Barnes hosted a workshop on 'Social-ecological systems as social-ecological networks'. Georgina Gurney co-chaired a session entitled 'Evaluating the ecological, social and economic effectiveness of marine protected areas'. Josh and Michele also co-hosted a workshop on 'Social-ecological research frontiers'. The Centre also provided numerous mentoring workshops for early career delegates at the Symposium, including a 'getting published in peer-review' workshop hosted by Josh and Terry.

In September, ten members of Program 1 held a retreat on Magnetic Island, off Townsville, to plan the development of the Centre's social science research program. The first day of the workshop was designed to provide opportunities for synergies, by showcasing what each social science Research Fellow is currently exploring and their near-term plans. The second day focussed on developing potential synergies and future research planning. One outcome is a new project entitled, 'Coral reefs in the Anthropocene', and an initial conceptual article on this theme led by Terry Hughes has been accepted for publication in a high profile journal in 2017.

PHOTO TANE SINCLAIR-TAYLOR

"It is a very interesting report [2015 annual] which highlights the need for greater action of all stakeholders in the protection of our remaining coral reefs globally."

Dr Al O. Orolfo
Regional Director
Negros Island Region
Philippines

16 JUN
2016

PHOTO TANE SINCLAIR-TAYLOR

MEDIA RELEASE

BRIGHT SPOTS SHINE LIGHT ON THE FUTURE OF CORAL REEFS

Researchers have discovered a handful of 'bright spots' among the world's embattled coral reefs, offering the promise of a radical new approach to conservation.

In one of the largest global studies of its kind, researchers conducted over 6,000 reef surveys in 46 countries across the globe, and discovered 15 'bright spots' – places where, against all the odds, there were a lot more fish on coral reefs than expected.

Thirty-nine scientists from 34 different universities and conservation groups conducted the research led by Professor Josh Cinner from the ARC Centre of Excellence for Coral Reef Studies and James Cook University.

"Given the widespread depletion of coral reef fisheries globally, we were really excited to find these bright spots that were faring much better than we anticipated," says Prof Cinner.

"These 'bright spots' are reefs with more fish than expected based on their exposure to pressures like human population, poverty, and unfavourable environmental conditions."

"To be clear, bright spots are not necessarily pristine reefs, but rather reefs that have more fish than they should, given the pressures they face."

"We wanted to know why these reefs could 'punch above their weight' so-to-speak, and whether there are lessons we can learn about how to avoid the degradation often associated with overfishing."

Co-author, Professor Nick Graham of Lancaster University says globally, coral reefs are in decline and current strategies for preserving them are insufficient.

"Our bright spots approach has identified places that previously we did not know were so successful, and the really interesting thing is that they are not necessarily untouched by humans," he says.

"We believe their discovery offers the potential to develop exciting new solutions for coral reef conservation."

"Importantly, the bright spots had a few things in common, which, if applied to other places, might help promote better reef conditions."

"Many bright spots had strong local involvement in how the reefs were managed, local ownership rights, and traditional management practices," says co-author Dr Christina Hicks of Lancaster and Stanford Universities.

This type of bright spots analysis has been used in fields such as human health to improve the wellbeing of millions of people. It is the first time it has been rigorously developed for conservation.

"We believe that the bright spots offer hope and some solutions that can be applied more broadly across the world's coral reefs," says Prof Cinner.

Cinner, JE, Huchery, C, MacNeil, MA, Graham, NAJ, McClanahan, TR, Maina, J, Maire, E, Kittinger, JN, Hicks, CC, Mora, C, Allison, EH, D'Agata, S, Hoey, A, Feary, DA, Crowder, L,... 23 others and Mouillot, D (2016). Bright spots among the world's coral reefs. *Nature* 535(7612): 416-419.

PHOTO REBECCA WEEKS

29 JUL
2016

MEDIA RELEASE

CONSERVATION SCIENTISTS HELP FISH CATCH A BREAK

Underneath the waves of Palikir Pass, one of the world's top surf breaks in the Pacific Ocean, lies a new safe zone which aims to ensure the survival of local fisheries in Pohnpei, Micronesia and the species that are caught.

It's all thanks to a group of scientists from Australia and Micronesia who have found that by measuring how far fish travel, habitats can be better protected.

The study led by Dr Rebecca Weeks from the ARC Centre of Excellence for Coral Reef Studies was undertaken in conjunction with The Nature Conservancy and the Conservation Society of Pohnpei.

Researchers targeted the island of Pohnpei as a case study to examine how effective their designated marine protected areas (MPAs) are for conservation and fisheries management.

"We asked local fishers to tell us the top ten species they wanted to protect and found the majority of MPAs in Pohnpei were too small to protect the fish they cared about the most," said Dr Weeks.

The fishers ranked favoured food fish - groupers, rabbitfish, parrotfish, surgeonfish, snapper and trevally - along with those with cultural and conservation importance like the humphead wrasse and bumphead parrotfish.

"We then calculated the home range of each species – the area where a fish spends most of its time eating and sleeping."

"We know that if their entire home range is within an MPA the fish will be protected but if the MPA is too small then it is likely the fish will swim out of the safe zone and risk being caught."

"By focusing on particular species that the fishers care about and using information on the ecology of those species, like how far they move on a day-to-day basis, we were able to determine how large no-take zones actually needed to be."

"We then took that information to community workshops and involved local fishers in the conversation which has resulted in the creation of larger MPAs."

Since the study, Pohnpei has established its largest MPA called the Palikir Pass Marine Sanctuary. The location is better known to many as P-Pass, a world-class surf break.

Pohnpei is committed to achieving international targets for biodiversity conservation through the Micronesia Challenge, and has already protected 30% of its marine habitats. However, not all of their MPAs are performing well, as many are too small.

"The larger the area set aside for no-take zones, the smaller the area for fishing. There is this trade-off between livelihoods, food security and conservation and people are less likely to follow the rules if they don't see how they will benefit from them."

"Because we focussed the conversation on the fish they wanted to protect, it engaged more people.

"We anticipate that focusing on these species will mean better protection and an increase in their abundance which will ultimately benefit both conservation and local fisheries."

Weeks, R, Green, AL, Joseph, E, Peterson, N and Terk, E (2016). *Journal of Applied Ecology* 54(1): 145-152.

RESEARCHER PROFILE

PROFESSOR GRAEME CUMMING

The ARC Centre welcomed Professor Graeme Cumming in mid-2015, as a new Coral Reef Research Leader. Graeme's pathway to coral reef research has been an unorthodox one. He was raised by two biologists, and spent his youth camping, fishing, and hiking in the national parks of Zimbabwe. He was awarded a highly competitive Rhodes scholarship, enabling him to enrol in a PhD at Oxford University and to follow his early interests in savannah ecology, biodiversity, and conservation. He began his thesis with the idea of using parasites to track the gradual introduction of cattle into Africa. After discovering that most ticks were actually generalists, not specialists, he shifted his focus to the biogeography of ticks.

In retrospect, Graeme believes he "was lucky to do a doctorate at a time when desktop geographic information systems (GIS) had recently reached a level of sophistication that allowed ecologists to do useful things with them". Graeme was able to capitalise on new GIS technologies to advance the science of modelling species occurrences, leading to a career-defining interest in spatial pattern and the processes involved. Graeme's PhD proved that the species ranges of African ticks are shaped by climate rather than by host distributions. This ground-breaking research paved the way for better assessments of climate-driven changes in tick species ranges, and changed our understanding of the distributions of tick-borne pathogens.

Graeme moved to the USA when he was awarded a D.H. Smith Postdoctoral Fellowship by The Nature Conservancy. At the Centre for Limnology, University of Wisconsin, Graeme adapted the methods he developed during his PhD on terrestrial systems and applied them to networks of rivers. His research focused on the distributions of fish, which brought with it the added bonus of easy access to some fantastic fly-fishing waters. Graeme's postdoctoral research was among the first to demonstrate empirically that impoundments have significant upstream, as well as downstream, effects on fish communities.

In 2001, Graeme accepted an academic position in the Department of Wildlife Ecology and Conservation, University of Florida (UF). Here Graeme assessed the impacts of landscape structure and change on insects and bats, while he also became increasingly engaged in research on social-ecological systems and the activities of the Resilience Alliance (an international network of eminent scientists). At UF, he co-led an interdisciplinary team working on the social-ecological impacts of the trans-Amazon highway. This diverse group made several important conceptual advances in the study of resilience. Graeme's growing interdisciplinary interests also led to a deep engagement with two initiatives of the Millennium Ecosystem Assessment: the Global Scenarios Group, and the Caribbean Sea Assessment. Both had far-reaching global and regional impacts on sustainability science.

Graeme returned to southern Africa in 2006 after being awarded the inaugural Pola Pasvolsky Chair in Conservation Biology at the Percy FitzPatrick Institute, University of Cape Town. He developed two major research programs in Cape Town: one on the movements of waterfowl and their relevance for avian influenza, and the other on protected area networks and their long-term sustainability. In Cape Town, Graeme built a team of five senior academics, two full-time field assistants, and more than 80 students and volunteers, resulting in research outputs that constitute most of what is currently known about avian influenza in wild birds in southern Africa. His work on African protected areas is ongoing and will provide a useful counterpoint to his new initiatives in Australia.

Graeme has brought to the ARC Centre a new set of skills and insights that he is now applying to coral reef science. He has developed an exciting research programme, focusing on the impacts of changes in scale and connectivity on ecological and social-ecological processes in coral reef ecosystems and marine protected areas. This will set new directions and push existing boundaries in both ecology and sustainability science, and contribute to the expanding influence of the ARC Centre at the interface between ecology and social science.

"Our Great Barrier Reef continues to be an extraordinary marvel and the 1.9 million people who visit it each year are a testament to that. But what's going on now is a serious wakeup call."

Dr Steven Miles
Minister for Environment and Heritage Protection and Minister for National Parks and the Great Barrier Reef
Queensland Government, Australia

PHOTO ED ROBERTS TETHYS IMAGES

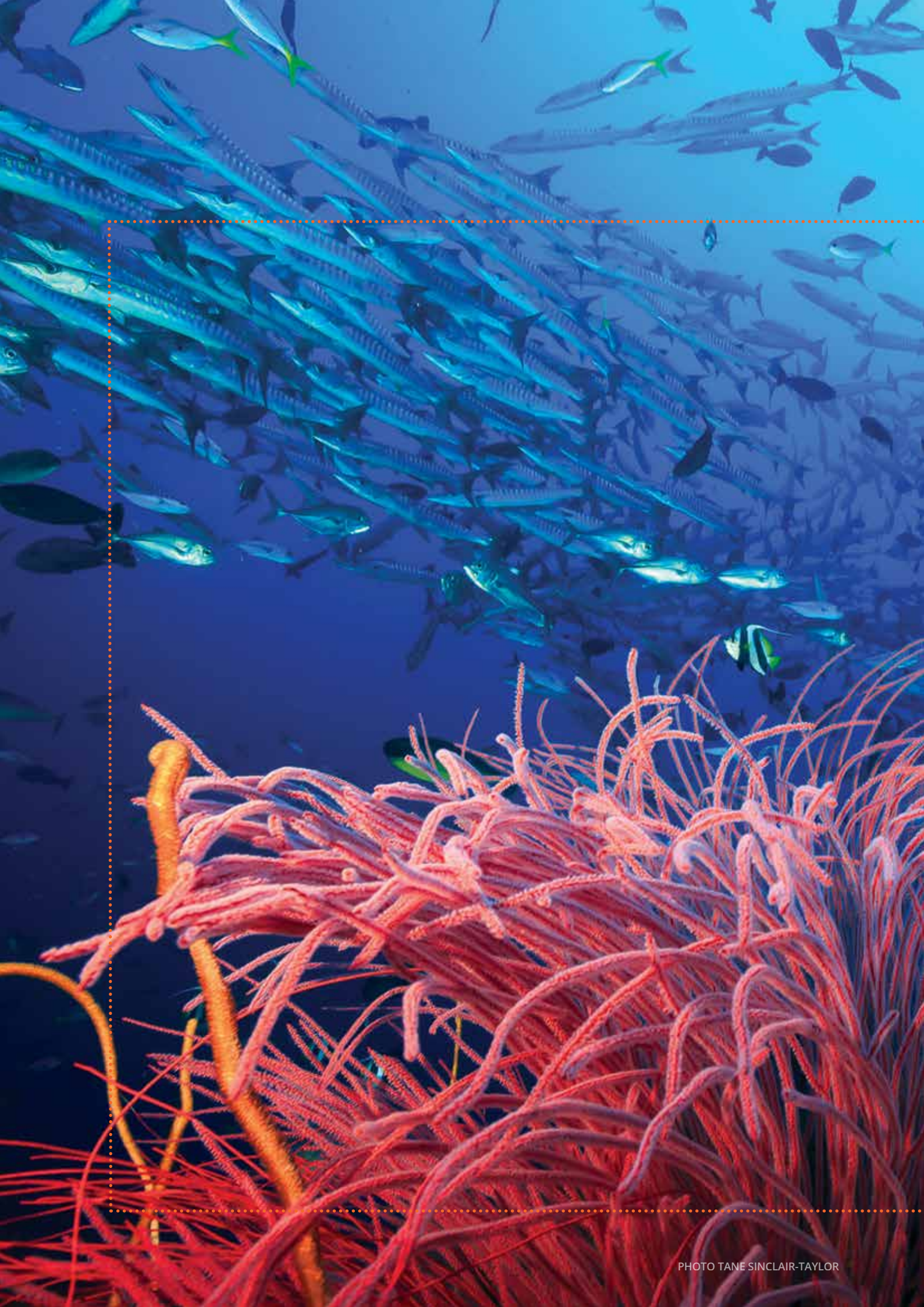


PHOTO TANE SINCLAIR-TAYLOR

RESEARCH PROGRAM 2
ECOSYSTEM DYNAMICS: PAST, PRESENT AND FUTURE

RESEARCH PROGRAM LEADERS

PROFESSOR SEAN CONNOLLY

Professor Sean Connolly, from James Cook University, is co-leader of Research Program 2. Sean combines mathematical and statistical modelling with fieldwork and laboratory experiments to study the dynamics of biological turnover at all scales, including ecophysiology, population dynamics, species interactions and biodiversity, and macroevolution. He received his doctorate in 1999 from Stanford University in California, USA, for research on the ecology of rocky shores. In 1999-2000, he was a postdoctoral Research Fellow at the University of Arizona, USA, where he examined global dynamics of marine biodiversity in the fossil record. In 2000, he was recruited to JCU to develop and lead a research program in ecological modelling applied to coral reefs. Sean has more than 100 publications in leading international journals, including 11 papers in *Science* or *Nature*, and he has supervised 39 postgraduate and Honours students. In 2008 he was awarded an ARC Australian Professorial Fellowship (2008-2012), and in 2009, the *Fenner Medal* of the Australian Academy of Science, which honours outstanding research in the biological sciences by a scientist under 40. Sean has also twice received a national *Citation for Outstanding Contributions to Student Learning*, in 2006 and 2014, for his innovative and highly effective approaches to teaching ecological modelling to undergraduate students.

PROFESSOR JOHN PANDOLFI

Professor John Pandolfi, from the School of Biological Sciences and Centre for Marine Science, University of Queensland, is co-leader of Research Program 2. John is the world's leading expert on coral reef palaeoecology. He has broad research interests in marine palaeoecology, with emphasis on the effects of anthropogenic impacts and climate change on the recent past history of modern coral reefs. His focus on coral reef ecosystems is shedding light on a number of fundamental ecological questions where long-term data are essential. John has published more than 150 papers, including 21 contributions to *Science* or *Nature*. He has served as President of the Australian Coral Reef Society, and chief editor of *Paleobiology*, and now is associate editor for *Proceedings of the Royal Society B*, and *Global Ecology and Biogeography.* He has supervised 17 PhD students. John has provided frequent briefings on coral reef management and policy (e.g. US Congress, Australian Senate) and has been invited to serve on numerous international working groups. In 2001, he received the Discovery Magazine *Science Story of the Year* award. In 2013 he was awarded a prestigious Discovery Outstanding Researcher Award from the ARC (2013–2016). He was recently elected as a Fellow in both the International Society for Reef Studies (2015) and The Paleontological Society (2016).

RESEARCHERS

Kristen Anderson, Andrew Baird, David Bellwood, Pim Bongaerts, Mary Bonin, Yves-Marie Bozec, Tom Bridge, Jon Brodie, Karen Chong-Seng, Peter Cowman, Graeme Cumming, Hugo Harrison, Andrew Hoey, Terry Hughes, Jeremy Jackson, Geoff Jones, Michael Kingsford, Nils Krück, Ryan Lowe, Vimoksalehi Lukoschek, Laurence McCook, Mark McCormick, Vanessa Messmer, Peter Mumby, Philip Munday, Stephen Palumbi, Chiara Pisapia, Serge Planes, Morgan Pratchett, George Roff, Garry Russ, Eugenia Sampayo, Greg Torda, Sue-Ann Watson.

PHOTO TANE SINCLAIR-TAYLOR

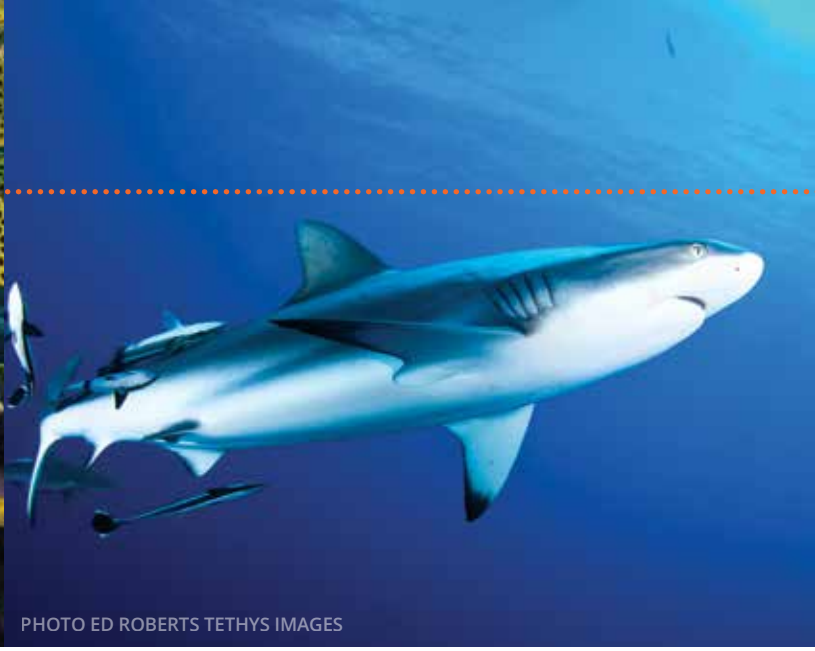


PHOTO ED ROBERTS TETHYS IMAGES

Program 2 aims to understand the multi-scale dynamics of coral reefs, through the innovative integration of ecology, evolution, genetics, oceanography and paleontology. Program 2 researchers focus particularly in four key research areas. We examine the historical transition from pristine ecosystems to the systems of today, improving knowledge of how the resilience of coral reefs evolves and responds to human impacts. We aim to increase understanding of the dynamics and resilience of ecosystems over multiple spatial and temporal scales and in response to environmental change, and to bring those findings to bear on the management of coral reefs. We examine how populations of organisms living on different reefs are connected to each other through the dispersal of their offspring, as well as through the social impacts of human connectivity, diseases, and new species introductions. Finally, we study the level of functional diversity and redundancy in coral reef assemblages, modelling and assessing the effects of changes in biodiversity on ecosystem function at regional to global scales, as well as investigating the effects of management on the dynamics of reef ecosystems.

In 2016, Program 2 saw ground-breaking progress in understanding the ecological response of coral reefs and human societies to climate change. Program 2 focussed much of their time on understanding the severity and factors that influenced both bleaching and mortality in the Great Barrier Reef and Torres Strait during the 2016 bleaching event. In a paper published in *Molecular Ecology*, Vimoksalehi Lukoschek and Partner Investigator Madeleine van Oppen showed coral gene flow from the northern to southern Great Barrier Reef, but not the reverse. This research indicates that reefs in the south that were moderately impacted by the 2016 bleaching event might not reseed severely impacted reefs in the north. In *Science*, John Pandolfi and Tom Bridge, working with a large team of international researchers, demonstrate the near ubiquity of biological processes that have been impacted by global warming and the implications for food security and human health. Program 2 also sponsored the *Sub-tropical bleaching workshop* held at the National Marine Science Centre, Coffs Harbour, bringing together 15 marine scientists to collate and analyse records of coral bleaching along the eastern Australian sub-tropical coastline.

Program 2 produced a series of cutting-edge papers on the evolution of fish and corals in 2016. John Pandolfi co-authored a paper in *Current Biology* that found coral populations harbour rich genetic variation to adapt to climate change. In *Nature Communications,* adjunct fellow David Mouillot, Peter Cowman, David Bellwood and Terry Hughes report that individual coral species and the breadth of evolutionary history across the Tree of Life are underrepresented in marine protected areas, and consequently a global, coordinated expansion of marine reserves is required to fully secure the Tree of Life on coral reefs. In *Biological Reviews,* David Bellwood examined recent advances in molecular phylogenetics and palaeoecology, and placed the evolution of fishes and corals in a functional context. Peter Cowman, David Bellwood and David Mouillot also published a paper together in *Nature Communications* with colleagues in France that showed plate tectonics play a major role in driving tropical-marine, shallow-reef, biodiversity dynamics.

In 2016, Program 2 researchers made significant progress in understanding the fundamental biological and ecological responses of reef organisms to environmental change. In *Biology Letters*, Sue-Ann

Watson reported that ocean acidification alters predator behaviour and reduces predation rates in deadly cone snails. A series of papers by Morgan Pratchett in *Reviews in Fish Biology* and *Nature Scientific Reports* assess the effects of climate change on coral trout. Vanessa Messmer, Andrew Hoey and Morgan Pratchett found that global warming may disproportionately affect larger coral trout adults in a paper published in *Global Change Biology.* In *Proceedings of the National Academy of Science* (*PNAS*), Andrew Hoey and Yves-Marie Bozec found that global warming increases the proportion of herbivorous fish in kelp forests and leads to a persistent state of deforestation. Also in *PNAS,* Yves-Marie Bozec and Peter Mumby evaluated the ecosystem impacts of fishing on Caribbean corals, and identified trade-offs between profitable fisheries and reef resilience under climate change (p24). Andrew Baird showed, in a paper in the *Proceedings of the Royal Society B*, that the seasonal rise in sea temperature is the main determinant of the timing of spawning of *Acropora* colonies. Eugenia Sampayo also led a paper in *Scientific Reports*, with Program 3's Sophie Dove and Ove Hoegh-Guldberg, showing that thermal stress on corals living near irradiance range limits causes disproportionately higher mortality compared to those living within normal light ranges.

Program 2 continues to pioneer work on the functioning of fish and sharks, especially in relation to marine reserves. In *PNAS,* Geoff Jones and Serge Planes co-authored the first genealogy of a marine fish, tracking five generations of successful protection in a marine reserve. In a world-first study published in *Current Biology*, PhD student Jess Hopf, Sean Connolly and Geoff Jones developed a mathematical approach to examine how changes in the abundance and catch of coral trout on the Great Barrier Reef are affected by marine reserves and the restructuring of the reef line fishery. Their research has global implications for fisheries management because it found a synergistic and positive effect of marine reserves and traditional fishery management tools on both fish populations and catch.

In a series of high profile papers in *Scientific Reports, Proceedings of the Royal Society B* and *Global Change Biology*, Mark McCormick and colleagues applied innovative techniques to understand how reef degradation affects how some fish assess the risk of predation. Other researchers in Program 2 are also exploring the connections between fish and their habitats. George Roff and Peter Mumby published a paper in *Trends in Ecology and Evolution* on the ecological roles of sharks on coral reefs, finding limited evidence to support the paradigm of shark-driven trophic cascades benefiting corals. Partner Investigator Serge Planes and adjunct fellow Michael Bode co-authored a seminal paper in *Current Biology* that showed how sharks overcome food shortages by feeding on fish spawning aggregations. Their research showed that protecting fish spawning aggregations can help conserve shark populations, especially if combined with limits on shark fishing.

PHOTO GRACE FRANK

During the year, the Centre has undertaken fieldwork in 25 tropical countries, particularly in Australia, the Coral Triangle (Philippines, Indonesia, Malaysia, Papua New Guinea, Timor-Leste, Solomon Islands), Fiji, French Polynesia, Micronesia, Saudi Arabia, Kenya, the Maldives, the Seychelles, Mexico, and the Caribbean.

5 APR
2016

PHOTO PETER MUMBY

MEDIA RELEASE

FISHING FOR THE FUTURE OF CORAL REEFS

New science-based fishery regulations are needed if coral reefs are to have a future in the face of climate change.

An international team, led by ARC Centre of Excellence and University of Queensland (UQ) researchers, has found that tighter fishery regulations are needed to preserve corals of the Caribbean.

The study shows that Caribbean coral reefs are experiencing mounting pressure from global warming, local pollution and over-fishing of herbivorous fish.

Dr Yves-Marie Bozec from the ARC Centre of Excellence for Coral Reef Studies at UQ, said herbivorous parrotfish were needed because they eat seaweed, which can smother coral and prevent corals from recovering.

"While several countries in the Caribbean have taken the bold step of banning the fishing of parrotfish (including Belize, Bonaire, Turks and Caicos Islands), parrotfish fisheries remain in much of the region," Dr Bozec said.

The research team analysed the effects of fishing on parrotfish and combined this with an analysis of the role of parrotfish on coral reefs.

"We conclude that unregulated fisheries will seriously reduce the resilience of coral reefs," Dr Bozec said.

"However, implementation of size limits and catch limits to less than 10 per cent of the fishable stock provide a far better outlook for reefs, while also allowing the fishery to persist."

Study co-author Professor Peter Mumby also from the ARC Centre of Excellence for Coral Reef Studies at UQ said a number of countries wanted to modify their fisheries to reduce impacts on reefs.

"What we've done is identify fisheries' policies that might help achieve this," Professor Mumby said.

The new study, published in the journal *Proceedings of the National Academy of Sciences*, argues that science should be used to revise current fisheries practices for herbivorous fish in the Caribbean.

The authors have provided tools to help fisheries managers make such changes.

"Ultimately, the more we do to maintain healthy coral reefs, the more likely it is that fishers' livelihoods will be sustained into the future," Professor Mumby said.

"We already know that failure to maintain coral habitats will lead to at least a threefold reduction in future fish catches."

Bozec, Y-M, O'Farrell, S, Bruggemann, JH, Luckhurst, BE and Mumby, PJ (2016). Tradeoffs between fisheries harvest and the resilience of coral reefs. *Proceedings of the National Academy of Sciences of the United States of America* 113(16): 4536-4541.

22 JUN
2016

MEDIA RELEASE

TAPPING FISHERS' MEMORIES REVEALS LONG LOST FISHING TRENDS

Scientists have reconstructed long-term data on fish catches using fishers' memories to reveal how their rewards have declined over the past 50 years.

More than 100 fishers from the commercial and recreational fishing sectors were asked to recall what they remembered about fishing on the Great Barrier Reef, Australia.

"The historic data revealed that catch rates (the number of coral trout caught per fisher per hour) have declined since the 1970s, despite the rapid advances in fish finding technology we have today," says Dr Ruth Thurstan who conducted the research with the ARC Centre of Excellence for Coral Reef Studies.

"In the past, recreational fishers have blamed the commercial live reef fish trade for a decline in catches, while commercial fishers claim expanding no-take zones on the Great Barrier Reef in 2004 is behind the problem. However, we found catch rates actually began falling way before either of those factors were introduced."

The scientists travelled 1400 kilometres up and down the coastline interviewing fishers about the type of gear they used in the past, the number of fish caught, and how far offshore people fished. The historical information was then translated into data to map long-term fishery trends dating from the 1950's to now.

The commercial fishery trade began in Australia after WWII but no official records of individual catches were kept until the late 1980s.

"We found that some people were able to recall their earliest memories of fishing on the Great Barrier Reef, up to 60 years ago.

"The oldest person we spoke to was 92-years old. He had fished around Green Island, near Cairns, his entire life. Not only was he able to tell us about catch rates but he also provided valuable information about how the wider environment had changed as the region became more populated."

"Fishing rewards have clearly changed through time, but fishers have a huge contribution to make - they understand the value of knowing where we've come from to help manage trout fisheries for the future," says Prof John Pandolfi, from the ARC Centre of Excellence for Coral Reef Studies and the University of Queensland.

Thurstan, R, Buckley, SM and Pandolfi, JM (2016). Oral histories: informing natural resource management using perceptions of the past. In: Schwerdtner Máñez, K, and Poulsen, B. (eds). *Perspectives on oceans past,* Springer Netherlands 155-173pp.

RESEARCHER PROFILE

DR EUGENIA SAMPAYO

Dr Eugenia Sampayo is a Research Fellow in Program 2 at the University of Queensland node of the ARC Centre. Eugenia was born in The Netherlands, many thousands of kilometres from the nearest tropical coral reef. She developed a passion for the ocean after spending part of her childhood living on the Caribbean island of Curaçao. Eugenia remembers that "it was hard for my parents to get me out of the water. I was always snorkelling and, at the age of seven, I knew that I wanted to become a marine biologist". Eugenia jumped at the opportunity to work on coral reefs during her Masters degree at the University of Groningen, in The Netherlands, when she returned to the Caribbean to study the reproductive ecology of corals.

Eugenia moved to Australia in 2004 to pursue a PhD at the University of Queensland with ARC Centre Chief Investigators Sophie Dove and Ove Hoegh-Guldberg. Her thesis broadly focussed on the symbiosis between corals and the single-celled dinoflagellates living inside their tissues. During Eugenia's PhD, she "tagged colonies so I could follow them long-term, and then, in the summer of 2006, a bleaching event occurred in the southern Great Barrier Reef. I was able to test how the coral symbionts influence the response of corals to the increased sea surface temperatures". Her research, published in the *Proceedings of the National Academy of Sciences* in 2008, showed that the particular species of coral symbionts living inside a coral determine how sensitive they are to thermal stress, leading to coral bleaching and subsequent mortality.

After completing her PhD in 2008, Eugenia worked as postdoctoral Research Fellow at Pennsylvania State University, USA with Professor Todd LaJeunesse, one of the world's leading experts in *Symbiodinium* taxonomy and evolutionary ecology. After living under a thick cover of snow for two winters, Eugenia was awarded a fellowship at the University of the Ryukyus, Japan. Eugenia used this fellowship to combine her expertise on coral symbioses with Dr Saki Harii's expertise on coral spawning and recruitment. This enabled her to conduct experiments on the early life stages of corals, during which the coral symbiosis is established, and when the largest potential for adaptive change is likely to occur.

Eugenia returned to the University of Queensland in 2012 to join Program Leader John Pandolfi's group as a Research Fellow. She is currently studying whether coral symbionts play a role in limiting the latitudinal ranges in sub-tropical reefs, and if symbionts influence the success of young corals that come southwards from tropical regions. Eugenia is combining field ecology with experimental studies to test what the effects are of changed symbiotic partnerships and to what extent these partnerships are able to exist outside the current geographic limits of corals. Much of the focus of her research is on the early life stages of corals and the processes that regulate recruitment success, such as interspecific competition between recruits, and on differences in nutrient cycling between tropical and subtropical corals.

Eugenia had a successful 2016. She was one of only twelve early- to mid-career researchers in Australia to receive an inaugural Thomson Reuters *Women in Research Citation Award*. With colleagues at the ARC Centre, Eugenia was awarded a $413,500 ARC Discovery Project for her studies of sub-tropical refugia in coral reefs. She also led a paper in *Scientific Reports* demonstrating that thermal stress on corals living near irradiance range limits causes disproportionately higher mortality compared to those living within normal light ranges. According to Eugenia, "our research shows that corals living near their tolerance range limits, such as sub-tropical corals, are particularly susceptible to environmental fluctuations or stress events".

"You and your colleagues are doing a great job in the analysis and promulgation of the science of the reef and in the communication of the nature of the environmental stress that the reef is suffering."

Professor Andrew B. Holmes
President, Australian Academy of Science

PHOTO ED ROBERTS TETHYS IMAGES

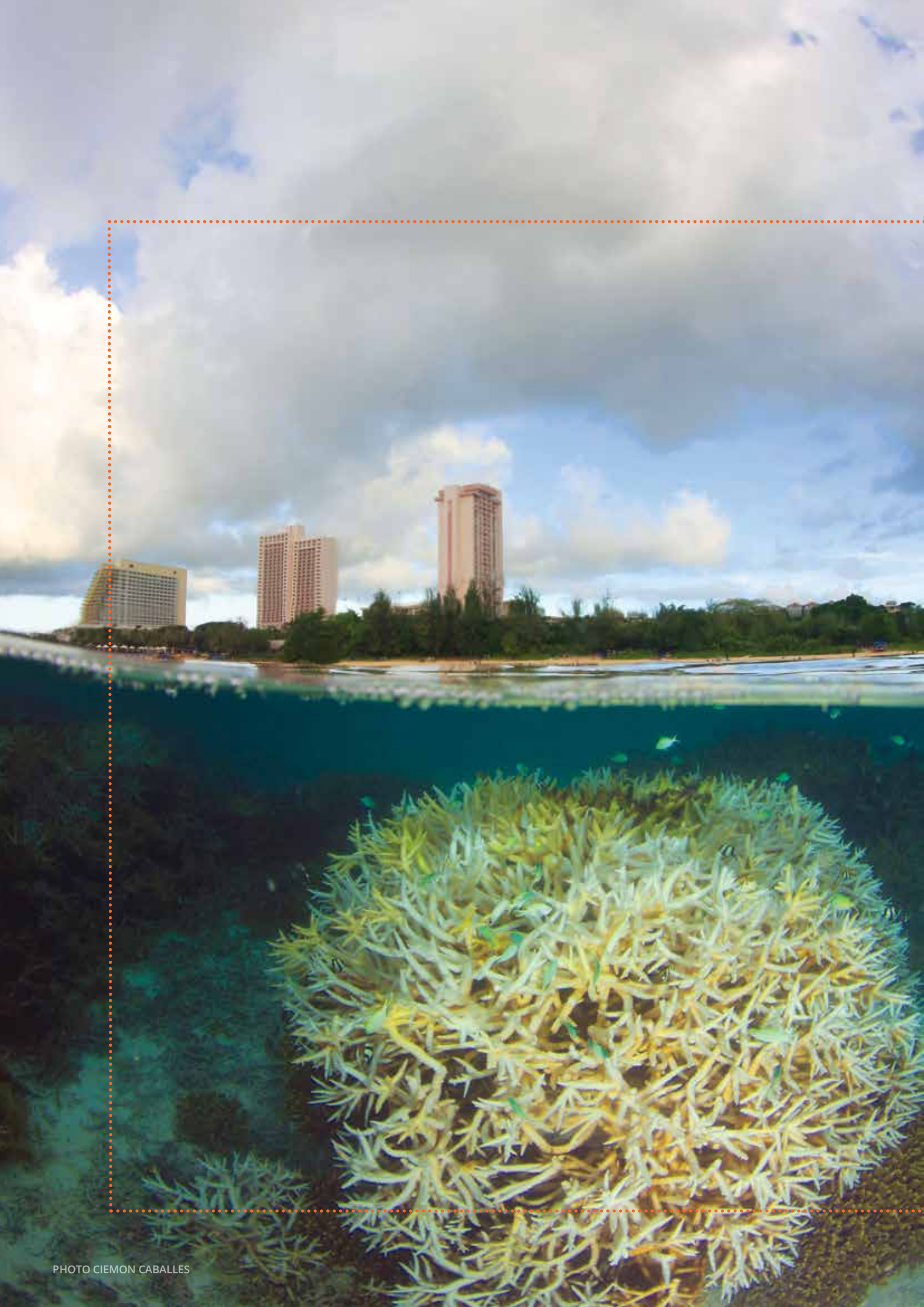


PHOTO CIEMON CABALLES

RESEARCH PROGRAM 3
RESPONDING TO A CHANGING WORLD

RESEARCH PROGRAM LEADERS

DR MIA HOOGENBOOM

Dr Mia Hoogenboom, from James Cook University, is co-leader of Research Program 3. Mia is an expert on coral reef ecophysiology. She received her PhD in 2008 from JCU and, from 2008–2011, she was a postdoctoral Research Fellow at the Centre Scientifique de Monaco and University of Glasgow, UK. Mia has broad research interests in aquatic ecophysiology and her research establishes mechanistic links between environmental change, physiology, and population and community dynamics. Mia's research is multidisciplinary and collaborative and in the last 10 years she has published papers with 82 authors in 15 countries, addressing diverse topics. Mia has published more than 40 papers in leading international journals, including *Trends in Ecology and Evolution* and *Global Change Biology*. She has supervised 26 postgraduate and Honours students since 2010, and participates in educational outreach programs that provide authentic field and laboratory experiences of marine biology for secondary school students. Her ecotoxicology research informs strategies for managing the impacts of environmental contaminants on coastal marine ecosystems.

PROFESSOR MALCOLM MCCULLOCH *FRS*, *FAA*

Professor Malcolm McCulloch is one of the ARC Centre's two Deputy Directors and co-leader of Research Program 3. Malcolm is an ARC Australian Laureate Fellow in the School of Earth and Environment at The University of Western Australia. His research addresses important contemporary issues such as the impacts of climate change and direct human activities on coral reefs, and he has indentified innovative new indicators of climate change that are preserved in coral skeletons. His research is characterised by the development and application of new sets of quantitative tools utilising changes in the geochemistry of corals as proxies for determining sediment discharge into reefs, changes in freshwater river runoff, ocean temperatures, sea-levels, and most recently ocean acidification from rising CO_2 emissions. Malcolm is an elected Fellow of The Royal Society (London), the Australian Academy of Science, the American Geophysical Union, the Geochemical Society and the Geological Society of Australia. He was awarded the *Jaeger Medal* for career excellence in the earth sciences from the Australian Academy of Science, and an Honorary Doctorate from Curtin University. He held a WA Premier's Research Fellowship at UWA from 2009–2013.

RESEARCHERS

Tracy Ainsworth, Bridie Allan, Kristen Anderson, Andrew Baird, Dorothea Bender-Champ, Pim Bongaerts, Tom Bridge, Steeve Comeau, Sean Connolly, Christopher Cornwall, Juan Pablo D'Olivo Cordero, Peter Cowman, Sophie Dove, Francois Dufois, Jim Falter, Sylvain Forêt, Sofia Fortunato, Miguel Gongalez-Rivero, Hugo Harrison, Ove Hoegh-Guldberg, Michael Kingsford, Andreas Kubicek, Bill Leggat, Janice Lough, Ryan Lowe, Vimoksalehi Lukoschek, David Miller, Aurélie Moya, Philip Munday, Stephen Palumbi, Morgan Pratchett, Jodie Rummer, Eugenia Sampayo, Verena Schoepf, Greg Torda, Madeleine van Oppen, Heather Veilleux, Sue-Ann Watson, Bette Willis.

PHOTO TORY CHASE

PHOTO ED ROBERTS - TETHYS IMAGES

Program 3 aims to understand the responses of coral reef organisms to rapidly changing local and global environments. Our goal is to advance fundamental knowledge of processes underpinning reef resilience in three vital areas: the dynamics of coral-microbial associations that govern coral health, the integrity of carbonate reef frameworks that provide the foundation of the coral reef ecosystem, and the capacity of coral reef organisms to adapt to a challenging future. Such knowledge is key to understanding the future sustainability of coral reefs and the ecosystem services they provide to societies and economies.

In 2016, Program 3 hosted two working group meetings to address our research goals. During a 3-day meeting at the ARC Centre's University of Western Australia node, Chief Investigators Sophie Dove, David Miller, Ryan Lowe, Morgan Pratchett and Malcolm McCulloch worked with research fellows and external and international participants to synthesise existing knowledge of the response of reef carbonate frameworks to environmental change. A second working group meeting organised by Greg Torda, Jenni Donelson, Bette Willis and Philip Munday investigated rapid adaptive responses to climate change on coral reefs. Twenty leading coral reef scientists and invited experts, including participants from ARC Centre research partners at the Australian Institute of Marine Science, King Abdullah University of Science and Technology (KAUST) and five other institutions, assessed the effects of transgenerational plasticity and other evolutionary responses to buffer coral reef species from climate change.

The ARC Centre and KAUST also co-hosted a working group meeting in October to plan research activities within the new $US1.4m Cooperative Research Grant awarded by KAUST to Philip Munday and Jodie Rummer (ARC Centre) and Timothy Ravasi, Michael Berumen and Valerio Orlando (KAUST). The project entitled *Genomic evidence for adaptation of marine fishes to ocean acidification* links unique multigenerational experiments conducted at the ARC Centre with cutting-edge molecular analyses at KAUST to investigate the molecular basis for adaptation to ocean acidification in reef fishes.

Program 3 continued its outstanding contribution to understanding the implications of a changing climate for coral reefs. In a seminal paper in *Science*, Tracy Ainsworth and Bill Leggat in collaboration with Program 2's Peter Mumby, showed that previous coral bleaching events have involved temperature trajectories that subject corals to a sub-bleaching stress that can decrease subsequent loss of symbionts by ~50% (p33). Program 3 researchers at all of the Centre's nodes were active participants in the National Coral Bleaching Taskforce. For example, Verena Schoepf, Steeve Comeau, Christopher Cornwall and Ryan Lowe surveyed reefs in Western Australia and assessed drivers of change during the 2016 bleaching event. These surveys showed that almost all inshore Kimberley reefs had 30-60% bleaching, which is unprecedented according to local Indigenous Rangers and Traditional Owners.

Program 3 produced further ground breaking research on the impacts of ocean acidification on reef organisms in 2016. Using 3D x-ray microscopy, PhD student Taryn Foster, and her supervisors Jim Falter and Malcolm McCulloch demonstrated, in a paper published in *Science Advances*, that ocean acidification causes deformities in the skeletons of newly-settled corals (p32). In *Global Change Biology*, Aurélie Moya, Greg Torda, Sue-Ann Watson, Sylvain Forêt and David Miller used a multidisciplinary approach to reveal that ocean acidification alters calcification and metabolism of sea snails that are ubiquitous in marine environments. In *Nature Climate Change*,

PhD student Megan Welch and Philip Munday, together with collaborators from KAUST, found novel evidence in the brain transcriptome of fish's offspring for the heritability of tolerance to higher CO_2 levels.

New research by Program 3 revealed the impacts of changes to local environmental conditions, including declining water quality, on coral reefs. In *Scientific Reports*, PhD student Kathryn Berry and Mia Hoogenboom, together with collaborators from AIMS, quantified the impacts of chronic exposure to suspended coal particles on coral survival, and on the growth of reef fish and seagrasses. Pim Bongaerts and Sophie Dove reported in *Coral Reefs* that the capacity of corals to remove sediment from their tissues depends on water temperature, providing new insight into the capacity of corals to tolerate periods of increased sedimentation. In *Proceedings of the Royal Society B*, Centre alumnus Joleah Lamb, Amelia Wenger and Bette Willis showed that the prevalence of coral disease is lower inside marine reserves than on unprotected reefs, following chronic exposure to terrestrial run-off from a degraded river catchment, highlighting the links between water quality and coral condition.

In a major multi-nodal collaborative project, Program 2 and 3's Mia Hoogenboom, Sean Connolly, Andrew Baird and John Pandolfi, together with numerous international collaborators, published a major paper in *Trends in Ecology and Evolution*, led by ARC Centre alumnus Joshua Madin. The paper developed a new trait-based approach to understand the biology of reef building corals and to protect ecosystem function in the future by linking species traits to ecosystem functions. A related publication in the journal *Scientific Data* collated coral trait data, drawing on the ongoing research of many additional ARC Centre researchers, including Kristen Anderson, Tom Bridge, Janice Lough, Morgan Pratchett and PhD students Chaoyang Kuo and Ed Roberts.

Program 3 conducted multiple outreach and capacity-building activities during 2016. For example, Ryan Lowe and Andrew Pomeroy led a one week long professional training course in Mauritius on integrated coastal zone management, hosted by the University of Mauritius and the Ministry of Environment. The course was attended by over 30 local professionals who are employed as coastal and marine managers and educators. Bette Willis conducted a coral identification workshop at the 13th International Coral Reef Symposium in Hawaii where she also chaired a public forum on *Threats and management of coral diseases across the Indo-Pacific*.

PHOTO CATHERINE KIM

"I am acutely aware of the need to provide science that underpins the sustainable management of coral reefs. It's a key responsibility for researchers who work on this important ecosystem".

Bette Willis (p65)

20 FEB
2016

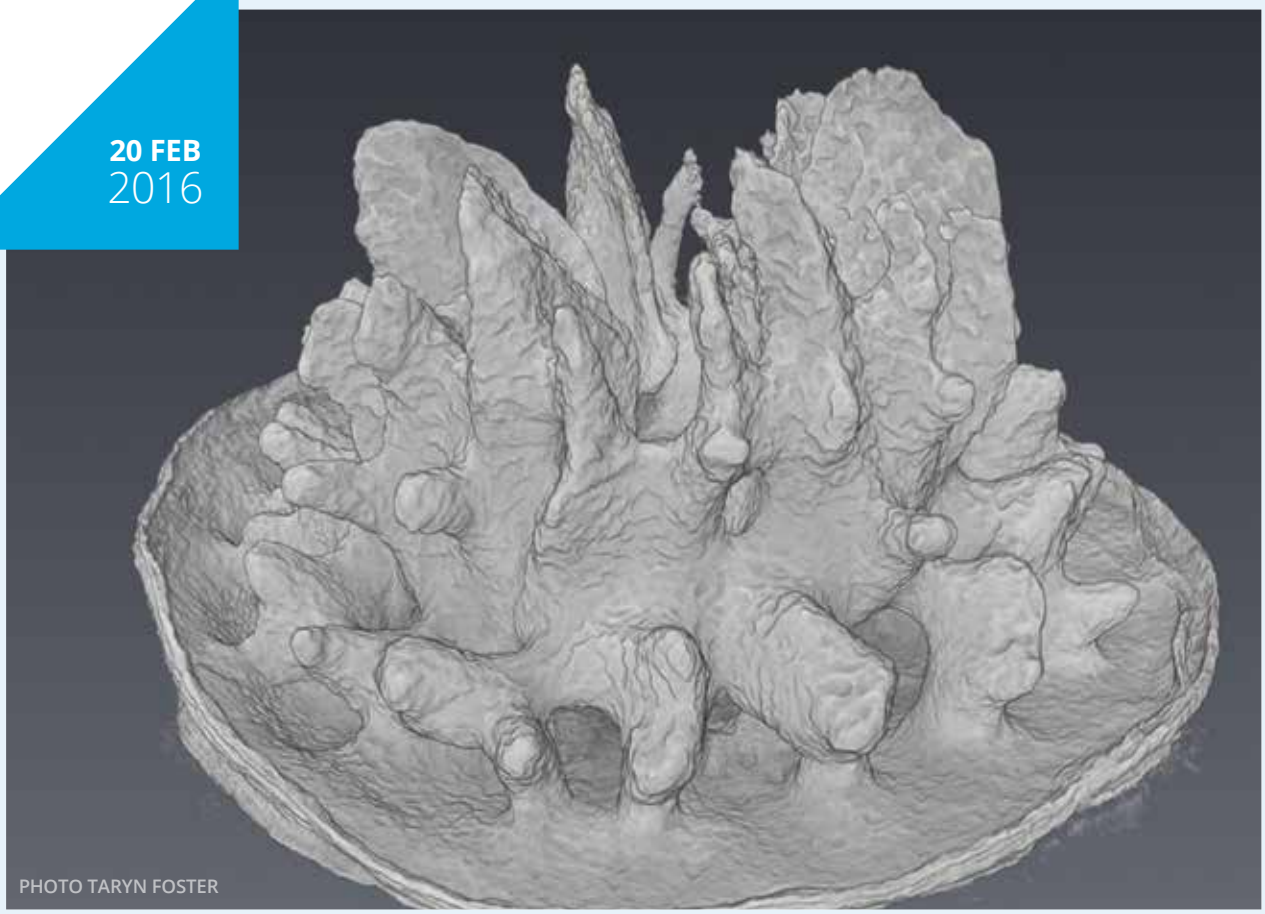


PHOTO TARYN FOSTER

MEDIA RELEASE

OCEAN ACIDIFICATION CAUSES DEFORMITIES IN YOUNG CORAL SKELETONS

Ocean acidification could lead to smaller, more porous and malformed skeletons in coral recruits by 2100 say a team of scientists from the ARC Centre of Excellence for Coral Reef Studies and the University of Western Australia.

"New coral recruits are only about 1 mm in diameter and so they are more vulnerable to stressors like predation, overgrowth and damage from storms," explains Taryn Foster author of the paper, which was published this week in the journal *Science Advances*, an online journal of *Science*.

"They need to be able to build robust skeletons and do this quickly, in order for them to move out of these small and vulnerable size classes. Unfortunately, ocean acidification is making this task more difficult."

"We mimicked the oceanic conditions predicted to occur under a 'business-as-usual' emissions scenario, elevating both the water temperature and CO_2 levels. We then used 3D X-ray microscopy and scanning electron microscopy to both visualise and quantify changes in the skeletal formation and found that coral recruits were unable to build normal skeletons under acidified conditions."

"Not only did we record reduced overall skeletal deposition, but we also observed a number of deformities in the skeletons grown under high CO_2. These ranged from gaps, fractures and disrupted symmetry to large sections of missing skeleton. We also saw deep pitting and a corroded-looking skeletal surface in the high CO_2 corals."

"One encouraging and surprising finding was that elevated temperature didn't seem to exacerbate the effects of high CO_2. Instead we saw the opposite effect, with elevated temperature having a mitigative effect under acidified conditions. But we think this response will only be seen in sub-tropical and temperate corals such as those used in this study, which were from the sub-tropical Houtman Abrolhos Islands."

"This study exposes for the first time, changes to the structure of the coral recruit skeleton under predicted ocean acidification. Using 3D X-ray microscopy has made it possible to measure internal structures, volume and look at each individual X-ray slice; things that are impossible to do using conventional 2D imaging methods. It also makes it much easier to communicate the changes that ocean acidification could cause in these tiny animals, which are essential for replenishing the reef and recovery after disturbances."

Foster, T, Falter, JL, McCulloch, MT and Clode, PL (2016). Ocean acidification causes structural deformities in juvenile coral skeletons. *Science Advances* 2(2):e1501130.

PHOTO BILL LEGGAT

15 APR
2016

MEDIA RELEASE

GREAT BARRIER REEF RISKS LOSING TOLERANCE TO BLEACHING EVENTS

A new study has found that Great Barrier Reef (GBR) corals were able to survive past bleaching events because they were exposed to a pattern of gradually warming waters in the lead up to each episode. However, this protective pattern is likely to be lost under near future climate change scenarios.

In a paper published in *Science*, researchers from the ARC Centre of Excellence for Coral Reef Studies (Coral CoE) and the USA National Oceanic and Atmospheric Administration (NOAA) investigated what this warming pattern means for GBR coral bleaching events into the future.

Lead author Dr Tracy Ainsworth from the Coral CoE at James Cook University explains that bleaching is like a marathon for corals. "When corals are exposed to a pre-stress period in the weeks before bleaching, as temperatures start to climb, this acts like a practice run and prepares the coral. Corals that are exposed to this pattern are then less stressed and more tolerant when bleaching does occur."

The researchers found that this "practice run" induces heat shock responses in the coral that reduce their severity of bleaching and mortality. The protective "practice run" was observed in three-quarters of stress events that occurred on the GBR in the past three decades.

The pre-stress conditions are expected to disappear when seawater temperatures rise by as little as 0.5°C, such as predicted for the near future. Corals will then instead be directly exposed to stress events.

"When corals lose the practice run, there is no break, or "relaxing" for the corals as summer stress develops," explains co-author Dr Scott Heron, from Coral Reef Watch at NOAA. "In future summers, bleaching events will occur more often and, without the practice run, become even more severe—with a greater risk for coral mortality and a fast decline in coral cover across reefs."

The study examined 27 years worth of satellite data for sea surface temperatures, previous coral bleaching events, and studied how corals responded to different seawater warming conditions.

Under future climate change predictions, different reefs on the GBR will lose their protective mechanism at different rates. The study recommends that reefs able to retain the "practice run" of protective conditions prior to bleaching be given high priority for conservation efforts.

Associate Professor Bill Leggat, adds, "Knowing which temperature patterns are present on different reefs, how these impact coral survival and their capacity to recover from bleaching, and how quickly changes in these patterns occur, will inform reef management. This knowledge will help managers increase the likelihood of coral surviving bleaching events in the future by reducing the impact of other stressors, such as pollution and over-use, at both local and regional scales."

Professor Peter Mumby from the Coral CoE at UQ, concludes, "Our results underscore, once again, the importance of global action to reduce greenhouse gas emissions. We can still have a beautiful reef if people are willing to change behaviour."

Ainsworth, TD, Heron, SF, Ortiz, JC, Mumby, PJ, Grech, A, Ogawa, D, Eakin, CM and Leggat, W (2016). Climate change disables coral bleaching protection on the Great Barrier Reef. *Science* 352(6283): 338-342.

RESEARCHER PROFILE

DR STEEVE COMEAU

Steeve Comeau is an ARC Discovery Early Career Researcher Award (DECRA) Fellow in Program 3 at the University of Western Australia node of the ARC Centre. His curiosity for the marine environment was fostered at an early age as he spent his childhood living near the Mediterranean Sea. Steeve was awarded his Bachelors and Masters Degrees in biology and ecology from the Université Aix-Marseille II, in France. His desire to continue studying marine organisms as a PhD student enticed Steeve to move from the almost warm waters of the south of France, to the icy seas of the Arctic.

Steeve's PhD research, at the Laboratoire d'Oceanographie de Villefranche, Université Pierre et Marie Curie, in Paris assessed the impact of environmental change on *Thecosomata* pteropods in the Arctic Sea. *Thecosomata* pteropods, also known as sea butterflies, are zooplanktonic organisms that perform a critical role in marine foodwebs. Steeve was the first to demonstrate that ocean acidification affects pteropod calcification and the functioning of marine ecosystems. His thesis' significant contribution to marine science was recognised with an award from the Foundation of Albert II, from the Oceanographic Institute, in Monaco.

After completing his PhD in 2010, Steeve moved across the Atlantic to join the California State University (CalState) as a postdoctoral Research Fellow. It was during this fellowship that Steeve's research interests expanded to include coral reefs. Steeve says he "has always been interested by the impact of humans on the ocean. Working on coral reefs represented a unique opportunity to contribute to the understanding of this highly threatened emblematic ecosystem".

While at the CalState, Steeve conducted research on coral reefs across the Pacific Ocean, including French Polynesia, Hawaii and Japan. He used a multiscale approach to investigate the effects of ocean acidification on calcification mechanisms, organisms and biological communities. He also assessed the effects of other environmental parameters (e.g. temperature, nutrient, light, and water flow) on corals and coralline algae. Steeve's research predicted that ocean acidification will reduce the capacity of reef calcifiers to form extensive reefs, but also demonstrated the potential resistance of some organisms to ocean acidification.

In 2015, Steeve joined the ARC Centre at the University of Western Australia node to continue his research on the effects of global change on coral reefs. Soon after joining the ARC Centre, he was awarded an ARC DECRA to develop a new understanding of coral calcification and their ability to acclimate to climate change. According to Steeve, "the formation of mineral skeleton by coral is the key process controlling the creation of reef structures upon which the entire ecosystem depends. Despite the importance of corals to ecosystem function, how calcification works, and why small modifications of their physical and chemical environment can have large effects on growth, is poorly understood".

Steeve's DECRA project uses geochemical proxies, including boron isotopes, to study how ocean acidification affects coral calcification mechanisms. His experiments are primarily carried out in the recently refurbished Indian Ocean Marine Research Centre at Watermans Bay, Perth. Steeve and his colleagues have developed a complex experimental system that tightly regulates multiple environmental parameters, such as pH variability and flow, to examine how they affect calcification and growth of corals. His experimental research is supported by fieldwork that extends from the remote Kimberley region in the north to Rottnest Island in the south, where Steeve studies the role of seasonal and daily environmental variability on reef calcification. Ultimately, Steeve envisions his research at the ARC Centre providing "the basic knowledge to improve our ability to assess the future of corals, and to help policy-makers take adequate measures to preserve coral reefs".


PHOTO CLAIRE ROSS

15 JUN
2016

ARTICLE

SUPER-CORAL MAY TAKE HEAT OFF GREAT BARRIER REEF BLEACHING

By Peter Spinks

Australian scientists are studying a heat-resistant strain of super-corals that could withstand the rising ocean temperatures causing devastating bleaching of the Great Barrier Reef.

The breakthrough research raises hopes of one day counteracting some of the effects of coral bleaching, which are ravaging large parts of the reef.

"Knowing how corals cope with heat stress is critical to understanding if and how they may be able to adapt to climate change," said lead researcher Verena Schoepf of the University of Western Australia in Perth.

Living corals are co-operative communities of myriad tiny polyps that live in symbiosis with algae and trap food from the tides. The algae in the coral tissues help build stony skeletons, which form reefs.

When subjected to heat and other stresses, these algae are sometimes ejected, revealing a coral's bright white skeleton.

Dr Schoepf studied the highly resilient corals off WA's Kimberley coast that can tolerate huge temperature swings and other environmental nasties that most corals would not survive.

"I wanted to find out why these potentially super-corals were used to extreme temperature fluctuations as well as exposure to the air due to the region having the world's biggest tropical tides," Dr Schoepf said.

She simulated heat stress in aquarium tanks in the Kimberley and found that corals used to the extreme conditions of tide pools were more resistant to heat stress than those in less extreme sub-tidal zones.

"We found that neither tide pool nor sub-tidal corals were immune to coral bleaching," she said. "This meant that the extreme environment of the Kimberley made coral more resistant to heat waves but not to climate change."

This year the researchers discovered that the strong El Niño event triggered severe bleaching on many Kimberley reefs, further confirming that even these corals were affected by climate change.

"We are now examining the physiological and genetic mechanisms that underlie the superior capacity of Kimberley corals to cope with heat stress," Dr Schoepf said. "We'll also conduct experiments on how long they can maintain this capacity in much cooler waters."

But she cautioned that transplanting corals from one region to another had many risks. "So, right now, we are not planning on doing this," she said.

Today, our planet's coral treasures stretch for little more than 500,000 square kilometres – roughly twice the size of the British Isles – compared with 20 times that area for tropical forest. About two-thirds of reefs have already been lost and many of those remaining are in poor shape.

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NATIONAL PRIORITY CASE STUDY

THE 2016 CORAL BLEACHING EVENT

Record breaking temperatures during the 2015/2016 El Niño event severely affected the world's coral reefs, threatening the livelihoods and food security of many millions of people. In Australia, climate change has long been recognised as the number one threat to coral reefs, including iconic World Heritage Areas such as the Great Barrier Reef, Ningaloo Reef, Shark Bay, and Lord Howe Island. Severe thermal stress causes corals to lose their colour (bleaching), and if prolonged, bleaching causes heavy mortality. The loss of corals has broader impacts on other species, including commercially important fisheries. Understanding how to manage the impacts of climate change on these systems, and how to secure the critical ecosystem services they provide to people, is a key national benefit provided by the ARC Centre.

Members of the National Coral Bleaching Taskforce from the ARC Centre of Excellence for Coral Reef Studies, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority, Museum of Tropical Queensland and the National Oceanic and Atmospheric Administration (USA) gather to discuss survey strategy of the Great Barrier Reef

The global bleaching event was anticipated by the Australian Bureau of Meteorology, and by the US National Oceanographic and Atmospheric Administration (NOAA). In advance of the likelihood of major bleaching and mortality of corals on both the east and west coast of Australia, Centre Director Terry Hughes convened the National Coral Bleaching Taskforce in November 2015. The Taskforce consists of a network of leading researchers from 11 institutions and agencies, comprising over 300 scientists and reef managers. In December 2015 – February 2016, the Taskforce leaders in Townsville, Brisbane, Canberra and Perth convened repeatedly to formulate and coordinate research plans. The disciplinary breadth of the ARC Centre's Program structure allowed us to measure and understand the impact of bleaching nation-wide at the cellular, individual, population, and community level.

Summer temperatures in February-April 2016 caused severe and widespread coral bleaching around Australia (Figure 1). On the east coast, this is the third mass bleaching event for the Great Barrier Reef (GBR) and 93% of reefs were affected. In the remote northern 800km sector of the GBR (including the Torres Strait), >80% of reefs have been severely bleached with heavy losses of corals. More than half of the shallow-water corals between Cairns and Papua New Guinea died between February and October 2016. The Taskforce also documented severe bleaching in the Torres Strait, northern Coral Sea, and in Western Australia.

Our research findings – particularly our intensive aerial surveys of the GBR undertaken in March and April - were used on a daily basis by State and Commonwealth agencies. Underwater, Centre researchers checked the accuracy of the aerial scores, and measured an unprecedented shift in the species composition of corals, as susceptible species died. In collaboration with NOAA, we showed that the geographic pattern of bleaching in 1998, 2002 and 2016 is explained very precisely by patterns of thermal stress. The initial findings of our research will be published as the cover article in the March 16th 2017 issue of *Nature*. The article, led by Centre Director Terry Hughes has 46 authors from 21 institutions.

Throughout 2016, Centre researchers provided dozens of briefings to State and Commonwealth Ministers, the Great Barrier Reef Marine Park

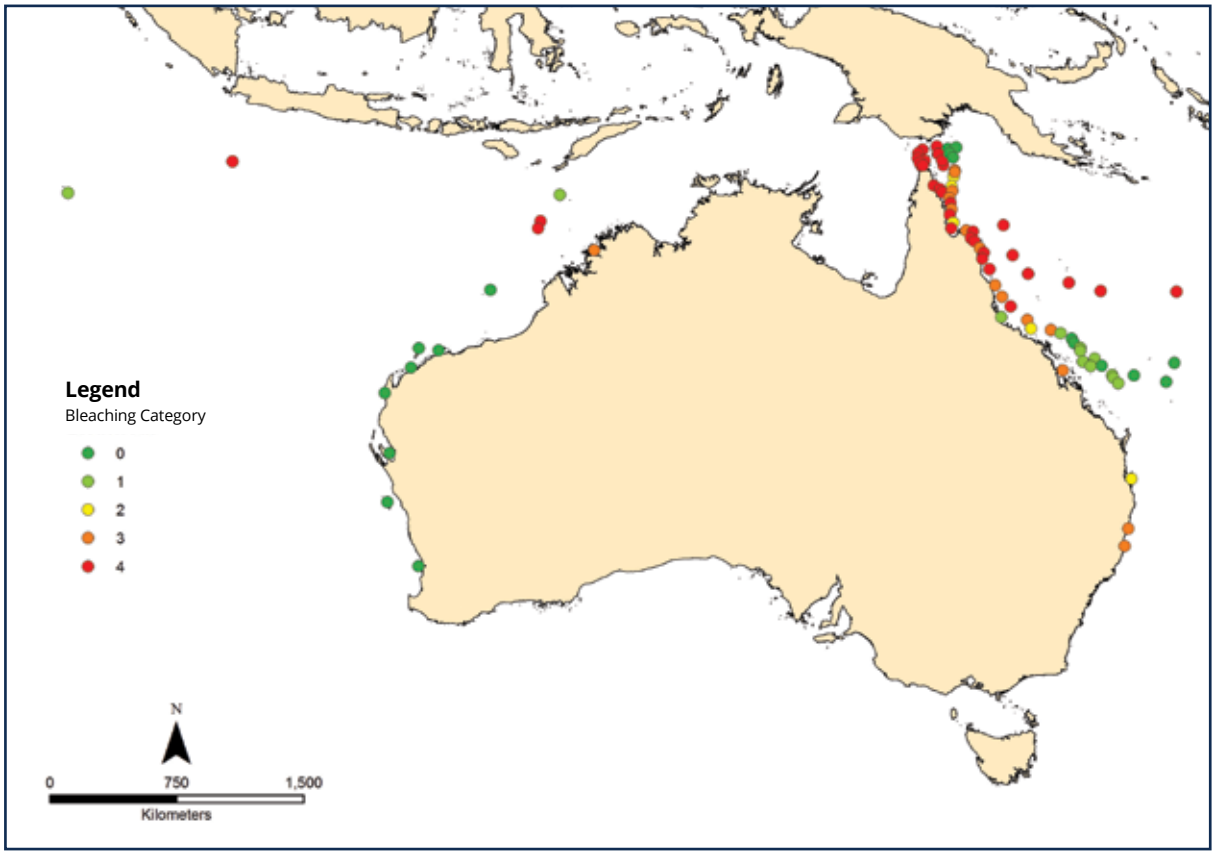

Figure 1: *The National Coral Bleaching Taskforce documented the impacts of climate change in 2016 at an unprecedented continental scale.*

Authority, and to multiple State agencies in Queensland, New South Wales and Western Australia. Public interest in the global bleaching has been intense – with over 5,000 media uptakes of the Centre's research on the bleaching event in April to June 2016 alone.

The unprecedented bleaching event presented both a challenge and an opportunity to the ARC Centre. It was a major test of the Centre's leadership, of our agility to respond at a national scale, and of the Centre's inter-nodal cohesion. It provided us with the opportunity to improve the strength and effectiveness of our external partnerships, to harness the multi-disciplinary expertise across the Centre's research programs, and to ensure rapid research uptake by governments and end-users, and to communicate our research findings globally.

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PHOTO TORY CHASE

ARTICLE

HOW MUCH CORAL HAS DIED IN THE GREAT BARRIER REEF'S WORST BLEACHING EVENT?

By Terry Hughes, Britta Schaffelke (AIMS), James Kerry and David Wachenfeld (GBRMPA)

Two-thirds of the corals in the northern part of the Great Barrier Reef have died in the reef's worst-ever bleaching event, according to our latest underwater surveys.

On some reefs in the north, nearly all the corals have died. However the impact of bleaching eases as we move south, and reefs in the central and southern regions (around Cairns and Townsville and southwards) were much less affected, and are now recovering.

In 2015 and 2016, the hottest years on record, we have witnessed at first hand the threat posed by human-caused climate change to the world's coral reefs.

Heat stress from record high summer temperatures damages the microscopic algae (zooxanthellae) that live in the tissues of corals, turning them white.

After they bleach, these stressed corals either slowly regain their zooxanthellae and colour as temperatures cool off, or else they die.

The Great Barrier Reef bleached severely for the first time in 1998, then in 2002, and now again in 2016. This year's event was more extreme than the two previous mass bleachings.

SURVEYING THE DAMAGE

We undertook extensive underwater surveys at the peak of bleaching in March and April, and again at the same sites in October and November. In the northern third of the Great Barrier Reef, we recorded an average (median) loss of 67% of coral cover on a large sample of 60 reefs.

The dieback of corals due to bleaching in just 8-9 months is the largest loss ever recorded for the Great Barrier Reef.

To put these losses in context, over the 27 years from 1985 to 2012, scientists from the Australian Institute of Marine Science measured the gradual loss of 51% of corals on the central and southern regions of the Great Barrier Reef.

They reported no change over this extended period in the amount of corals in the remote, northern region. Unfortunately, most of the losses in 2016 have occurred in this northern, most pristine part of the Great Barrier Reef.

BRIGHT SPOTS

The bleaching, and subsequent loss of corals, is very patchy. Our map shows clearly that coral death varies enormously from north to south along the 2,300km length of the Reef.

The southern third of the Reef did not experience severe heat stress in February and March. Consequently, only minor bleaching occurred, and we found no significant mortality in the south since then.

In the central section of the Reef, we measured widespread but moderate bleaching, which was comparably severe to the 1998 and 2002 events. On average, only 6% of coral cover was lost in the central region in 2016.

The remaining corals have now regained their vibrant colour. Many central reefs are in good condition, and they continue to recover from Severe Tropical Cyclones Hamish (in 2009) and Yasi (2011).

In the eastern Torres Strait and outermost ribbon reefs in the northernmost part of the Great Barrier Reef Marine Park, we found a large swathe of reefs that escaped the most severe bleaching and mortality, compared to elsewhere in the north. Nonetheless, 26% of the shallow-water corals died.

We suspect that these reefs were partially protected from heat stress by strong currents and upwelling of cooler water across the edge of the continental shelf that slopes steeply into the Coral Sea.

For visitors, these surveys show there are still many reefs throughout the Marine Park that have abundant living coral, particularly in popular tourism locations in the central and southern regions, such as the Whitsundays and Cairns.

DARKSPOTS

The northern third of the Great Barrier Reef, extending 700km from Port Douglas to Papua New Guinea, experienced the most severe bleaching and subsequent loss of corals.

On 25% of the worst affected reefs (the top quartile), losses of corals ranged from 83-99%. When mortality is this high, it affects even tougher species that normally survive bleaching.

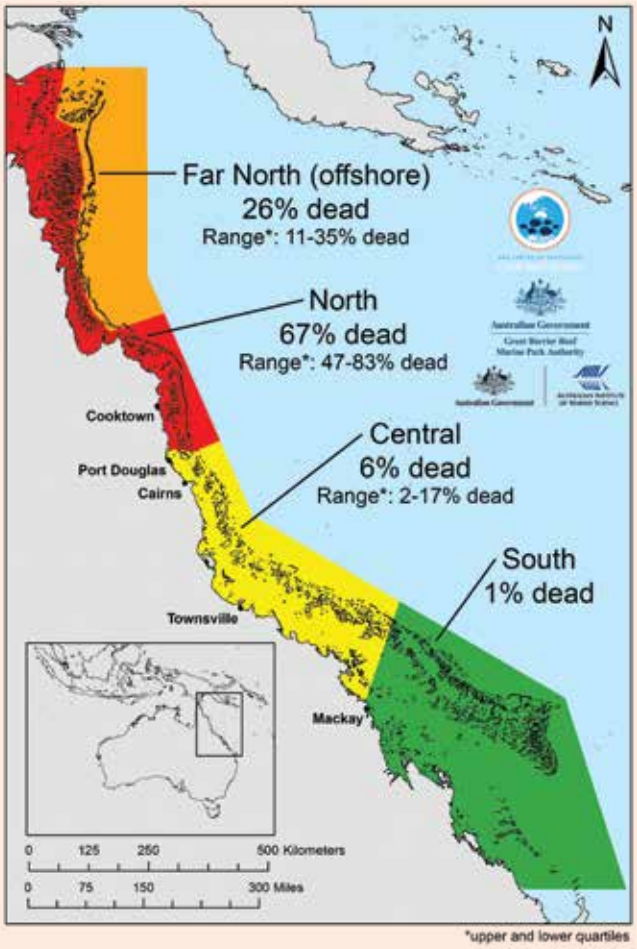
However, even in this region, there are some silver linings. Bleaching and mortality decline with depth, and some sites and reefs had much better than average survival. A few corals are still bleached or mottled, particularly in the north, but the vast majority of survivors have regained their colour.

WHAT WILL HAPPEN NEXT?

The reef science and management community will continue to gather data on the bleaching event as it slowly unfolds. The initial stage focused on mapping the footprint of the event, and now we are analysing how many bleached corals died or recovered over the past 8-9 months.

Over the coming months and for the next year or two we expect to see longer-term impacts on northern corals, including higher levels of disease, slower growth rates and lower rates of reproduction. The process of recovery in the north – the replacement of dead corals by new ones – will be slow, at least 10-15 years, as long as local conditions such as water quality remain conducive to recovery.

As global temperatures continue to climb, time will tell how much recovery in the north is possible before a fourth mass bleaching event occurs.



*upper and lower quartiles


PHOTO GREG TORDA

THE CONVERSATION

Original article
https://theconversation.com/how-much-coral-has-died-in-the-great-barrier-reefs-worst-bleaching-event-69494

WOMEN IN SCIENCE

The Australian Government Department of Education and Training report that women are underrepresented across science, technology, engineering, mathematics and medicine (STEMM), particularly at senior levels. Science in Australia Gender Equity (SAGE) is addressing this problem via a program of activities designed to improve gender equity and diversity and the promotion and retention of women. In 2016, Research Fellows at the ARC Centre were active participants in the implementation of SAGE's Athena Scientific Women's Academic Network (SWAN) pilot program. The pilot program ran training workshops this year on gender equity and provides gender equity accreditation for participating organisations.

The ARC Centre has implemented multiple policies and actions to address gender equity and diversity across the Centre's nodes. For example: eligible staff have access to parental leave and return to work on flexible working arrangements, and Research Fellows with children can apply for ARC Centre support to attend meetings and conferences. A Key Performance Indicator for the Centre is 50:50 recruitment of female and male Research Fellows.

The Department of Education and Training estimate that the proportion of female academic and research staff in the field of natural and physical sciences is 39%. In comparison, the ARC Centre has a slight majority, 53%, of university-based research scientists. However, women continue to be underrepresented at senior levels. In 2016, two outstanding female researchers, Jodie Rummer and Tracy Ainsworth, were promoted to Principal Research Fellows, and a third, Chief Investigator Mia Hoogenboom was promoted to Associate Professor. The ARC Centre also improved the representation of women in leadership roles, appointing Mia to Program Leader and Alana Grech to Assistant Director.

In 2016, the Centre welcomed 5 new female Research Fellows and 19 female PhD students. We also bid farewell to Program Leader Professor Bette Willis who retired at the end of the year (p65). Bette is a pioneer in the field of coral disease ecology, whose accomplishments were recognised in 2016 by an *Eminence in Research Award* from the International Society for Reef Studies.

Lauren Nadler (PhD student): 2016 Young Scientist Award, Society for Experimental Biology

PHOTO SHAUN KILLEN

JENNI DONELSON

Jenni Donelson joined the ARC Centre's JCU node in early 2016 to study the responses of coral reefs to climate change, in collaboration with our colleagues at King Abdullah University of Science and Technology, in Saudi Arabia. Before moving to the ARC Centre, Jenni was awarded a prestigious Chancellor's Postdoctoral Research Fellowship at the University of Technology, Sydney. Jenni has received multiple accolades for her research in 2016, including a *Young Tall Poppy Science Award*, a Lizard Island *Isobel Bennett Marine Biology Fellowship,* and a Sea World Research and Rescue Foundation Grant. Jenni is currently Treasurer of the Australian Coral Reef Society.

CARRIE SIMS

Carrie Sims joined the ARC Centre's UQ node as a graduate student in 2016 to study the biology, ecology and evolution of coral reef organisms. In the first year of her PhD, Carrie was awarded one of 17 inaugural *Westpac Future Leaders Scholarships* by the Westpac Bicentennial Foundation. The prestigious scholarship provides Carrie with $118,000 to support her PhD research and access to a nine-month Leadership Development Program. The goal of the program is to enhance leadership capabilities and create career pathways.

VERENA SCHOEPF

Verena Schoepf was recruited by the ARC Centre's UWA node in 2013, the same year she completed her PhD at The Ohio State University, USA. Her research explores the effects of warming and acidifying oceans on the physiology and geochemistry of corals. Verena performed an integral role in the National Coral Bleaching Taskforce by leading and coordinating fieldwork activities in Western Australia (p35). She contributed to the Centre's outreach in 2016 by presenting the results of her bleaching research in articles for *The Conversation* and *Australian Geographic*, and in interviews with *The New York Times, The Age, ABC News* and others.

TRACY AINSWORTH

Tracy Ainsworth joined the Centre in 2008 after receiving a prestigious ARC Postdoctoral Fellowship. Subsequently, she was awarded an ARC Super Science Research Fellowship. Tracy has chaired the ARC Centre's postdoctoral committee and plays an active role in the mentoring of Early Career Research Fellows, in particular women. In 2016, she published two first-author papers in the journal Science (p33) and was promoted to Principal Research Fellow at the ARC Centre. Tracy has also previously won a prestigious *L'Oreal-UNESCO Women in Science Fellowship*.

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THE AUSTRALIAN Women's Weekly

Women of the reef

The Great Barrier Reef is the largest, most spectacular living structure on earth and one of its seven natural wonders. **Samantha Trenoweth** meets four women for whom the reef is more than an Australian icon – it's home.

PHOTOGRAPHY ● **NICK SCOTT** STYLING ● **LEDA ROSS**

Dr Jodie Rummer
Scientist

Jodie Rummer was born far from the ocean, in Illinois in the US, but she learnt to swim soon after she could walk and, at six, she was given a mask and snorkel. "That was my first glimpse of maybe being a fish," she says, laughing.

Jodie spent long mid-western summers submerged in pools and lakes and, during the school term, she was a "science geek – obsessed with nature documentaries, *National Geographic Explorer* and Jacques Cousteau".

At university, she enrolled in a field course in Jamaica and the study of coral reef fish became her life's work. When she heard that the ARC Centre of Excellence for Coral Reef Studies at James Cook University was looking for a marine physiologist, she had her CV in the mail before you could say "Nemo".

The 39-year-old scientist says that her first glimpse of the reef "... was like seeing the Holy Grail. It was like, 'Here I am and this is what I've been working towards my whole life.' I was wide-eyed, awestruck. I felt like a kid."

So it was heartbreaking to witness the historic bleaching event this year.

"I was there in February and March," she says. "We started to get daytime low tides and the water became warmer. On February 20, the dive computers on our wrists gave spot readings of 34°C. That was insanely warm for these reefs – even 31°C is very warm. We thought, 'Wow, this isn't going to be good, bleaching will start now.'

"The water became murky – death was in the water. The corals began fluorescing and then they turned white. It became a seascape of bleached white coral. I've never seen destruction like that in my life."

The high temperatures were caused by an El Niño weather pattern, compounded by global warming, and the result was the most severe bleaching since records began. Yet even after an event like that, Jodie maintains that the reef can be saved.

"It depends on what we're willing to accept. Are we willing to accept this is the new normal? I'm not," she insists. "The elephant in the room is climate change. We need to reduce carbon emissions. I don't think we say it's over. I don't think we just let it burn."


1 SEP
2016
“Death was in the water ... I’ve never seen destruction like that in my life.”
THESE IMAGES HAVE BEEN RETOUCHED.

Our aim is to build human capacity and expertise in coral reef science worldwide. Our success is reflected in the Centre's 149 international students from 43 countries and that 80% of our Early Career Researchers are from overseas.

PHOTO ED ROBERTS - TETHYS IMAGES

GRADUATE AND EARLY CAREER TRAINING

The ARC Centre is the world's largest provider of graduate training for coral reef research. During 2016, the Centre supported 206 research students across four nodes. Almost 80% of the Centre's graduate students are enrolled in PhD research, with the remainder pursuing Honours or Masters degrees. Fifty-nine students graduated in 2016, while 39 new students enrolled in research degrees across the Centre's four nodes. The Centre also supports 28 Early Career Researchers (ECRs), who are within 5 years of their PhD.

The ARC Centre attracts students and ECRs from around the world. In 2016, 149 international students came from 43 countries. More than 80% of ECRs in the Centre also come from overseas.

The ARC Centre provides many outstanding mentoring and training opportunities to research students and ECRs. Each ECR is provided with individualised mentoring in a career development and performance management program. To further enhance mentoring, in 2016, the ARC Centre invited several leading researchers from across Australia to meet with students and ECRs. These included Professor Emma Johnston (University of New South Wales) and Professor Jenny Martin (Griffith University). The invited speakers covered a range of topics. For instance, in April, Jenny discussed gender imbalance and career planning with ECRs and students, and in August, Emma facilitated two sessions on career pathways.

In 2016, the ARC Centre continued to support the advancement of quantitative and modelling skills, an area of professional development highlighted by feedback between students, ECRs and established researchers. Research Fellow Peter Cowman led a one-day workshop in June with 25 students and six researchers on data manipulation in R. To further develop this critical skills set, Dr Murray Logan from the Centre's Partner Institution, the Australian Institute of Marine Sciences, will lead an advanced workshop, Statistics in R, for 30 Centre students and researchers in February 2017.

The ARC Centre also provides advice to ECRs and postgraduates on the preparation of journal articles, and on grant, fellowship and award applications. Kylie Simmonds, the Centre's communications manager, supports the outreach activities of ECRs, postgraduate students and more senior researchers across the Centre's nodes.

The ARC Centre sponsors both a postdoctoral committee and a research student committee. In 2016, a major focus for both committees was the 13th International Coral Reef Symposium (ICRS) held in Hawaii in June. Held once every four years only, ICRS offers a unique opportunity for graduate students to present their PhD research at the world's largest and premiere coral reef studies forum, and to network with research leaders. To facilitate this professional development activity, the ARC Centre provided $100K in conference travel support to assist students to attend. The Centre provided 148 talks and posters at this forum, many of them delivered by students.

Almost 100 postgraduate students from around the world attended the ARC Centre's Mentoring Workshops held in Hawaii during the International Coral Reef Symposium. Students were trained by Centre researchers in developing effective scientific presentations (Michele Barnes and Josh Cinner), getting the most out of conferences (John Pandolfi), and communicating with the media (Kylie Simmonds). Josh Cinner and Terry Hughes also presented a one-day workshop on getting published.

In 2016, the student committee was chaired by Zara-Louise Cowan and Katie Peterson. Other members were Michelle Achlatis, Brock Bergseth, Rebecca Green, Catherine Kim, Eva McClure, Laura Puk, Veronica Radice, Laura Richardson, Ed Sacre, and Oda Waldeland. Graduate Co-ordinator Olga Bazaka and Chief Operations Officer Jennifer Lappin continued to provide invaluable assistance to the student committee in 2016.

The student committee enjoyed a busy and productive 2016. Highlights included a writing workshop and training for *My Research in 3 Minutes* with experienced journalist and author Dr Liz Tynan, a two-day workshop on careers in conservation and management led by Dr Laurence McCook and Jon Day, the continuation and expansion of the student-mentor program, and multiple social events. Three additional workshops were provided by Centre researchers Terry Hughes, Andrew Hoey and Morgan Pratchett - in coral taxonomy, research ethics and on reviewing and editing manuscripts.

Research Fellow Jenni Donelson led a five-day student writing retreat in May, in partnership with the Australian Coral Reef Society (ACRS). The retreat was attended by 22 students from across Australia, including 13 ARC Centre students. Centre researchers Andrew Hoey, Mia Hoogenboom, Tom Bridge and Sue-Ann Watson provided intensive writing training to the students, resulting in multiple publications that were ready for peer-review by the close of the retreat.

Awards to ARC Centre students in 2016 included:

- Lauren Nadler received the Society for Experimental Biology's *2016 Young Scientist Award* for her research on behavioural and physiological effects of shoaling in a coral reef fish.
- PhD graduates Mélanie Hamel and Georgina Gurney each received a JCU *Dean's Award for Research Higher Degree Excellence* for their substantial contribution to coral reef studies.
- Carrie Sims received an $118,000 *Westpac Future Leaders Scholarship* to support her research, stipend and leadership development (p41).
- Alexia Graba-Landry was awarded a $28,000 Ian Potter Foundation's *Doctoral Fellowship at Lizard Island*, the ACRS's *Danielle Simmons Prize*, a Sigma Xi *Grants-in-Aid of Research Award,* and an award from the *Holsworth Wildlife Research Endowment*, Equity Trustees Charitable Foundation.
- Kathryn Berry represented James Cook University as a finalist in the *Asia-Pacific Three Minute Thesis (3MT)* competition.
- Zoe Loffler was awarded a $21,000 Ian Potter Foundation *Doctoral Fellowship at Lizard Island.* Zoe also received an ACRS award for her research on the changing susceptibility of *Sargassum* to grazing vs. browsing fishes.
- Rene van der Zande, Matheus Mello-Athayde and Michelle Achlatis were awarded research funding from the *Holsworth Wildlife Research Endowment*, Equity Trustees Charitable Foundation.
- Kristen Brown was awarded a *PADI Foundation Research Grant* and *Holsworth Wildlife Research Endowment*, Equity Trustees Charitable Foundation.
- Vanessa Haller received funding to attend the Australian Mathematical Science Institute (AMSI) Winter School from the BHP Billiton Foundation and AMSI.
- Ashton Gainsford was one of 78 female scientists selected worldwide for the *Homeward Bound* leadership program. As part of the award Ashton travelled to Antarctica for a three-week Women in Science leadership training expedition.
- Kathyrn Berry received the 2016 *Glenn Almany Memorial Prize* for her research on the potential effects of a major coal spill on tropical coral reef organisms. This is the second year that the *Glenn Almany Memorial Prize* has been awarded. Following Glenn's death in 2015, the prize was established in his honour, to inspire the next generation by his belief that research can make a difference in this world. The prize is awarded to a graduate student whose coral reef research required them to work with people beyond traditional academic boundaries to make a difference, or which has the potential to influence policy, management or practice.

  Berry KLE, Hoogenboom MO, Flores F and Negri A (2016). Simulated coal spill causes mortality and growth inhibition in a coral, seagrass and reef fish species. *Scientific Reports* 6: 25894.

- The ARC Centre's annual *Virginia Chadwick Awards* for outstanding first-authored publications by research students were won by Jordan Casey, Taryn Foster, Alejandra Hernandez-Agreda, Jess Hopf and Amin Mohamed:

  Casey JM, Baird AH, Brandl SJ, Hoogenboom MO, Rizzari JR, Frisch AJ, Mirbach CE and Connolly SR (2016). A test of trophic cascade theory: fish and benthic assemblages across a predator density gradient on coral reefs. *Oecologia* 183:161.

  Foster T, Falter JL, McCulloch MT and Clode PL (2016). Ocean acidification causes structural deformities in juvenile coral skeletons. *Science Advances* 2(2): e1501130 (p32).

  Hernandez-Agreda A, Gates RD and Ainsworth TD (2016). Defining the core microbiome in corals' microbial soup. *Trends in Microbiology* 25(2): 125-140.

  Hopf JK, Jones GP, Williamson DH and Connolly SR (2016). Synergistic effects of marine reserves and harvest controls on the abundance and catch dynamics of a coral reef fishery. *Current Biology* 26(12): 1543-1548.

  Mohamed AR, Cumbo V, Harii S, Shinzato C, Chan CX, Ragan MA, Bourne DG, Willis BL, Ball EE, Satoh N and Miller DJ (2016). The transcriptomic response of the coral *Acropora digitifera* to a competent *Symbiodinium* strain: the symbiosome as an arrested early phagosome. *Molecular Ecology* 25(13): 3127-3141.

2016 PHD STUDENTS IN THE ARC CENTRE

Michelle Achlatis	UQ	The Netherlands	Investigating future changes to bioerosion on reefs and potential downstream consequences for carbonate chemistry and calcification rates. (PhD)	S Dove, O Hoegh-Guldberg
Siham Affatta Taruc	UQ	Indonesia	Socio-ecological studies of climate change influence on marine resource and livelihoods of Indonesian small-scale fisheries system. (PhD)	O Hoegh-Guldberg
Catalina Aguilar Hurtado	JCU, ANU	Colombia	Transcriptomic analyses of the responses of corals to environmental stress. (PhD awarded)	D Miller, S Forêt
Bridie Allan	JCU	New Zealand	The effects of climate change on predator-prey interactions in coral reef fish. (PhD awarded)	M McCormick, P Munday
Mariana Alvarez Noriega	JCU	Mexico	Competition, growth form, and species coexistence in reef corals. (PhD)	S Connolly, A Baird
Ebrahim Ameer	UQ, USC	Seychelles	The role of four species of rabbitfish in delaying or resisting regime shifts on reefs in Seychelles. (PhD)	P Mumby
Kristen Anderson	JCU, AIMS	Canada	Temporal and spatial variation in the growth of branching corals. (PhD awarded)	M Pratchett, A Baird, J Lough
Natalia Andrade Rodriguez	JCU	Ecuador	Immunity and secondary metabolite production in the soft coral *Lobophytum pauciflorum* and the effects of stress (temperature; CO_2) on these processes. (PhD)	D Miller, A Moya
Adrian Arias	JCU	Costa Rica	Avoiding and reversing 'paper parks': integrating fishers' compliance into marine conservation efforts. (PhD awarded)	R Pressey, J Cinner, J Alvarez-Romero
Danielle Asson Batzel	JCU, AIMS, CSIRO	USA	Multi-scale patterns of benthic species composition in the Great Barrier Reef region and implications for spatial management. (PhD)	R Pressey, S Connolly, T Bridge
Jennifer Atherton	JCU	United Kingdom	The effect of parental and embryonic predator environments on offspring. (PhD awarded)	M McCormick, A Frisch, G Jones
Maria Eleanor Aurellado	UQ	Philippines	Effect of predation risk on the behaviour and habitat usage of coral reef fishes. (PhD awarded)	P Mumby
Anne Bauer-Civiello	JCU	USA	The effects of marine debris and fishing line on reef fish distribution and diversity. (PhD)	M Hoogenboom
Brock Bergseth	JCU	USA	Drivers of recreational fisher compliance on the Great Barrier Reef: implications for policy and practice. (PhD)	J Cinner, D Williamson, G Russ
Kathryn Berry	JCU, AIMS	Canada	Effects of coal contamination on tropical marine organisms. (PhD)	M Hoogenboom
Chico Birrell	UQ, Griffith University	Australia	Understanding the spatial and temporal variation in macroalgal growth and assemblage development on coral reefs. (PhD awarded)	P Mumby
Teressa Bobeszko	JCU	Australia	The role of carbonic anhydrase in the coral-dinoflagellate symbiosis. (PhD)	B Leggat, D Yellowlees
Chloe Boote	JCU	United Kingdom	Studying stress impacts using the mushroom coral *Heliofungia*. (PhD)	D Miller, A Moya
Lisa Boström-Einarsson	JCU	Sweden	Competitive interactions, habitat degradation and the structure of coral reef fish assemblages. (PhD awarded)	G Jones, P Munday, M Bonin
Ian Bouyoucos	JCU	USA	A challenging environment in a changing world for juvenile sharks: ecological energetics of climate change with implications toward conservation. (PhD)	J Rummer
Kristen Brown	UQ	USA	Assessing macroalgal species abundance and diversity in the Coral Triangle. (PhD)	S Dove, O Hoegh-Guldberg
Dominic Bryant	UQ	Australia	Effects of population density and land use on the coral communities of the Maldives. (PhD)	O Hoegh-Guldberg, S Dove
Sarah Buckley	UQ	Ireland	A reconstruction of historical baselines of Queensland fisheries since the Anthropocene. (PhD awarded)	J Pandolfi
Patrick Buerger	JCU, AIMS	Germany	Viruses in coral diseases: bacteriophages and phage therapy. (PhD)	M van Oppen, B Willis
Ciemon Caballes	JCU	Philippines	Environmental constraints on reproduction and development of crown-of-thorns starfish. (PhD)	M Pratchett, A Hoey
Carolina Castro Sanguino	UQ	Colombia	Ecological drivers of *Halimeda* abundance and their implications for the carbonate production of coral reefs. (PhD awarded)	P Mumby
Leela Chakravarti	JCU, AIMS	United Kingdom	The evolutionary potential of *Symbiodinium* and its role in assisting evolution in corals under rapid climate change. (PhD)	M van Oppen, B Leggat, B Willis
Tory Chase	JCU	USA	Effects of fish presence on coral health and bleaching tolerance. (PhD)	M Hoogenboom, M Pratchett

Sivee Chawla	JCU	India	Spatial modelling of individual service choices and their implications for social-ecological transitions. (PhD)	G Cumming, T Morrison
Jessica Cheok	JCU	Brunei	Systematic conservation planning in marine environments – sensitivities of the planning framework to multiple aspects of scale and resolution. (PhD)	R Pressey, R Weeks
Pedro Cipresso Pereira	JCU	Brazil	Competition and habitat selection in coral-dwelling fishes. (PhD awarded)	G Jones, P Munday
Harry Clarke	UWA	Australia	The use of coral geochemical records to deconvolve the impacts of edging and ocean warming in the Onslow/Dampier region of Western Australia. (PhD)	M McCulloch, J Falter, JP D'Olivo Cordero
Zara-Louise Cowan	JCU	United Kingdom	Predation on the early life stages of crown-of-thorns starfish (*Acanthaster* spp). (PhD)	M Pratchett, V Messmer
Jessica Cramp	JCU	USA	Evaluating the effectiveness of policy, fisheries management tools, and large marine reserves for wide-ranging sharks. (PhD)	R Pressey
Kay Critchell	JCU, Macquarie University	United Kingdom	Presence and effects of microplastics in coastal environments. (PhD)	M Hoogenboom
Michael Cuttler	UWA	USA	Production, transport and fate of carbonate sediment in a fringing reef-system. (PhD)	R Lowe, M McCulloch, J Falter
Blanche D'Anastasi	JCU, UWA	Australia	Population genetics and genomic dietary analyses of Australian sea snakes. (PhD)	V Lukoschek
Benjamin Davis	JCU	United Kingdom	Processes at multiple scales shape fish assemblage structure in tropical estuaries. (PhD awarded)	G Russ
Jon Day	JCU, CSIRO	Australia	Planning and managing the Great Barrier Reef – lessons learned for the future planning of the Reef and implications for marine protected areas elsewhere. (PhD)	R Pressey, T Morrison
Anderson de Sevilha	JCU	Brazil	Systematic conservation planning for the Parana River Basin, Brazil. (PhD awarded)	R Pressey
Andreas Dietzel	JCU	Germany	Primary habitat requirements of key herbivorous fish and stress-tolerant coral species in the Great Barrier Reef: which ecological factors govern their distribution and how to draw lessons for coral reefs? (PhD)	T Hughes, S Connolly
Edwin Drost	UWA	The Netherlands	The impact of tropical cyclone forcing on Australia's north-western coastal system. (PhD)	R Lowe
Michael Emslie	JCU	Australia	Effects of habitat versus fisheries management on spatio-temporal variation in fish assemblages on the Great Barrier Reef. (PhD)	M Pratchett
Norbert Englebert	UQ	The Netherlands	Phenotypic and physiological responses of a widespread coral species to changing environmental conditions: functional variability in natural populations of *Stylophora pistillata*. (PhD)	O Hoegh-Guldberg, S Dove, P Bongaerts
Hannah Epstein	JCU, AIMS	USA	The role of microbes in acclimatisation of corals. (PhD)	P Munday, M van Oppen, G Torda
Jacob Eurich	JCU	USA	Processes underlying ecological versatility in an equatorial guild of fishes. (PhD)	G Jones, M McCormick
Nicholas Evensen	UQ	United Kingdom	Comparing sources of population bottlenecks among coral taxa. (PhD)	P Mumby
Kerrie Fraser	UQ, JCU	Australia	Marine protected areas: evaluating policy efficacy and impact in conserving biodiversity. (PhD)	J Pandolfi, R Pressey
Ashton Gainsford	JCU	Australia	A multi-disciplinary evaluation of the hybrid anemonefish *Amphiprion leucokranos*: behaviour shaping evolutionary outcomes of hybridisation. (PhD)	G Jones
Anjani Ganase	UQ	Trinidad and Tobago	The use of a standardised method for a broad-scale survey of coral reefs worldwide, to identify the level of environmental impact on coral reef communities. (PhD)	O Hoegh-Guldberg, S Dove, P Mumby
Lucy Georgiou	UWA	United Kingdom	Constraining coral sensitivity to climate and environmental change: an integrated and experimental approach. (PhD awarded)	M McCulloch, J Falter, JP D'Olivo Cordero
Sarah Gierz	JCU	Australia	Acclimation of *Symbiodinium* to thermal stress. (PhD)	B Leggat, D Yellowlees
Bettina Glasl	JCU, AIMS	Austria	Microbial indicators for environmental stress and ecosystem health assessment. (PhD)	B Willis
Benjamin Gordon	JCU, AIMS	Australia	The metabolome of *Symbiodinium* phylotypes and their coral hosts. (PhD)	B Leggat
Alexia Graba-Landry	JCU	Canada	The effect of temperature on seaweed-herbivore interactions on tropical coral reef systems. (PhD)	A Hoey, M Pratchett

Rebecca Green	UWA	United Kingdom	Investigating biogeochemical responses to hydrodynamic processes at Scott Reef, a remote atoll off Western Australia. (PhD)	R Lowe, M McCulloch, J Falter
Renee Gruber	UWA	USA	Nutrient inputs and reef productivity: sources, transport and biogeochemical transformation in a macrotidal tropical ecosystem. (PhD)	R Lowe, J Falter
Rodrigo Gurdek	JCU, AIMS	Uruguay	Connectivity within fisheries species along the Great Barrier Reef: genomics and modelling (PhD)	H Harrison
April Hall	JCU	Australia	Top-down control, trophic interactions, and the importance of predatory fishes on coral reefs. (PhD awarded)	M Kingsford, D Williamson
Vanessa Haller	JCU, AIMS	Germany	Ecosystem modelling to evaluate multiple, uncertain threats on coral reefs. (PhD)	M Bode, G Russ
Margaux Hein	JCU, GBRMPA	Monaco	Investigating the socio-ecological benefits of coral restoration to support reef resilience. (PhD)	B Willis
Tessa Hempson	JCU, AIMS, U. Lancaster	South Africa	Coral reef mesopredator trophodynamics in response to reef condition. (PhD)	N Graham, A Hoey, G Jones, A MacNeill
Alejandra Hernandez-Agreda	JCU, UQ	Venezuela	Coral core microbiome: composition, microhabitat distribution, host influence and response to environmental change. (PhD)	T Ainsworth, B Leggat
Sybille Hess	JCU	Switzerland	The impact of sediments on coral reef fish. (PhD)	J Rummer, M Pratchett, A Hoey
Tessa Hill	JCU	United Kingdom	Direct and indirect effects of ocean acidification on reef corals. (PhD)	M Hoogenboom, B Willis
Jessica Hopf	JCU	Australia	The short and long term implications of marine reserves for fisheries on coral reefs. (PhD awarded)	S Connolly, G Jones, D Williamson
Adriana Humanes Schumann	JCU, AIMS	Venezuela	Combined effects of water quality and temperature on the early life history stages of the broadcast spawning coral *Acropora tenuis.* (PhD awarded)	B Willis
Sofia Jainschlaepfer	JCU	Canada	Assessment of the effects of boat noise on coral reef fish in their larval stage. (PhD)	G Jones, M McCormick
Matt Jankowski	JCU, U. Lancaster	United Kingdom	Effects of depth and aspect on distribution, habitat use and specialisation in coral reef fish. (PhD awarded)	G Jones, N Graham
Michael Jarrold	JCU	United Kingdom	The effects of natural variation in CO_2 and rising CO_2, on coral reef fish. (PhD)	P Munday, M McCormick
Young Koo Jin	JCU, AIMS	South Korea	Nature or nurture? Testing the correlation between stress tolerance and genotype in *Acropora millepora* on the Great Barrier Reef. (PhD awarded)	B Willis, M van Oppen
Saskia Jurriaans	JCU, Centre Scientifique de Monaco	The Netherlands	Thermal acclimation and the geographic range limits of reef-building corals. (PhD)	M Hoogenboom, S Connolly
Tania Kenyon	UQ	Australia	Physical, geochemical and biological processes affecting stabilisation, cementation and coral recruitment in areas of coral rubble. (PhD)	P Mumby
James Kerry	JCU, AIMS	United Kingdom	The role of tabular structure in the ecology of large reef fishes. (PhD awarded)	D Bellwood
Sun Kim	UQ	South Korea	The biological guide to moving: evolution and ecology of corals' range dynamics under climate change. (PhD)	J Pandolfi
Catherine Kim	UQ	USA	Determining drivers of benthic composition, marine biodiversity, and coral health in Timor-Leste. (PhD)	O Hoegh-Guldberg, S Dove
Chelsea Korpanty	UQ	USA	Central Indo-Pacific coral reef development surrounding the establishment of a novel climatic regime. (PhD)	J Pandolfi
Michael Kramer	JCU	New Zealand	Crustacea on coral reefs: habitat associations and trophic relationships. (PhD awarded)	D Bellwood, S Connolly
Felicity Kuek	JCU, AIMS	Malaysia	Organic sulphur metabolism in corals. (PhD)	D Miller, A Moya
Chao-Yang Kuo	JCU	Taiwan	Functional groups and functional diversity of corals. (PhD)	A Baird, T Hughes, M Pratchett
Vivian Lam	UQ	China	Operationalising resilience: from metrics to measurement. (PhD)	P Mumby
Marie Lapointe	JCU	Canada	Managing marine protected areas to promote the resilience of coral reef ecosystems. (PhD)	G Cumming
Jacqueline Lau	JCU, U. Lancaster	Australia	Winners and losers in marine conservation: investigating access to coral reef ecosystem services. (PhD)	J Cinner, C Hicks
Susannah Leahy	JCU	Australia	Habitat determinants of chaetodon butterflyfish and fishery-targeted coral reef fish assemblages in the central Philippines. (PhD awarded)	G Russ, G Jones

Anne Leitch	JCU, CSIRO	Australia	Social resilience to climate change: the adaptive capacity of local government. (PhD)	T Hughes
Johanna Leonhardt	JCU	Australia	Spatial dynamics in the territories of *Stegastes* spp. relative to coral growth, disease and mortality within Opal reef. (PhD)	M Pratchett, M Hoogenboom, A Hoey
Govinda Liénart	JCU, U. Saskatchewan	Austria	Effects of temperature and food availability on the antipredator behaviour of juvenile coral reef fishes. (PhD awarded)	M McCormick
Mei-Fang Lin	JCU, ANU	Taiwan	Transcriptomics of Corallimorpharian *Rhodactis indosinensis* (Cnidaria: Anthozoa) and its usefulness to understanding coral bleaching. (PhD Awarded)	D Miller, S Forêt
Zoe Loffler	JCU	Australia	Influence of canopy-forming macroalgae on key reef processes. (PhD)	A Hoey, M Pratchett
Karmen Lužar	JCU	Slovenia	Relationships between value sharing and management effectiveness of management of protected areas. (PhD)	G Cumming
Chancey Macdonald	JCU, MTQ	New Zealand	Depth patterns in coral reef fish distributions and microhabitat associations: are deep reefs a refuge? (PhD)	G Jones, T Bridge
Rafael Magris	JCU, U. Victoria	Brazil	Advancing conservation planning for persistence: design of a conservation strategy for Brazilian coral reefs. (PhD awarded)	R Pressey, A Baird, R Weeks
Martino Malerba	JCU, AIMS	Italy	Extending quota models to nitrogen-limited growth of phytoplankton populations. (PhD awarded)	S Connolly
Hannah Markham	UQ	United Kingdom	Long-term ecological dynamics along a gradient of anthropogenic activity on the inshore Great Barrier Reef. (PhD)	J Pandolfi, G Roff
Robert Mason	UQ, NOAA	Australia	Linking coral physiology to remote sensing of reefs. (PhD)	S Dove, O Hoegh-Guldberg
Samuel Matthews	JCU, AIMS	Australia	Modelling outbreaks of crown-of-thorns starfish: coupling biophysical, demographic and connectivity processes. (PhD)	M Pratchett, V Messmer
Emmanuel Mbaru	JCU, U. Lancaster	Kenya	Using fisheries dependent data and socio-economic indicators to develop ecosystem based fisheries management tools. (PhD)	J Cinner, N Graham, C Hicks
Eva McClure	JCU	Australia	The impact of typhoons on the effectiveness of marine reserve networks in the Coral Triangle. (PhD)	G Russ, A Hoey
Michael McWilliam	JCU	United Kingdom	Coral reef resilience - learning from the past. (PhD)	T Hughes, M Hoogenboom
Mattheus Mello Althayde	UQ	Brazil	Metabolism and calcification rates of corals across distinct reef zones and in response to climate change. (PhD)	S Dove
Thane Militz	JCU	USA	Enhancement of mariculture techniques of marine ornamental fishes promoting long-term economic sustainability in developing island communities. (PhD)	M McCormick
Meira Mizrahi	JCU	Australia	Maximising potential impact of marine protected area placement: an integrated socio-economic perspective. (PhD)	R Pressey, R Weeks
Amin Mohamed Esmail	JCU	Egypt	Distribution and characterisation of chromerids and apicomplexans associated with coral reefs. (PhD Awarded)	D Miller, B Willis
José Montalvo Proano	JCU, AIMS	Ecuador	Non-genetic inheritance of stress tolerance in corals. (PhD)	M van Oppen, P Munday
Stefano Montanari	JCU, AIMS	Italy	Hybridisation in reef fishes: ecological promoters and evolutionary consequences. (PhD)	M Pratchett
Christopher Mooney	JCU	Australia	Statoliths of Cubozoan jellyfishes: their utility to discriminate taxa and elucidate population ecology. (PhD awarded)	M Kingsford
Renato Moraisaraujo	JCU, U. Lancaster	Brazil	Tropic pathways between primary production and biomass accumulation on tropical reefs. (PhD)	D Bellwood, N Graham
Lauren Nadler	JCU	USA	Behavioural and physiological effects of shoaling in a coral reef fish. (PhD awarded)	M McCormick, P Munday
Tiffany Nay	JCU	USA	Physiological adaptation and use of microhabitats in coral reef fishes. (PhD)	J Rummer, A Hoey
Katia Nicolet	JCU	Switzerland	Aetiology of Indo-Pacific coral diseases: disease dynamics and the role of vectors in disease outbreaks. (PhD)	M Hoogenboom, B Willis, M Pratchett
Jessica Nowicki	JCU	USA	The roles of nonapeptides in modulating animal personality and reproductive behaviour in coral reef fish. (PhD)	M Pratchett

Maria Palacios Otero	JCU	Colombia	Ecological selection in a complex marketplace. (PhD)	M McCormick, G Jones
Katie Peterson	JCU	USA	Social-ecological dynamics of coral reef fisheries. (PhD)	T Hughes, S Connolly
Andrew Pomeroy	UWA, CSIRO	Australia	The interaction between hydrodynamic processes and sediment dynamics in fringing coral reef environments. (PhD awarded)	R Lowe
Davina Poulos	JCU	Australia	Priority effects and the dynamics of coral reef fish assemblages. (PhD awarded)	M McCormick, G Jones
Martina Prazeres	UQ, AIMS	Brazil	Foraminifera as tools for analysis of interactions between water quality and climate change effects on the Great Barrier Reef: historical reconstruction and biology at community, individual and cellular scales. (PhD awarded)	J Pandolfi
Mark Priest	UQ, Palau ICRC	United Kingdom	A multi-disciplinary approach to predictive management of coral reef fisheries. (PhD)	P Mumby
Abdi Priyanto	UQ, MMAF Indonesia	Indonesia	Marine spatial planning in Indonesia: options for improved efficiency. (PhD)	P Mumby
Laura Puk	UQ	Thailand	Assessment of key fish species controlling macroalgae growth in a coral reef of Koh Panghan, Gulf of Thailand. (PhD)	P Mumby
Kate Quigley	JCU, AIMS	Spain	Genetic and environmental basis for *Symbiodinium* specificity in the coral-dinoflagellate association. (PhD)	B Willis, B Leggat, L Bay
Veronica Radice	UQ	USA	Assessing echinoderm abundance, diversity and function across distinct coral reefs. (PhD)	O Hoegh-Guldberg, S Dove
Blake Ramsby	JCU, AIMS	USA	The effects of a changing marine environment on the bioeroding sponge *Cliona orientalis.* (PhD)	M Hoogenboom
Tries Razak	UQ, AIMS	Indonesia	The effects of climate change on the growth rates of modern corals. (PhD)	P Mumby
Laura Richardson	JCU, U. Lancaster	United Kingdom	Effects of coral community composition on ecosystem structure, function and ecological interactions. (PhD)	A Hoey, N Graham
Johan Risandi	UWA	Indonesia	Investigating the hydrodynamics and morphodynamics of a reef-fringed pocket beach. (PhD)	R Lowe
Thomas (Ed) Roberts	JCU, MTQ	Australia	Depth distribution patterns in reef-building corals. (PhD)	A Baird, T Bridge, G Jones
Jan Robinson	JCU, U. Lancaster	United Kingdom	Understanding the causes of vulnerability to fishing in reef fishes that aggregate. (PhD awarded)	N Graham, J Cinner
Melissa Rocker	JCU, AIMS	USA	Effects of water quality on the health and condition of inshore corals. (PhD awarded)	B Willis
Giverny Rodgers	JCU	Australia	Climate change in a stable thermal environment: effects on the performance and life history of a coral reef fish. (PhD awarded)	M McCormick, P Munday, J Rummer
Claire Ross	UWA	Australia	Environmental controls on the growth and physiology of high-latitude coral in the south-west region of Western Australia (32°-35°S). (PhD)	M McCulloch, J Falter, V Schoepf
Theresa Rueger	JCU	Germany	Social relationships in small habitat dependent coral reef fish: an ecological behavioural and genetic analysis. (PhD awarded)	G Jones
Edmond Sacre	JCU	Australia	The greatest problems we currently face when using marine protected areas for the protection of marine biodiversity. (PhD)	R Pressey, R Weeks
Katie Sambrook	JCU, GBRMPA	United Kingdom	The role of ecological connectivity between seagrass beds and coral reefs on coral reef fish assemblages. (PhD)	A Hoey, M Bonin
Jimena Samper-Villarreal	UQ	Costa Rica	Carbon sequestration by seagrasses in Moreton Bay. (PhD awarded)	P Mumby
Jodie Schlaefer	JCU	Australia	The sources and physical tolerances of *Chironex fleckeri*, a stinging jellyfish. (PhD)	M Kingsford
Molly Scott	JCU, AIMS	Australia	Impacts of ocean warming and climate induced habitat modification on the behaviour and ecology of coral trout and other key fisheries species. (PhD)	M Pratchett
Laura Segura Mena	UWA	Costa Rica	A quantitative assessment of the morphological behaviour of reef-fronted and exposed beaches in Western Australia. (PhD)	R Lowe
Tiffany Sih	JCU, AIMS	USA	Fisheries for deep sea snappers. (PhD)	M Kingsford
Carrie Sims	UQ	Australia	Biotic versus environmental controls over coral community assembly. (PhD)	J Pandolfi
Jennifer Smith	JCU	Canada	Influence of patch dynamics on coral reef fishes on the southern Great Barrier Reef. (PhD)	G Jones, M McCormick

Blake Spady	JCU, Griffith	USA	The effects of projected near-future CO_2 on cephalopod behaviours and learning. (PhD)	P Munday, S-A Watson
Leanne Sparrow	JCU	Australia	Trophic transfer of ciguatoxins in marine foodwebs. (PhD)	G Russ
Jessica Spijkers	JCU, U. Stockholm	Sweden	The future for governing highly migratory straddling stocks: conflict or cooperation? (PhD)	T Morrison, G Cumming
Rachel Spinks	JCU	Australia	Warming up to climate change: the evolutionary potential of transgenerational acclimation of coral reef fishes to elevated sea temperature. (PhD)	P Munday, J Donelson, M McCormick
Jessica Stella	JCU, Aust. Museum	USA	Effects of climate changed induced thermal stress and habitat degradation on the biodiversity and species composition of coral-associated invertebrates. (PhD awarded)	G Jones, M Pratchett, P Munday
Robert Streit	JCU	Kenya	Spatial ecology and space use in browsing herbivorous reef fishes: ecological drivers and effects on ecosystem function. (PhD)	D Bellwood
Cheng-Han Tsai	JCU, AIMS	Taiwan	The structure and dynamics of reef fish communities. (PhD)	S Connolly, D Bellwood
Rene van der Zande	UQ	Curacao	Monitoring metabolic changes to reef sediment and framework in response to present day and future diurnal and seasonal dynamics. (PhD)	O Hoegh-Guldberg, S Dove
Arnold van Rooijen	UWA	The Netherlands	Modelling wave-driven hydrodynamics and sediment transport within aquatic canopies. (PhD)	R Lowe
Francisco Vidal Ramirez	UQ	Chile	Effect of possible future seawater environments on sea cucumbers and the sediments they process. (PhD)	S Dove
Estefania Maldonado Villacis	JCU	Ecuador	Biological conservation planning for multiple species habitat restoration in Ecuador. (PhD)	R Pressey
Peter Waldie	JCU, TNC	Australia	Investigating spatial aspects of the community-based management of a small-scale artisanal grouper fishery. (PhD)	J Cinner
Melissa Walsh	JCU	USA	Marine conservation finance: strategies and finance mechanisms to improve the amount and efficacy of investment into marine conservation. (PhD)	R Pressey
Wei-Wen Wang	ANU	China	Coral genome assembly and annotation. (PhD)	S Forêt
Donald Warren	JCU, UTS	USA	The impacts of $C0_2$ on competitive interactions and the potential for acclimation? (PhD)	M McCormick, P Munday, J Donelson
Megan Welch	JCU	USA	Transgeneration effects of CO_2 on fish behaviour. (PhD awarded)	P Munday, M McCormick
Justin Welsh	JCU	Canada	The spatial ecology of coral reef fishes. (PhD awarded)	D Bellwood, S Connolly
Wiebke Wessels	JCU, ANU	Germany	Molecular bases of soft coral reproduction. (PhD awarded)	D Miller, S Forêt
Casey Whalen	JCU	USA	Coral mediation of associated microbial community. (PhD)	D Miller, A Moya
James White	JCU, AIMS	USA	The role of boldness and other personality traits in the ecology of juvenile marine fishes. (PhD awarded)	M McCormick
Jennifer Wilmes	JCU	Belgium	Distribution and abundance of juvenile crown-of-thorns starfish on the Great Barrier Reef. (PhD)	M Pratchett, A Hoey
Gundula Winter	UWA	Germany	An investigation of the nearshore hydrodynamics on contrasting open-coast and reef-protected beaches in Western Australia. (PhD)	R Lowe
Matthew Young	JCU	Australia	Recreational spearfishing: an historical, ecological and sociological perspective. (PhD awarded)	D Bellwood

GRADUATE PROFILE

DR PETE WALDIE

PHOTO TANE SINCLAIR-TAYLOR

Millions of the world's most vulnerable people rely on small-scale fisheries for their livelihoods and food security. Pete Waldie's goal is to understand the social and ecological processes that underpin small-scale fisheries, and to better support sustainable exploitation.

After completing his Honours Degree at the University of Queensland, a string of serendipitous events led Pete to an unforgettable trip on a large traditional sailing canoe across the Bismarck Sea to a remote, uninhabited group of islands in Papua New Guinea. During this trip, Pete learned of the long history of fisheries management carried out locally under clan-based tenure systems, and it triggered his interest in how government and non-government organisations can incorporate these traditional systems into contemporary management.

Pete found "it was confronting to watch our crew hunting and eating vulnerable species that we have been actively involved in protecting in other areas of the world, but it was far from our place to lecture anyone about their traditions and customs. In fact, given the lack of legal protections as we know them, the remote ecosystems were in remarkable health. The Titans, whose canoe we were aboard, acknowledged their responsibility to sustain the ecosystem's health and were conscious of the threat of over-exploiting their resources".

These conversations sowed the seed of Pete's PhD project on community-based management of fisheries, supervised by the ARC Centre's Dr Glenn Almany and Professor Josh Cinner, and by Dr Richard Hamilton from The Nature Conservancy (TNC). Pete's PhD investigated one of the most commonly recurring criticisms of community-based management: that local governance institutions cannot effectively manage larger, more mobile coral reef fishes, where fish ranges extend far beyond small areas of jurisdiction.

Pete's research was based at Dyual Island in Papua New Guinea, where a decade-long co-management partnership between local fishing communities and TNC has resulted in the recovery of a spawning aggregation of two threatened species of grouper. He lived for almost a year in multiple remote communities, listening and recording what the locals were telling him, whilst also collecting empirical ecological and social data.

Multiple hardships plagued Pete's PhD candidature. The talented coral reef ecologist and Pete's primary adviser, Glenn Almany, passed away in early 2015. One of the communities Pete worked with was raided during civil unrest. During this raid, and subsequent retaliation attacks, numerous community members who worked with Pete were seriously injured and three men were killed. Despite these tragic events, Pete persevered to deliver an outstanding PhD with real-world impact.

One of the principal findings of Pete's research is that mobile coral reef fishes can be effectively managed at community scales if nursery and spawning areas are protected, leaving other areas of high importance to fishers open to exploitation. By working in close partnership with TNC, and directly involving over 100 local community members in the research process, Pete's PhD has resulted in immediate on-the-ground uptake.

"Several spawning aggregations and other specific areas have been designated as no-take zones around Dyual since the completion of our research. The communities are currently developing the best ways to police and enforce the locally protected areas. The data we collected during the project has directly supported local communities in decision-making".

Pete submitted his PhD in September 2016 and was immediately hired by TNC to continue his important work in Micronesia and Melanesia. In this position, and in an ongoing practical partnership with the ARC Centre, he continues to deliver the evidence local communities need to effectively conserve and manage their marine resources.

NATIONAL AND INTERNATIONAL LINKAGES

The ARC Centre is continuously expanding its national and international linkages, providing a global hub for coral reef research excellence through unprecedented collaborations in transdisciplinary research.

Examples in 2016:

261 publications with cross-institutional co-authorship, involving researchers from **280** institutions in **60** countries.

20 international working groups convened by Centre researchers.

Across four nodes, the ARC Centre hosted **71** international visitors from **24** countries.

ARC Centre personnel visited international collaborators at **103** laboratories and research facilities in **28** countries.

149 of our current graduate students were attracted to Australia from **43** countries (p45), including **74%** of our new graduate enrolments.

Our field work was conducted in **25** countries.

In addition, the ARC Centre has formal international partnership agreements with the Center for Ocean Solutions at Stanford University in the USA, the International Union for the Conservation of Nature (IUCN), France's Centre National de la Recherche Scientific (CNRS), and WorldFish in Malaysia.

Centre personnel are actively involved on many editorial boards for international journals. We undertake consultancies worldwide, and our outreach is global (p58). In June 2016, the ARC Centre was the largest single contributor to the quadrennial International Coral Reef Symposium held in Hawaii. Centre researchers gave 148 presentations including 2 plenaries (Peter Mumby and Janice Lough). In addition, Josh Cinner, Ove Hoegh-Guldberg and Terry Hughes were three of the five panellists in the final day plenary discussion on climate change and its impacts on coral reefs.

The ARC Centre's researchers are major contributors to intergovernmental organisations such as the Intergovernmental Panel on Climate Change (IPCC), the World Bank, UNESCO, and the International Council for Science (ICSU). In 2016, David Bellwood was elected as a Fellow of the Australian Academy of Science joining other Centre leaders who are also Fellows: Ove Hoegh-Guldberg, Terry Hughes, Malcolm McCulloch and Bob Pressey. Malcolm McCulloch is also a Fellow of The Royal Society (London).

Highlights of some of the ARC Centre's larger national and international collaborations in 2016 include:

THE AUSTRALIAN INSTITUTE OF MARINE SCIENCE

AIMS is the ARC Centre's major Australian research partner outside of the University sector. They undertake a range of research on tropical marine environments and aquaculture, are responsible for the long-term monitoring of the Great Barrier Reef, and increasingly they provide extensive research services to industry, including oil and gas companies, government agencies, port authorities and other clients and partners, particularly in Queensland, Western Australia and the Northern Territory. The Chief Executive Officer of AIMS is a member of the Centre's Advisory Board and two of AIMS' senior principal scientists, Janice Lough and Madeleine van Oppen are very active Partner Investigators in the Centre. AIMS and the ARC Centre share valuable infrastructure, co-supervise graduate students (37 in 2016) and in 2016 we have co-funded three postdoctoral fellows: Tom Bridge, Greg Torda and Kristen Anderson. AIMS and Centre researchers co-authored an unprecedented 50 papers in 2016. AIMS researchers Janice Lough and Neil Cantin, a Centre alumnus, were key members of the Centre-led National Coral Bleaching Taskforce (p36).

GREAT BARRIER REEF MARINE PARK AUTHORITY

The ARC Centre's most important end-user in Australia is GBRMPA, the Australian government agency with the primary responsibility of protecting and managing the Great Barrier Reef (GBR) Marine Park and the GBR World Heritage Area. Their task is to assess, inform,

and implement government policies to maintain the environmental quality of the Great Barrier Reef. GBRMPA's partnership with the ARC Centre provides them with direct access to the research expertise of our ARC Centre scientists, whose research goals are strongly aligned with the scientific information needs of GBRMPA. GBRMPA is firmly linked to the ARC Centre's governance to facilitate research planning and the exchange of information and data: GBRMPA's Chairman is a member of the Centre's Advisory Board, and the agency's Director of Reef Recovery sits on the Scientific Management Committee. GBRMPA managers receive regular updates, advice and briefings on the reef from Centre researchers. The Centre also is a major contributor to technical courses and workshops, providing information and reviewing GBRMPA reports, education and training**.** For example, in 2016, Centre researchers Bette Willis, Greg Torda and Bill Leggat joined 27 GBRMPA managers for presentations, information exchange and discussions in GBRMPA's *Pre-Summer Reef Health Workshop*. In 2016, Centre researchers and GBRMPA managers worked very closely and tirelessly during the coral bleaching event on the Great Barrier Reef, under the umbrella of the National Coral Bleaching Taskforce, led by the ARC Centre.

WORLDFISH, MALAYSIA

Centre partner, WorldFish is one of our largest international linkages. WorldFish is an international non-profit research organisation headquartered in Malaysia, engaged in research for a food secure future. They undertake projects in Africa, Asia and the Pacific to improve the livelihoods of poor people by achieving environmentally sustainable increases in the supply of fish. WorldFish has more than 400 staff globally, permanent offices in seven countries and ongoing projects in 25 countries. The ARC Centre and WorldFish share a common research interest in the dynamics and sustainable interaction between human societies and coral reef fisheries. WorldFish senior scientists Dr David Mills and Dr Pip Cohen are based in the Centre at the Townsville node, and until mid-2016 Centre Research Fellow Mike Fabinyi had been embedded in the WorldFish headquarters in Penang. The Centre and WorldFish also co-fund two postdoctoral researchers: Jessica Blythe, who researches governance and sustainability of Pacific Island coastal fisheries; and Andrew Song, who joined us in 2016 to pursue research in the governance and geography of small scale fisheries. WorldFish's Pacific Regional Director, Neil Andrew, is a Partner Investigator and a member of the Centre's Advisory Board. This ongoing collaboration creates strong links to end-users, including many inter-governmental organisations and NGOs, as well as local communities and the governments of many developing countries, particularly in the Coral Triangle.

KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, SAUDI ARABIA

The King Abdullah University of Science and Technology (KAUST) is Saudi Arabia's premiere coral reef science institution. Its primary focus is developing a scientific basis for sustaining and conserving coral reef environments along the Red Sea coast of Saudi Arabia. Situated just north of Jeddah, KAUST has state of the art facilities for both field- and laboratory-based coral reef research. In 2016, Centre Director, Terry Hughes, was a continuing member of the Advisory Board of KAUST's Red Sea Research Centre. Nine researchers from KAUST and the Centre convened a highly successful working group meeting on *Genomic mechanisms for coral reef fishes in a changing world* in Australia in October. A new research project, led by Tim Ravasi (KAUST), and Philip Munday (ARC Centre), *Genomic evidence for adaptation of marine fishes to ocean acidification*, commenced in 2016. Two Research Fellows, Heather Veilleux and Jenni Donelson based in the Centre, have been recruited for these projects and are funded through this partnership.

UNIVERSITY OF EXETER, UNITED KINGDOM

The University of Exeter is a research-intensive university in Devon and Cornwall in the UK, with strong linkages to our ARC Centre. Exeter is one of the most highly ranked universities in the UK and in the top 100 in the world. The ARC Centre works closely with Exeter's Environment

and Sustainability Institute (ESI). Professor Kate Brown, who holds the Professorial Chair in Social Science at ESI, is the ARC Centre's Distinguished International Researcher who chairs the Centre's Scientific Management Committee. In 2016, the ARC Centre co-hosted a joint working group meeting on *Power, authority and performance in polycentric systems* with our Exeter colleagues. The week-long workshop was co-convened by Principal Research Fellow Tiffany Morrison from the ARC Centre and Professor Brown. The participants included the Centre Director, Terry Hughes, and Pip Cohen and Andrew Song, two of the Centre-based researchers from *WorldFish*.

OVERSEAS VISITING RESEARCHERS

In 2016, the ARC Centre hosted 71 international visitors:

Visitor	Organisation	Country
Dr Rene Abesamis	Silliman University	Philippines
Muhammad Abrar	Indonesia Institute of Science	Indonesia
Dr Michele Barnes	University of Hawaii	USA
Dr Oscar Beijbom	Berkeley Vision and Learning Centre	USA
Dr Greg Bennett	WorldFish	Solomon Islands
A/Prof Örjan Bodin	Stockholm University	Sweden
Dr Rohan Brooker	University of Delaware	USA
Xuefei Chen	Guangzhou Institute of Geochemistry, Chinese Academy of Sciences	China
Dr Karen Chong-Seng	Seychelles Islands Foundation	Seychelles
Hayley Clements	University of Cape Town	South Africa
Dr Claire Dell	Georgia Institute of Technology	USA
Dr Nurul Dhewani	Indonesia Institute of Science	Indonesia
Adam Downie	University of New Brunswick	Canada
Elizabeth Duncan	California State University	USA
A/Prof Giyanto	Indonesia Institute of Science	Indonesia
Julia Glebe	Hannover University	Germany
Dr Mélanie Hamel	Consultant, National Center for Scientific Research	France
Dr Emmanuel Hanert	Université Catholique de Louvain	Belgium
Emily Hay	University of Manchester	England
Dr Nani Hendiarti	Director for Maritime Science & Technology CMMA	Indonesia
Dr Missaka Hettiarachchi	University of Moratuwa/WWF	Sri Lanka/USA
Dr Eric Hochberg	Bermuda Institute of Ocean Sciences	Bermuda
Dr Marc Humblett	Nagoya University	Japan
Dr Andreas Hutahaean	Coordinating Ministry for Maritime Affairs	Indonesia
Dr Björn Illing	University of Hamburg	Germany
Prof Jahn Petter Johnsen	The Arctic University of Norway	Norway
Rucha Karkarey	Nature Conservation Foundation, Manipal University	India
Dr Stuart Kininmonth	University of Oslo	Norway
Dr Joleah Lamb	Cornell University	USA
Sarah Lawless	Consultant WorldFish	Solomon Islands

Visitor	Organisation	Country
Morane Le Nohaïc	La Rochelle University	France
Prof Christophe Lécuyer	Claude Bernard University	France
Dr Robert Lehman	King Abdullah University of Science and Technology	Saudi Arabia
Dr Damien Lightfoot	King Abdullah University of Science and Technology	Saudi Arabia
Prof Monica Medina	Pennsylvania State University	USA
Dr Paolo Montagna	Institute of Marine Science	Italy
Ignasi Montero Serra	University of Barcelona	Spain
Prof David Mouillot	University of Montpellier	France
Achmad Murman	Coordinating Ministry for Maritime Affairs	Indonesia
Dr Saleh Nugrahadi	Deputy Director for Integrated Marine Observation	Indonesia
Dr Masami Obuchi	University of the Ryukyus	Japan
Dr Sahat Panggabean	Coordinating Ministry for Maritime Affairs	Indonesia
Mimi Pearle	New York City Department of Education	USA
Dr Chiara Pisapia	California State University	USA
Dr F Joseph Pollock	Pennsylvania State University	USA
Dr Hollie Putnam	Hawaii Institute of Marine Biology	USA
Prof Tim Ravasi	King Abdullah University of Science and Technology	Saudi Arabia
José Ricardo Paula	University of Lisbon	Portugal
Dr Manuel Rigo	University of Padova	Italy
Dr Cristian Rojas	University of Wyoming	USA
Dr Rui Rosa	University of Lisbon	Portugal
Prof Charles Rubin	Nanyang Technological University	Singapore
Dr Aleksey Sadekov	Cambridge University	England
Dr Pablo Saenz-Agudelo	Universidad Austral de Chile	Chile
Nathanael Sangare	Aix-Marseille University	France
Dr Celia Schunter	King Abdullah University of Science and Technology	Saudi Arabia
Dr Kim Selkoe	University of California Santa Barbara	USA
Prof Lui Sheng	South China Sea Institute of Oceanology	China
Tane Sinclair-Taylor	King Abdullah University of Science and Technology	Saudi Arabia
Suparman	Coordinating Ministry for Maritime Affairs	Indonesia
Aoi Sugimoto	University of Tokyo	Japan
Prof Suharsono	Indonesia Institute of Science	Indonesia
Dr Reuben Sulu	WorldFish	Solomon Islands
Dr Lida Teneva	Conservation International	USA
Tarateiti Uriam	Secretariat of the Pacific Community	Kiribati
Dr Jan Van de Ploeg	WorldFish	Solomon Islands
Marie Voisine	LFB Biomedicaments	France
Prof Amos Winter	Indiana State University	USA
Dr Angela Yangihara	University of Hawaii	USA
Dr Guojie Zhang	Bejing Genomics Institute	China

MEDIA AND PUBLIC OUTREACH

The ARC Centre has developed a highly successful strategy for communication of our research findings to a diverse audience. In 2016, we provided media training and one-to-one coaching to Centre researchers, including early to mid-career researchers and postgraduate students. Throughout the year, we promoted new research, PhD opportunities, public lectures, our activities at international symposia, and other activities and achievements through media releases, the Centre's website, and on social media. Centre researchers regularly provide government and industry briefings and host educational and capacity-building workshops. The Centre's weekly seminar series is open to the public and advertised through Facebook, Twitter and our website.

The ARC Centre's online audience has grown by 30% since the launch of our new website in March 2016, reaching 16 million hits for the year. In 2016, ARC Centre researchers delivered 42 international keynote addresses. A highlight of the year was Centre Director Terry Hughes' TEDx Talk, 'Yes, we can save the world's coral reefs'.

In March 2016, the Centre alerted the world to coral bleaching on the Great Barrier Reef, which triggered global media attention. Aerial footage of the bleaching taken from a helicopter by Centre Director Terry Hughes and research officer, James Kerry, featured in stories read by millions around the world. Within 5 days a short video was viewed 2.4 million times on social media. The *Washington Post's* article highlighting our bleaching research 'And then we wept' reached an audience of 25 million people online alone, with the story also featuring in the *New York Times, BBC London, National Geographic* and *Time* magazine.

Josh Cinner's *Nature* article 'Bright spots among the world's coral reefs', which highlighted where coral reef fisheries are thriving against the odds (p16), also received extensive media attention. The paper was tweeted 461 times and was picked up by more than 110 news outlets, including *The Atlantic*, *Vox*, and the *LA Times*. In Western Australia, Verena Schoepf's research on super corals featured in a documentary series *Women and Oceans* for German/French TV broadcaster ARTE. The series featured five episodes on female marine scientists working in the world's five oceans.

We continued our commitment to childhood education throughout the year. For example, Mia Hoogenboom contributed to the *Classroom on the Reef* program, funded by the Queensland Department of Education and Training. Mia trained high school students and teachers who participated in coral reef field-based research on James Cook University's Orpheus Island Research Station. PhD student Blanche D'Anastasi trained 15 female high school students from remote indigenous communities, also at Orpheus Island Research Station.

Jodie Rummer (p42) and PhD student Ian Bouyoucos hosted secondary school biology students from Lycée Agricole d'Opunohu in Moorea, as part of Jodie's shark research program in French Polynesia (#physioshark), in a workshop at the Centre de Recherches Insulaires et Observatoire de l'Environnement (CRIOBE). Increasing public awareness of the shark research program in Moorea is beneficial because it alleviates general misconceptions surrounding sharks, and facilitates dialogue between the researchers and the broader community.

Six Centre researchers developed videos on their research for the *Queensland Women in STEM Research's Thinkable* event. Thinkable is an online resource for researchers to share their ideas using video to raise community awareness.

In 2016, Centre researchers gave 111 briefings to stakeholders, government, industry, business and policy makers. Centre researchers met with representatives of the Great Barrier Reef Marine Park Authority (GBRMPA) dozens of times throughout the year. For example, Kathryn Berry, Mia Hoogenboom and Andrew Negri (AIMS) briefed GBRMPA on the effects of suspended coal particles on tropical marine organisms. Tom Bridge gave a presentation on monitoring deep reefs in the Great Barrier Reef, while Terry Hughes held multiple meetings with GBRMPA staff on the activities and findings of the National Coral Bleaching Taskforce. Terry also gave high-level coral bleaching briefings with: the Queensland Minister for Environment and Heritage Protection, Steven Miles; *The Reef 2050 Plan* Independent Expert Panel; Commonwealth Minister for the Environment, Greg Hunt, and the Australian Academy of Science.

In April, Sue-Ann Watson twice briefed the Leader of the Opposition in the Parliament of Australia, Bill Shorten, on the short to long term issues affecting the Great Barrier Reef, including coal dust and climate change. Sophie Dove also briefed members of the Australian parliament on climate change and the Great Barrier Reef.

In June, Centre Director Terry Hughes was invited to Buckingham Palace to meet Prince Edward, Earl of Wessex, after they both delivered a plenary address at a 2-day symposium, *Protecting the Future for Coral Reefs*, held in St. James's Palace, London. Josh Cinner and adjunct researchers Nick Graham and Christina Hicks also participated.

Ove Hoegh-Guldberg was invited by the Chilean government to address politicians, philanthropists and high level scientists at the *Our Oceans Conference* workshop in Washington DC. His keynote address, *Coral reefs in a rapidly warming and acidifying ocean: Is the Paris agreement enough to save coral reef ecosystems* aimed to bring together the ocean and climate communities in preparation for COP22 in Marrakech.

Andrew Baird and Philip Munday hosted a senior delegation from the Indonesian Ministry of Marine Affairs, advising them of the ARC Centre's research activities in Indonesia and exploring opportunities for increased research engagement. Mike Kingsford traveled to the Galapagos Islands to discuss research opportunities and the potential for that research to assist with the management of the national park. Michele Barnes met with local Chiefs and community members in Papua New Guinea to assess the status of fisheries and available options for fisheries management.

In Western Australia, Ryan Lowe, Morgan Pratchett, Bob Pressey, Amelia Wenger and Justin Osbaldiston briefed Western Australia Parks and Wildlife officers on the sustainability of coral harvesting, and the condition of reefs in the Kimberly region. Verena Schoepf, Chris Cornwall and Steeve Comeau held talks on climate change and coral reefs in the Kimberley with the Bardi Jawi Indigenous Rangers. Ryan Lowe and PhD student Andrew Pomeroy hosted a course in Mauritius for university academics on the coastal impacts of climate change.

Centre researchers with Prince Edward, Earl of Wessex, and others at Buckingham Palace

SOCIAL MEDIA

The ARC Centre's social media reach has grown substantially via Twitter and Facebook, which we introduced in 2015. Facebook is one of the biggest drivers of traffic to the Centre's website, and our posts are often taken up by the media. When we posted our media release 'Only 7% of the Great Barrier Reef has avoided coral bleaching' on Facebook in April, it reached over 100,000 people and generated nearly 5,000 reactions, comments and shares.

The Centre's Twitter account is also an active communication tool that allows our scientists to support each other's work and to promote their research to the wider community. @CoralCoE has more than 4,000 followers and registered more than 1 million impressions in Twitter feeds for the year. The highest ranking post was in December. 'We've got a closing window of opportunity to deal with climate change' which highlighted Terry Hughes' selection in *Nature's 10* list of scientists 'who mattered' for 2016. It created over 23,000 impressions. Individual members of the Centre are also active on Facebook, Twitter, and other social media platforms. For example, Mia Hoogenboom runs the popular *Biology of Reef Corals* Facebook page using video from her team's work in the field, and PhD student Jessica Cramp entered the virtual classroom on World Ocean Day, using Google Hangout to talk to school children around the globe.

THE CONVERSATION

The ARC Centre routinely delivers succinct, intelligible and high-quality summaries of our research to the public via *The Conversation*. In 2016, 16 Centre researchers from JCU, UQ and UWA published 25

articles on marine policy and conservation, coral bleaching, water quality, fisheries and marine reserves. The articles were read almost 200,000 times, and eight were republished by *The Guardian, IFLScience, Australian Geographic, ABC News* and *Fairfax newspapers*. Examples of 2016 articles include:

Morgan Pratchett, Janice Lough. *Coral Bleaching Taskforce: more than 1,000 km of the Great Barrier Reef has bleached*. 6 April 2016. Republished by *IFLScience* and *Australian Geographic.* https://theconversation.com/coral-bleaching-taskforce-more-than-1-000-km-of-the-great-barrier-reef-has-bleached-57282

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Terry Hughes, Britta Schaffelke, James Kerry, David Wachenfeld. *How much coral has died in the Great Barrier Reef's worst bleaching event?* 28 November 2016. Republished by *Australian Geographic.* https://theconversation.com/how-much-coral-has-died-in-the-great-barrier-reefs-worst-bleaching-event-69494

Ove Hoegh-Guldberg and Jamaluddin Jompa. *Indonesia and Australia are sleeping ocean superpowers.* 15 December 2016. https://theconversation.com/indonesia-and-australia-are-sleeping-ocean-superpowers-69886

MEDIA RELEASES

The ARC Centre produced 44 media releases in 2016, which generated 12,631 media commentaries, nationally and internationally. Coverage of our research was picked up by prominent online, print and broadcast media organisations including *The New York Times, National Geographic, the BBC, Washington Post* and *IFLScience*.

Some highlights of media uptake during the year include:

Nature World News – *Forked tails allow twilight zone fish to swim silently past deep water predators*, T Bridge, 20 January, 2016 http://www.natureworldnews.com/articles/19442/20160120/forked-tails-allow-twilight-zone-fish-swim-silently-past-deep.htm

The Brisbane Times – *Reef sharks like their food bite sized*, A Frisch, 22 February 2016 http://www.brisbanetimes.com.au/queensland/reef-sharks-like-their-food-bite-sized-20160222-gn0t18.html

Australasian Science – *Marine parks don't protect diversity*, D Bellwood, 24 February 2016 http://www.australasianscience.com.au/article/issue-march-2016/marine-parks-don't-protect-diversity.html

National Geographic – *Warming threatens the Great Barrier Reef even more than we thought* T Hughes, T Ainsworth, D Wachenfeld, 14 April, 2016 http://news.nationalgeographic.com/2016/04/160414-great-barrier-reef-coral-bleaching-australia-climate-change-science/

Cosmos - W*arming wears down coral's defence system*, M McCulloch, T Ainsworth, 15 April 2016 https://cosmosmagazine.com/climate/warming-wears-down-corals-defence-system

Washington Post – *'And then we wept': Scientists say 93 percent of the Great Barrier Reef now bleached*, T Hughes, 20 April, 2016 https://www.washingtonpost.com/news/energy-environment/wp/2016/04/20/and-then-we-wept-scientists-say-93-percent-of-the-great-barrier-reef-now-bleached/?utm_term=.33472287221f

Sydney Morning Herald – *Coral bleaching puts damselfish in distress by masking predator scent*, M McCormick, 11 May, 2016 http://www.smh.com.au/environment/coral-bleaching-puts-damselfish-in-distress-by-masking-predator-scent-20160511-goseco.html

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Lateline, ABC TV – Interview: *Mass bleaching kills 35% of coral on Great Barrier Reef*, T Hughes, 30 May 2016 http://www.abc.net.au/lateline/content/2015/s4472312.htm

The Guardian – *Great Barrier Reef marine science program boosts indigenous numbers at university*, J Pollock, 2 June 2016 https://www.theguardian.com/environment/2016/jun/02/great-barrier-reef-marine-science-program-boosts-indigenous-numbers-at-university

Los Angeles Times – *Coral reef census will help scientists protect fragile underwater habitats*, J Cinner, 15 June 2016 http://www.latimes.com/science/sciencenow/la-sci-sn-coral-reef-census-20160613-snap-story.html

Australian Geographic – *'Bright spots' found among damaged coral reefs*, J Cinner, N Graham, 17 June 2016 http://www.australiangeographic.com.au/news/2016/06/bright-spots-found-among-damaged-coral-reefs/

ABC North Queensland – *Women break down barriers to save the Reef,* N Andrade, 6 July 2016 http://www.abc.net.au/news/2016-07-06/women-break-down-barriers-to-save-the-reef/7572904

Reuters - *Some fish tackle ocean global warming by pretending it's night*, P Munday, 2 August 2016 https://www.yahoo.com/news/fish-tackle-ocean-global-warming-pretending-night-152459305.html

Smithsonian Magazine – *Humans have promoted the reef shark to apex predator,* P Mumby, G Roff, 5 August 2016 http://www.smithsonianmag.com/science-nature/are-we-overvaluing-reef-sharks-180960041/

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Science Magazine – *Some relief for Great Barrier Reef*, O Hoegh-Guldberg, T Hughes, 29 September 2016 http://www.sciencemag.org/news/2016/09/some-relief-great-barrier-reef

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The Saturday Age, Melbourne – *Saving the Reef*, T Hughes, J Day, J Brodie, 26 November 2016 http://www.theage.com.au/interactive/2016/saving-the-reef

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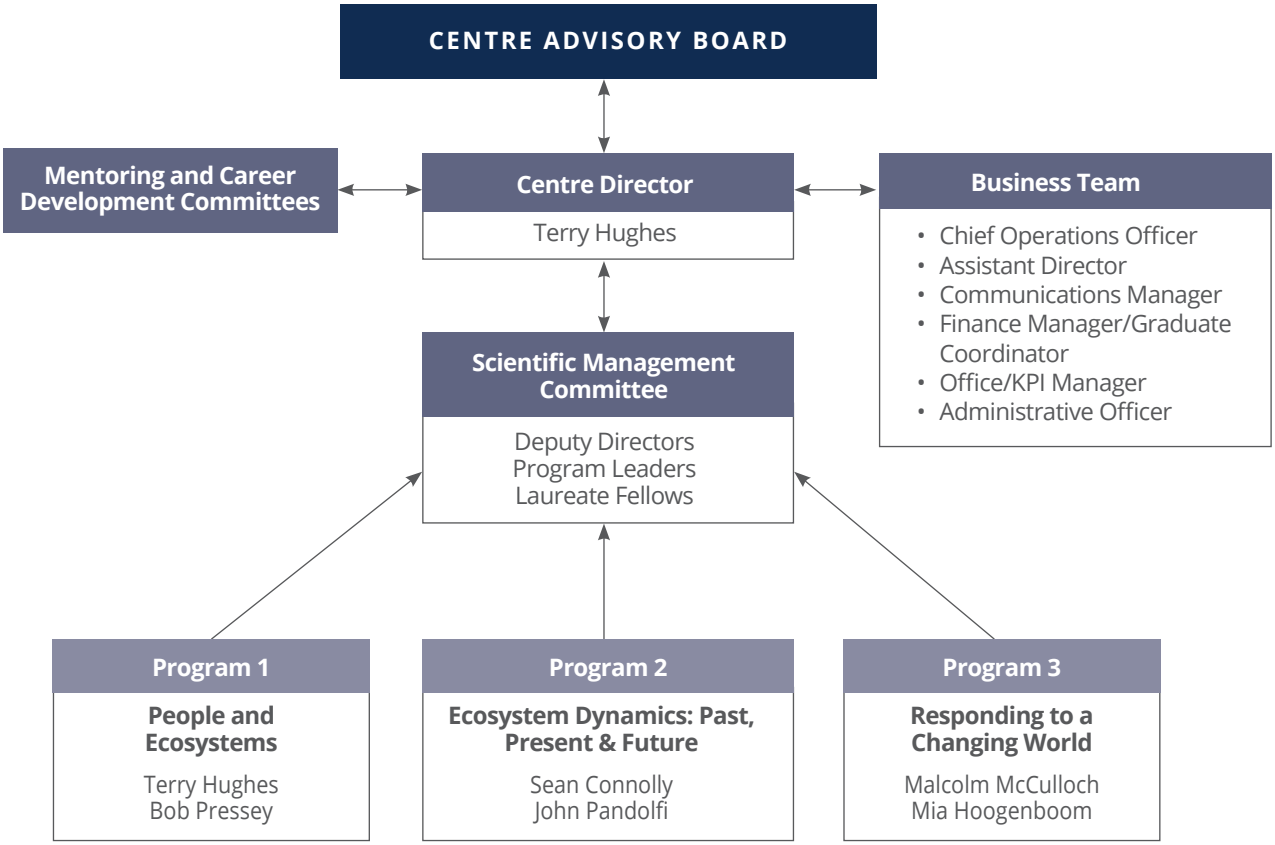
GOVERNANCE

The ARC Centre has a clearly defined and effective governance structure that engages key stakeholders in the Centre's strategic planning, research program development, knowledge transfer and communications, management and operations.

The ARC Centre's Administering Organisation is James Cook University. The Centre Director, Terry Hughes, reports directly to the Senior Deputy Vice-Chancellor, Professor Chris Cocklin. The longstanding placement of the Centre within JCU's Division of Research and Innovation is a key element of successful governance. This high-level placement ensures the Centre's independence in multi-disciplinary recruitment of researchers and students, reduces the bureaucracy of day to day operations, and enhances the ability of the Centre to operate as a multi-nodal national Centre with exceptionally strong international linkages. Operations are managed by the Chief Operations Officer, Jennifer Lappin, in consultation with the Centre Director and Assistant Director. In 2016 we farewelled David Yellowlees, the ARC Centre's inaugural Assistant Director (p66) and welcomed Dr Alana Grech to the position. Alana's expertise in environmental management, spatial information science and conservation planning will strengthen these areas of the Centre's interdisciplinary research.

The diagram below illustrates the Centre's highly successful governance structure. Director Terry Hughes oversees the Centre's research programs in conjunction with the two Deputy Directors, Ove Hoegh-Guldberg (UQ) and Malcolm McCulloch (UWA). Chief Investigators are located in the Centre's four nodes at James Cook University, 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 leading overseas research institutions (p54). Adjunct researchers also make a significant contribution to the Centre's research programs.

The Centre's two principal governance committees are the Centre Advisory Board and the Scientific Management Committee. Both committees are chaired by an eminent international researcher, with the Chief Operations Officer, Jennifer Lappin, as secretary. The Centre also supports two additional committees run by Centre graduate students and Early Career Research Fellows, tasked with the organisation of annual retreats and training workshops, and contributing to career development and mentoring (p45).

CENTRE ADVISORY BOARD

The Centre's Advisory Board provides high-level strategic advice to the Centre Director, and facilitates building linkages between the Centre and industry, State, Territory and Commonwealth Governments and non-government organisations. The Centre Director and the Chief Operations Officer provide the link between the Centre Advisory Board, the Scientific Management Committee, and Centre operations.

Dr Brian Walker *FAA* is the Chair of the Board. Membership of the Centre's Advisory Board reflects the Centre's strong multi-disciplinary research activities and includes the Chief Executive Officer of the Australian Institute of Marine Science, the Chair of the Great Barrier Reef Marine Park Authority, and a senior representative from WorldFish, an international nonprofit research organisation. Professor Mandy Thomas brings a wealth of experience from the ARC and University sector.

The Centre Advisory Board met formally on 21st April 2016 in Townsville. A key focus for the Board during 2016 was preparing the Centre for its formal mid-term review to be conducted by the ARC in June 2017. A trial review of the Centre was undertaken during October, by Board members Dr Brian Walker (CSIRO) and Professor Mandy Thomas (QUT) and independent reviewer Professor Robert Costanza (ANU). The Centre is grateful for the trial review panel's expertise and advice which will provide invaluable assistance in preparing the Centre for the upcoming formal review.

Membership of the Centre Advisory Board:

Dr Brian Walker *FAA* (Chair)
Fellow
CSIRO Ecosystem Sciences

Dr Neil Andrew
Regional Director, Pacific
WorldFish, Malaysia

Professor Terry Hughes
Director
ARC Centre of Excellence for Coral Reef Studies

Margaret Johnson
General Manager, Policy & Stewardship
Great Barrier Reef Marine Park Authority
(Delegate of Dr Russell Reichelt, Chair)

Dr David Souter
Research Manager
Australian Institute of Marine Science
(Delegate of John Gunn, Chief Executive Officer,)

Professor Mandy Thomas
Executive Dean, Creative Industries Faculty,
Queensland University of Technology

SCIENTIFIC MANAGEMENT COMMITTEE

High level operational decisions of the Centre, planning and stewardship of the Centre's scientific research program are the responsibility of the Centre's Scientific Management Committee (SMC). The Committee is chaired by eminent international social science researcher, Professor Kate Brown from Exeter University, UK. Other members are the leaders of each of the Centre's Research Programs, the Centre's current Laureate Fellows, and the Director – Reef Recovery, GBRMPA (the Federal Government agency responsible for reef management in Australia, and the Centre's principal end-user).

In 2016 the SMC welcomed Dr Mia Hoogenboom as co-leader of Program 3, replacing Professor Bette Willis who retired at the end of 2016. We sincerely thank Bette for her strong and inspired leadership of Program 3, for building cross institutional collaborations and providing effective mentoring and opportunities for Early Career Researchers (p65).

The SMC met three times during 2016: in Honolulu during the 13th International Coral Reef Symposium (ICRS), and twice in Townsville. The SMC's priority in 2016 was coordinating the Centre's National Coral Bleaching Taskforce in response to the devastating coral bleaching event on the Great Barrier Reef in early 2016. Additionally, the SMC planned and implemented the Centre's activities at the ICRS in Hawaii in June 2016. Members of the SMC continue to take a key role in providing advice to the Queensland and Australian Governments on the *Reef 2050 Long Term Sustainability Plan*.

Membership of the Scientific Management Committee:

Professor Kate Brown (Chair)
Chair in Social Science
Environment and Sustainability Institute
University of Exeter
United Kingdom

Distinguished Professor Terry Hughes *FAA*
ARC Australian Laureate Fellow and Leader Research Program 1
James Cook University

Distinguished Professor Bob Pressey *FAA*
Leader, Research Program 1
James Cook University

Professor Sean Connolly
Leader, Research Program 2
James Cook University

Professor John Pandolfi
Leader, Research Program 2
University of Queensland

Professor Malcolm McCulloch *FAA FRS*
ARC Australian Laureate Fellow and Leader Research Program 3
University of Western Australia

Dr Mia Hoogenboom
Leader, Research Program 3
James Cook University

Professor Ove Hoegh-Guldberg *FAA*
ARC Australian Laureate Fellow and Deputy Director
University of Queensland

Dr David Wachenfeld
Director – Reef Recovery
Great Barrier Reef Marine Park Authority

PROFILE

EMERITUS PROFESSOR BETTE WILLIS

Long standing Chief Investigator and Program Leader in the ARC Centre, Professor Bette Willis, formally retired at the end of 2016, following an outstanding research career spanning more than 30 years. We wish Bette well in her 'retirement' and thank her for her leadership, dedication to her research, patience and inclusiveness.

Bette Willis is a world leader in the biology and ecology of reef corals, with over 14,500 citations. She has published more than 160 peer-reviewed publications, including seven book chapters, and has won numerous awards and accolades. In 2015, she was awarded the title of *Distinguished Professor* by James Cook University for exceptional scholarly contribution and prominence as an international research leader. She has served on several committees of the Great Barrier Reef Marine Park Authority (GBRMPA), on expert working groups and has collaborated with GBRMPA on the development of management plans. She has also been an active member of numerous international marine research networks, targeting awareness and research into coral diseases. For example, between 2003 and 2009, Bette was co-chair of the *Coral Disease Working Group* funded by the Global Environment Facility and the World Bank.

Bette was awarded her PhD from JCU in 1987. Since then, she has become a leading academic figure internationally and at JCU. Throughout her career, Bette has produced seminal work. In 1984, she and her colleagues made a landmark discovery of synchronous spawning of corals on the Great Barrier Reef, published in *Science*, for which they received the *Pol Eureka Prize for Environmental Science*. In 2007, Bette co-authored the first paper to use remote sensing to pinpoint thermal anomalies underlying coral disease outbreaks on the Great Barrier Reef. Bette's research over the past decade has focussed on the ecological significance of coral disease, and on links between disease prevalence, ocean warming and water quality. In tandem, her recent research has also focussed on the capacity of corals to cope with climate change through their potential to form symbiosis with a range of *Symbiodinium* clades that affect their thermal tolerance. Taken together, these two research themes continue to form a timely, critical component of our understanding of the risks and adaptive capacities of corals in an era of global climate change.

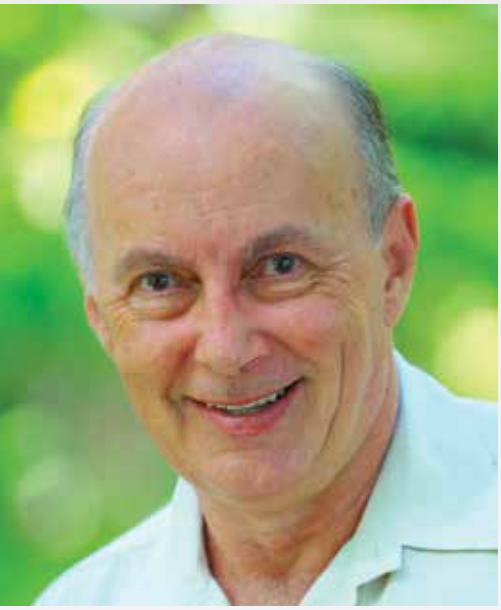
Bette comments that, "I am acutely aware of the need to provide science that underpins the sustainable management of coral reefs. It's a key responsibility for researchers who work on this important ecosystem". Whether she is researching larval dispersal and recruitment of corals or the role of marine protected areas in ameliorating coral disease, Bette has made a major contribution to the sustainability of the Great Barrier Reef and reefs worldwide.

Many coral reef scientists owe their research careers to Bette, who is an outstanding and inspirational teacher and mentor. As a consequence, she has received many accolades, including the *Outstanding Career Achievement in Higher Degree by Research Supervision* awarded by James Cook University. Bette has supervised more than 100 postgraduate students, many of whom are now prominent coral reef scientists. She has also been an inspiring role model and mentor for early to mid-career women around the world. There are very few senior women in coral reef science, and Bette has played a major role in the professional development of female early career researchers.

In 2016, Bette Willis was awarded the International Society for Reef Studies *Eminence in Research Award* for her 'outstanding body of research over an extended period of time'. In recognition of Bette's distinguished academic service to the scholarly community JCU also bestowed on her the prestigious title of *Professor Emeritus*. We are looking forward to continuing to collaborate with Bette as she combines this role with her 'retirement'.

PROFILE

EMERITUS PROFESSOR DAVID YELLOWLEES



Professor David Yellowlees retired in 2016, having made an exceptional contribution to the ARC Centre of Excellence in leadership and research, as both the Assistant Director and a Chief Investigator. We extend our profound thanks to David for his wisdom, diplomacy, and commitment to mentoring students and early career researchers. Mostly we thank David for his good humour and infectious laugh.

Following his PhD in biochemistry at Heriot Watt University in Edinburgh in 1970, David's research interests have been diverse, but in recent years he is best known internationally for his publications on the biochemistry of coral reef organisms, a field he entered in the mid-1980s. In particular, he is widely recognised as one of Australia's pioneers on the symbiosis between dinoflagellates and coral reef organisms, publishing over 50 original peer-reviewed journal articles on this topic alone. David's group made significant contributions to several areas of symbiosis research. These include the discovery that zooxanthellae, the coral's dinoflagellate symbionts, fix carbon dioxide using a molecular form of the enzyme Rubisco that previously was thought to occur only in anaerobic microorganisms. His research on the acquisition of inorganic carbon in corals and clams, and its photosynthetic fixation and transfer from zooxanthellae to the animal host, forms the basis of much of our understanding of the metabolism of these organisms.

David joined James Cook University as a young lecturer in 1971, his career with JCU spanned a prodigious 45 years. Over that time, he has been an excellent teacher, researcher, and postgraduate supervisor, and later, an outstanding and creative staff and graduate mentor and academic leader.

In addition to his own research outputs, David has continued to make an extraordinary contribution as a research mentor, fostering the research development and careers of a huge number of graduate students and early and mid-career researchers. Many of these people have established themselves as key research performers both in the ARC Centre and elsewhere, nationally and internationally. For these contributions David was presented with the Vice-Chancellor's inaugural *Dugong Award* in 2008, which 'recognises senior staff who have made a difference in University leadership and management – above and beyond the call of duty'.

In his role as Assistant Director of the ARC Centre, David has been a key member of the leadership team. He was an integral part of the core group who wrote the successful $28m grant for the renewal of the ARC Centre from 2014 to 2020, as well as being key to the original ARC Centre funding application in 2005.

David was a key member of the Organising Committee of the 12th International Coral Reef Symposium (ICRS), which the ARC Centre and JCU co-hosted in 2012 in Cairns. This highly successful major event attracted more than 2000 delegates from 80 countries, generated huge international media attention, and cemented the ARC Centre's reputation in coral reef research leadership. David was the Chair of the Fundraising Committee, attracting an impressive $1m in sponsorship, and he also executed an outstanding job as editor of the Symposium Proceedings.

David Yellowlees has given unparalleled, distinguished service to every dimension of research and leadership of the ARC Centre. On retiring, JCU deservedly awarded him the title of *Professor Emeritus*. We believe that David in his 'retirement' will continue to provide expert advice and service to the ARC Centre's community and a new generation of researchers for many years.

MEMBERSHIP

In 2016, the Centre's membership comprised: 65 Chief Investigators, Research Fellows and Associates; 30 Partner Investigators, resident international scholars and adjunct researchers; and 206 research students (p45). Eleven of the Centre's Research Fellows were funded by ARC awards (Laureate, Future Fellow and DECRA), and one by a Society-in-Science Branco-Weiss Fellowship.

Tragically, in late 2016 we received the dreadful news that our colleague and friend Sylvain Forêt, a Chief Investigator in the ARC Centre, had died suddenly. He was a brilliant scholar and dear friend to many in the Centre and will be greatly missed. Vale Sylvain (p10).

In 2016, the Centre welcomed 9 new Research Fellows: Bridie Allan, Kristen Anderson, Jon Brodie, Karen Chong-Seng, Francois Dufois, Peter Cowman, Jenni Donelson, Mélanie Hamel, and Andrew Song. The Centre exceeded its gender equity goal by recruiting more female than male Research Fellows.

We also farewelled a number of our researchers who have taken up new positions elsewhere, extending the Centre's network of alumni collaborators: Mary Bonin, Jana Brotánková, Michael Fabinyi, Alistair Harborne, and Amelia Wenger. We wish them well in their continuing research careers.

CHIEF INVESTIGATORS AND RESEARCH FELLOWS

Professor Terry Hughes
Centre Director
ARC Australian Laureate Fellow
James Cook University

Dr Tracy Ainsworth
Research Fellow
James Cook University

Dr Bridie Allan
Research Fellow
James Cook University

Dr Jorge Álvarez-Romero
Research Fellow
James Cook University

Dr Kristen Anderson
Research Fellow
James Cook University and Australian Institute of Marine Science

Professor Andrew Baird
Research Fellow
James Cook University

Professor David Bellwood
Chief Investigator
James Cook University

Dr Dorothea Bender-Champ
Research Fellow
University of Queensland

Dr Jessica Blythe
Research Fellow
James Cook University and WorldFish, Malaysia

Dr Pim Bongaerts
Discovery Early Career Researcher Award (DECRA)
University of Queensland

Dr Mary Bonin
Research Fellow
James Cook University

Dr Yves-Marie Bozec
Research Fellow
University of Queensland

Dr Tom Bridge
Research Fellow
James Cook University, AIMS and Queensland Museum

Professor Jon Brodie
Research Fellow
James Cook University

Dr Jana Brotánková
Research Associate
James Cook University

Professor Joshua Cinner
ARC Future Fellow
James Cook University

Dr Steeve Comeau
Discovery Early Career Researcher Award (DECRA)
University of Western Australia

Professor Sean Connolly
Chief Investigator
James Cook University

Dr Christopher Cornwall
Research Fellow
University of Western Australia

Dr Peter Cowman
Research Fellow
James Cook University

Professor Graeme Cumming
Research Fellow
James Cook University

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

Dr Jenni Donelson
Research Fellow
James Cook University and King Abdullah University of Science and Technology

Dr François Dufois
Research Fellow
University of Western Australia

Assoc Professor Sophie Dove
Chief Investigator
University of Queensland

Dr Michael Fabinyi
Society in Science Research Fellow
James Cook University

Dr James Falter
Research Fellow
University of Western Australia

Dr Sylvain Forêt
Chief Investigator
Australian National University

Dr Sofia Fortunato
Research Fellow
James Cook University

Dr Manuel González-Rivero
Research Fellow
University of Queensland

Dr Georgina Gurney
Research Fellow
James Cook University

Dr Hugo Harrison
Discovery Early Career Researcher Award (DECRA)
James Cook University

Professor Ove Hoegh-Guldberg
Deputy Director
ARC Australian Laureate Fellow
University of Queensland

Dr Andrew Hoey
Research Fellow
James Cook University

Dr Mia Hoogenboom
Chief Investigator
James Cook University

Professor Geoffrey Jones
Chief Investigator
James Cook University

Professor Michael Kingsford
Chief Investigator
James Cook University

Dr Nils Krück
Research Fellow
University of Queensland

Dr Andreas Kubicek
Research Fellow
University of Queensland

Assoc Professor Bill Leggat
Research Fellow
James Cook University

Professor Ryan Lowe
Future Fellow
University of Western Australia

Dr Vimoksalehi Lukoschek
Discovery Early Career Researcher Award (DECRA)
James Cook University

Professor Mark McCormick
Chief Investigator
James Cook University

Professor Malcolm McCulloch
Deputy Director, ARC Australian Laureate Fellow
University of Western Australia

Dr Vanessa Messmer
Research Fellow
James Cook University

Professor David Miller
Chief Investigator
James Cook University

Dr Tiffany Morrison
Research Fellow
James Cook University

Dr Aurélie Moya
Research Fellow
James Cook University

Professor Peter Mumby
Chief Investigator
University of Queensland

Professor Philip Munday
ARC Future Fellow
James Cook University

Professor John Pandolfi
Chief Investigator
University of Queensland

Professor Morgan Pratchett
Research Fellow
James Cook University

Professor Bob Pressey
Research Fellow
James Cook University

Dr George Roff
Research Fellow
University of Queensland

Dr Jodie Rummer
Discovery Early Career Researcher Award (DECRA)
James Cook University

Professor Garry Russ
Chief Investigator
James Cook University

Dr Eugenia Sampayo
Research Fellow
University of Queensland

Dr Verena Schoepf
Research Fellow
University of Western Australia

Dr Andrew Song
Research Fellow
James Cook University and WorldFish, Malaysia

Dr Greg Torda
Research Fellow
James Cook University and Australian Institute of Marine Science

Dr Heather Veilleux
Research Fellow
James Cook University and King Abdullah University of Science and Technology

Dr Sue-Ann Watson
Research Fellow
James Cook University

Dr Rebecca Weeks
Research Fellow
James Cook University

Dr Amelia Wenger
Research Associate
James Cook University

Professor Bette Willis
Chief Investigator
James Cook University

RESIDENT INTERNATIONAL SCHOLARS

Dr Michele Barnes
National Science Foundation Research Fellow, USA

Dr Karen Chong-Seng
Aldabra Marine Researcher
Seychelles Islands Foundation

Dr Pip Cohen
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WorldFish, Malaysia

Dr Mélanie Hamel
Research Consultant
Centre National de la Recherche Scientifique, France

Dr David Mills
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Dr Chiara Pisapia
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California State University
USA

PARTNER INVESTIGATORS AND ADJUNCT RESEARCHERS

Dr Vanessa Adams
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University of Melbourne

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University of Exeter
United Kingdom

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Lancaster University
United Kingdom

Dr Alison Green
The Nature Conservancy

Dr Richard Hamilton
The Nature Conservancy

Dr Christina Hicks
Lancaster University
United Kingdom

Dr Anne Hoggett
Lizard Island Research Station

Professor Jeremy Jackson
International Union for Conservation of Nature, USA

Professor Janice Lough
Australian Institute of Marine Science

Dr Tim McClanahan
Wildlife Conservation Society, Kenya

Dr Laurence McCook
South China Sea Institute of Oceanology

Dr Aaron MacNeil
Australian Institute of Marine Science

Professor David Mouillot
Université Montpellier, France

Professor Stephen Palumbi
Stanford University, USA

Dr Serge Planes
University of Perpignan, France

Professor Madeleine van Oppen
Australian Institute of Marine Science

Dr David Wachenfeld
Great Barrier Reef Marine Park Authority

GRADUATE STUDENTS (SEE PAGE 45)

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Cindy Huchery
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Mizue Jacobson
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James Cook University

Anton Kuret
University of Western Australia

Shannon McMahon
James Cook University

Anne-Marin Nisumaa-Comeau
University of Western Australia

Jue Sheng Ong
Australian National University

Justin Osbaldiston
James Cook University

Dr Alison Paley
James Cook University

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University of Western Australia

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PUBLICATIONS

In 2016, researchers from the ARC Centre of Excellence produced 328 publications, including 315 journal articles, 1 book, 5 book chapters, 2 conference papers and 5 reports.

Centre researchers published 113 articles in journals with Impact Factors greater than four, including 26 in prestige journals – *Science*, the *Nature* Journals, *Trends in Ecology and Evolution*, *Ecology Letters* and *Proceedings of the National Academy of Sciences USA*. The average Impact Factor for all 315 journal articles in 2016 was 5.1. The Centre's research outputs were published in a total of 106 journal titles, spanning many fields of research and reflecting the multidisciplinary breadth of the Centre's activities.

According to Scopus, Centre researchers were cited 31,025 times in 2016. Twenty-six researchers were each cited more than 500 times and 17 had more than 1,000 citations in the past 12 months.

The six articles that received the highest Altmetric scores for ARC Centre publications in 2016 were:

Scheffers, BR, De Meester, L, Bridge, TCL, Hoffmann, AA, Pandolfi, JM, Corlett, RT, Butchart, SHM, Pearce-Kelly, P, Kovacs, KM, Dudgeon, D, Pacifici, M, Rondinini, C, Foden, WB, Martin, TG, Mora, C, Bickford, D, and Watson, JEM (2016). The broad footprint of climate change from genes to biomes to people. *Science* 354(6313): 1-13.
Altmetric 1407 (mentioned by 70 news outlets, tweeted by 1053, ranked in top 10 climate papers for news and social media attention in 2016).

Cinner, JE, Huchery, C, MacNeil, MA, Graham, NAJ, McClanahan, TR, Maina, J, Maire, E, Kittinger, JN, Hicks, CC, Mora, C, Allison, EH, D'Agata, S, Hoey, A, Feary, DA, Crowder, L, Williams, ID, Kulbicki, M, Vigliola, L, Wantiez, L, Edgar, G, Stuart-Smith, RD, Sandin, SA, Green, AL, Hardt, MJ, Beger, M, Friedlander, A, Campbell, SJ, Holmes, KE, Wilson, SK, Brokovich, E, Brooks, AJ, Cruz-Motta, JJ, Booth, DJ, Chabanet, P, Gough, C, Tupper, M, Ferse, SCA, Sumaila, UR and Mouillot, D (2016). Bright spots among the world's coral reefs. *Nature* 535: 416-419.
Altmetric 1131 (mentioned by 112 news outlets, tweeted by 461, on 17 Facebook pages)

Ainsworth T, Heron S, Ortiz J, Mumby P, Grech A, Ogawa D, Eakin C and Leggat W (2016). Climate change disables coral bleaching protection on the Great Barrier Reef. *Science* 352(6283): 338-342.
Altmetric 704 (mentioned by 60 news outlets, tweeted by 224)

Nadler L, Killen S, McClure E, Munday P and McCormick M (2016). Shoaling reduces metabolic rate in a gregarious coral reef fish species. *Journal of Experimental Biology* 219(18): 2802-2805.
Altmetric 302 (mentioned by 34 news outlets, tweeted by 34).

Ainsworth, T, and Gates, R (2016). Corals' microbial sentinels. *Science* 352(6293): 1518-1519.
Altmetric 241 (mentioned by 20 news outlets, tweeted by 120).

Bozec, YM, O'Farrell, S, Bruggemann, JH, Luckhurst, BE and Mumby, PJ (2016). Tradeoffs between fisheries harvest and the resilience of coral reefs. *Proceedings of the National Academy of Sciences USA* 113(16): 4536-4541.
Altmetric 207 (mentioned by 17 news outlets, tweeted by 122).

PHOTO CIEMON CABELLES

BOOK (1)

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BOOK SECTION (5)

1. Bridge, T (2016). Mesophotic coral reefs examined: Great Barrier Reef. In: Baker, EK, Puglise, KA and Harris, PT. (eds). *Mesophotic coral ecosystems - a lifeboat for coral reefs?* The United Nations Environment Programme and GRID - Arendal, Nairobi and Arendal, 21-22 pp.
2. Budd, AF and Pandolfi, J (2016). Contrasting patterns of speciation in reef corals and their relationship to population connectivity species and speciation in the fossil record. In: Allmon, WD and Yacobucci, MM. (eds). *Species and Speciation the Fossil Record*, The University of Chicago Press, Cambridge, 217-236 pp.
3. Harris, PT and Bridge, T (2016). Introduction. In: Baker, EK, Puglise, KA and Harris, PT. (eds). *Mesophotic coral ecosystems - a lifeboat for coral reefs?* The United Nations Environment Programme and GRID - Arendal, Nairobi and Arendal, 9-10 pp.
4. Laverick, JH, Bejarano, I, Bridge, T, Colin, P, Eyal, G, Jones, R, Kahng, S, Reed, J, Smith, T, Spalding, H, Weil, E and Wood, E (2016). Threats to mesophotic coral ecosystems and management options. In: Baker, EK, Puglise, KA and Harris, PT. (eds). *Mesophotic coral ecosystems - a lifeboat for coral reefs?* The United Nations Environment Programme and GRID - Arendal, Nairobi and Arendal, 67-82 pp.
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JOURNAL ARTICLE (315)

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5. Ainsworth, TD, Heron, SF, Ortiz, JC, Mumby, PJ, Grech, A, Ogawa, D, Eakin, CM and Leggat, W (2016). Climate change disables coral bleaching protection on the Great Barrier Reef. *Science* 352(6283): 338-342.
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2017 ACTIVITY PLAN

RESEARCH

1. Continue to develop the Centre's interdisciplinary research capabilities through strategic recruitment of two Research Fellows with expertise in economics and social networks.
2. Modify the Centre's Research Programs in response to the review undertaken in 2016.
3. Refresh the Centre's Chief and Partner Investigators to reflect the Centre's evolving research profile.
4. Support the publication of research arising from the National Coral Reef Bleaching Taskforce, and maintain the research and resourcing effort for it among Australia's marine science research community.

RESEARCH TRAINING AND PROFESSIONAL DEVELOPMENT

1. Develop further multi-institutional and/or multi-disciplinary supervisory arrangements.
2. Enhance the Centre's professional development program in preparation for the Centre's National Student Mentoring Day.
3. Complete planning of the programs for the Student and Early Career Researcher Retreats, and attendance at the Centre's annual symposium (Student Committee).
4. Deliver professional development workshops on statistics, the effective use of social media to amplify students' research profile, improving oral presentations, and on publishing strategies and skills.
5. Initiate a multiple stranded leadership development program for women in STEM for PhD students through to Research Fellows.

NATIONAL AND INTERNATIONAL LINKAGES

1. Strengthen collaboration with King Abdullah University of Science and Technology, Saudi Arabia, and University of Exeter, UK, through increased Research Fellow exchanges, working group meetings and co-tutelle arrangements.
2. Provide Program-level funding for six working groups.
3. Improve videoconferencing infrastructure for seminars and workshops.
4. Strengthen policy linkages with the Australian Academy of Science.
5. Develop international research program, 'Coral Reefs in the Anthropocene'.

IMPACTS AND END USER ENGAGEMENT

1. Continue to engage with government and stakeholders regarding the *Reef 2050 Long Term Sustainability Plan*.
2. Plan and deliver the Centre's annual symposium in Canberra on 15th and 16th June.
3. Host a Public Forum on the *Future of Coral Reefs* with Dr Karl Kruszelnicki as MC in Canberra on 15th June.
4. Review and renew the Centre's communication plan, particularly social media engagement strategies.
5. Launch an ARC Centre Instagram account as part of our expanding social media platform.

GOVERNANCE

1. Appoint a new Chair to the Centre Advisory Board, and expand membership to include representatives from end-user groups and industry.
2. Recruit and mentor more female researchers into leadership roles within the Centre.
3. Update ARC Centre's Strategic Plan in response to the outcomes from the 2016 Program Review.
4. Review funding to the Centre's research programs.
5. Replace and improve the Key Performance Indicator data collection and reporting system.

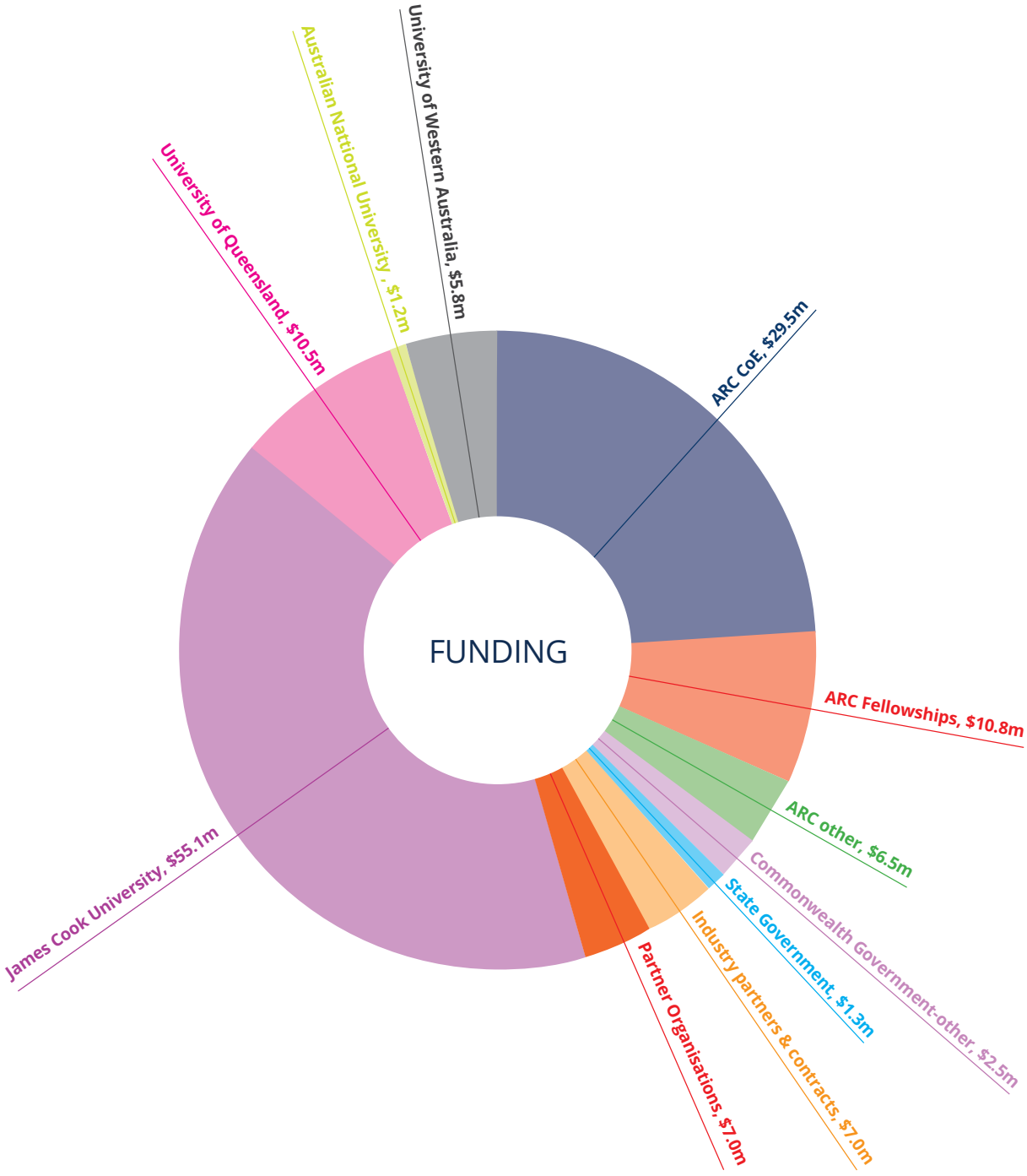
FINANCIAL STATEMENT

ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES
STATEMENT OF OPERATING INCOME AND EXPENDITURE FOR YEAR ENDED 31 DECEMBER 2016

Income	2015 $	2016 $	2017 forecast $
ARC Centre Grant	4,194,688	4,265,997	4,329,987
ARC Fellowships	1,605,747	1,187,662	1,218,604
ARC Other			130,290
Host Institutions cash support	3,614,394	3,664,501	3,769,737
State Government	30,000	65,500	185,000
Commonwealth Government other grants	489,160	493,731	650,000
International and other contracts	1,009,862	1,367,409	930,000
Total Income	**$10,943,851**	**$11,044,801**	**$11,218,618**
Expenditure			
Salaries	6,969,931	7,281,253	7,649,478
Equipment	492,963	443,055	495,000
Travel	1,356,655	1,541,483	1,561,626
Research maintenance and consumables	1,550,360	1,394,134	1,588,970
Scholarships and prizes	134,993	223,260	187,039
Public outreach and administration	92,105	136,719	124,706
Total Expenditure	**$10,324,007**	**$11,019,904**	**$11,606,819**
Surplus (Deficit)	**$619,844**	**$24,897**	**$(388,201)**

FINANCIAL OUTLOOK

As at December 2016, the total cash and inkind financial outlook for the ARC Centre of Excellence for Coral Reef Studies for 1 January 2014 to 31 December 2020 totals $137m, 13% higher than when the Centre was established in 2014. The ARC Centre of Excellence grant represents 22% of the total funding pool.



KEY PERFORMANCE INDICATORS

RESEARCH FINDINGS

Measure	Target 2016	Outcome 2016
Research outputs (p70)	300	**328**
Publications in journals with an Impact Factor > 4	80	**113**
Mean Impact Factor for journals published	3.8	**5.1**
Faculty of 1000 commentaries	7	**7**
Citations (p70)	19,000	**31,025**
Centre researchers with >500 citations	17	**26**
Invited talks/papers/keynotes at international meetings	24	**42**
No. and nature of commentaries about the Centre's achievements (p58)		
Articles	2,400	**12,631**
Media releases	26	**44**
Awards, prizes or recognition (p8)	24	**40**

RESEARCH TRAINING AND PROFESSIONAL EDUCATION

Measure	Target 2016	Outcome 2016
No. of professional training courses for staff and postgraduate students attended	24	**49**
No. of Centre attendees at all professional training/ development courses offered by the Centre	90	**1135**
No. of students mentored	170	**175**
No. of student attendances at the Centre's professional development events	70	**754**
No. of early career researchers participating in annual performance reviews, attending seminars, visiting other Centre nodes, attending ECR committee events	25	**28**
Stakeholder participation in Centre Working Group meetings, workshops and planning meetings	10	**118**
No. of new postgraduates enrolled (p45)	150 over life of Centre	**2016: 37 (130 to date)**
Postgraduate completions and completions times:		
No. of completions	175 over life of Centre	**2016: 55 (134 to date)**
No. submitting within 4 years of commencement	17	**29**
No. of new Honours students	80 over life of Centre	**2016: 2 (29 to date)**
No. of new postdoctoral researchers	40 over life of Centre	**2016: 9 (29 to date)**
No. of Early Career Researchers	14	**28**

INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

Measure	Target 2016	Outcome 2016
No. of international visitors (p54)	60	**71**
No. of national and international Working Groups held/ organised by the Centre	10	**20**
No. of visits to overseas laboratories and research facilities	100	**103**
Metrics of interdisciplinary research supported by the Centre:		
No. of journal titles in which Centre outputs are published	90	**106**
No. of four digit Field of Research disciplines in which the Centre research publications are classified	17	**19**
No. of students with multidisciplinary supervisory arrangements	40	**44**

END-USER LINKS

Measure	Target 2016	Outcome 2016
No. of government, industry and business briefings (p58)	80	**111**
No. of public awareness programs	34	**81**
No. of talks open to the public	45	**47**
Website hits	6.0m	**16.0m**

ORGANISATIONAL SUPPORT

Measure	Target 2016	Outcome 2016
Annual cash contributions from Administering and Collaborating Organisations:		
JCU	$1.0m	**$1.00m**
ANU	$0.05m	**$0.05m**
UQ	$0.27m	**$0.27m**
UWA	$0.20m	**$0.20m**
Annual in-kind contributions from Administering and Collaborating Organisations		
JCU	$5.8m	**$6.49m**
ANU	$0.077m	**$0.09m**
UQ	$1.19m	**$0.47m**
UWA	$0.62m	**$0.62m**

Annual cash contributions from Partner Organisations:		
AIMS	$110k	**$81k**
IUCN	$0k	**$0k**
CNRS	$7k	**$3k**
GBRMPA	$0k	**$145k**
Stanford	$4k	**$0k**
WorldFish	$56k	**$105k**
Annual inkind contributions from Partner Organisations:		
AIMS	$389k	**$389k**
GBRMPA	$25k	**$25k**
CNRS	$54k	**$54k**
Stanford	$167k	**$27k**
WorldFish	$100k	**$100k**
Other research income secured by Centre staff:		
ARC Grants	$2.8m	**$3.95m**
Other Australian competitive	$0.44m	**$0.30m**
Public sector	$0.40m	**$0.14m**
Industry and other research income	$0.36m	**$2.35m**
No. of new organisations collaborating with, or involved in the Centre	100 over life of Centre	**99**
Level and quality of infrastructure provided to the Centre	$1.46m	**$1.5m**

GOVERNANCE

Measure	Target 2016	Outcome 2016
Breadth, balance and experience of the members of the Advisory Board		**See page 62**
Frequency, attendance and value added by Advisory Board meetings	2 Centre Advisory Board meetings p.a. with 75% attendance 4 Scientific Management Committee meetings p.a. with 75% attendance	**See page 62**
Vision and usefulness 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**
Adequacy of the Centre performance measure targets	Benchmarking against world leading research institutions	**The Centre is ranked #1 in the world for citations and outputs in coral reef science**

Effectiveness of the Centre in bringing researchers together to form an interactive and effective research team:		
Participation in research program planning meetings	20	**43**
Attendance at annual symposium	80	**144**
No. of multi-institutional supervisory arrangements	44	**69**
No. of cross-nodal publications	34	**37**
Capacity building of the Centre through scale and outcomes:		
No. of countries where the Centre:		
Undertakes fieldwork	22	**25**
Advises governments and NGOs	11	**16**
No. of international co-authors	34	**747**
No. of overseas graduate student completions	100 over life of Centre	**2016: 43 (109 to date)**

NATIONAL BENEFIT

Measure	Target 2016	Outcome 2016
Measures of expansion of Australia's capability in the priority area(s):		
Growth in no. of publications and citations in environmental sustainability	10% annual increase from 2014 benchmark	**10%**
Interactions with industry, business and government	80 briefings	**111**
Cross-institutional publications	145	**261**
Contribution to national research priorities	1 case study highlighted in the annual report	**See page 36**
Measure of reputation and competitiveness	Benchmarking of publications and citations against other world leading institutions	**The Centre is ranked first in the world for publications and citations in coral reef science**

CENTRE SPECIFIC PERFORMANCE INDICATORS

Measure	Target 2016	Outcome 2016
Prestige publications (p70)	100 publications over life of Centre	**2016: 26 (65 to date)**
Publications with cross-institutional co-authorships	170	**261**
New Centre graduate students attracted to Australia from overseas (p45)	100 over life of Centre	**2016: 30 (109 to date)**
Centre graduate students with cross-nodal supervision	120 over life of Centre	**2016: 10 (61 to date)**
Gender equity in research fellow appointments (p40)	50:50	**56:44 5 females: 4 males**

ACKNOWLEDGEMENTS

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- Australian Academy of Science
- Australian Genome Research Facility (AGRF)
- Australian Government: Department of the Environment and Energy
- Australian Institute of Marine Science (AIMS)
- Australian Coral Reef Society
- Australian Marine Sciences Association
- Australian Museum
- Australian Society for Fish Biology
- Austral University of Chile
- Bioplatforms Australia
- Center for Ocean Solutions, Stanford University, USA
- Centre de Recherches Insulaires et Observatoire de l'Environnement (CRIOBE), French Polynesia
- Centre National de la Recherche Scientifique, France
- Comunidad y Biodiversidad, Mexico
- Conservation International, Philippines
- Deutsche Forschungsgemeinschaft, Germany
- Deutsche Forschungsgemeinschaft Excellence Cluster 'Future Ocean', University of Kiel, Germany
- Ecology of Infectious Marine Diseases Research Coordination Network, USA
- ETH Zurich, Switzerland
- Fisheries Research and Development Corporation, Canberra
- Great Barrier Reef Foundation, Australia
- Great Barrier Reef Marine Park Authority, Australia
- Holsworth Wildlife Research Endowment, Equity Trustees Charitable Foundation
- Institut des récifs coralliens du Pacifique (IRCP), French Polynesia
- International Union for the Conservation of Nature
- James S. McDonnell Foundation, USA
- King Abdullah University of Science and Technology, Saudi Arabia
- Lizard Island Research Station and Foundation, Australia
- Lord Howe Island Board, Australia
- L'Oreal Australia
- Marine Parks Authority, Lord Howe Island Marine Park, Australia
- National Climate Change Adaptation Facility, Australia
- National Environment Science Programme, Australia
- National Oceanic and Atmospheric Administration (NOAA), USA
- National Research Foundation of South Africa
- National Science Foundation, USA
- National University of Singapore
- Oceania Chondrichthyan Society, Australia
- Okinawa Institute of Science and Technology Graduate University, Japan
- Palawan State University, Philippines
- Pew Charitable Trusts, USA
- Queensland Museum
- RARE Conservation, Philippines
- Reef Rescue, Australia
- Royal Dutch and Belgian Zoological Societies
- Sea World Research and Rescue Foundation, Australia
- Secretariat for the Pacific Community, Noumea
- Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Japan
- Seychelles Islands Foundation
- Smithsonian Marine Network, USA
- Society for Experimental Biology
- Stockholm Resilience Centre, Sweden
- The Nature Conservancy
- University of Exeter, United Kingdom
- University of Perpignan, France
- United States Geological Survey (USGS), USA
- Western Australian Department of Fisheries
- Western Australian Department of Parks and Wildlife
- Western Australian Marine Science Institute (WAMSI)
- Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, USA
- Wildlife Preservation Society of Queensland
- WorldFish, Malaysia
- World Wildlife Fund (International), USA

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