ARC CENTRE OF EXCELLENCE
Coral Reef Studies

ANNUAL REPORT **2017**

2017

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COVER PHOTO: WINNER OF THE ARC CENTRE OF EXCELLENCE 2017 PHOTO COMPETITION: A PAIR OF BIGNOSE UNICORNFISH SWIMMING IN PARALLEL AND DISPLAYING SPAWNING OR AGGRESSION COLOUR PATTERNS. LOCATION: PALAU. PHOTOGRAPHER: MARK PRIEST, PHD STUDENT.

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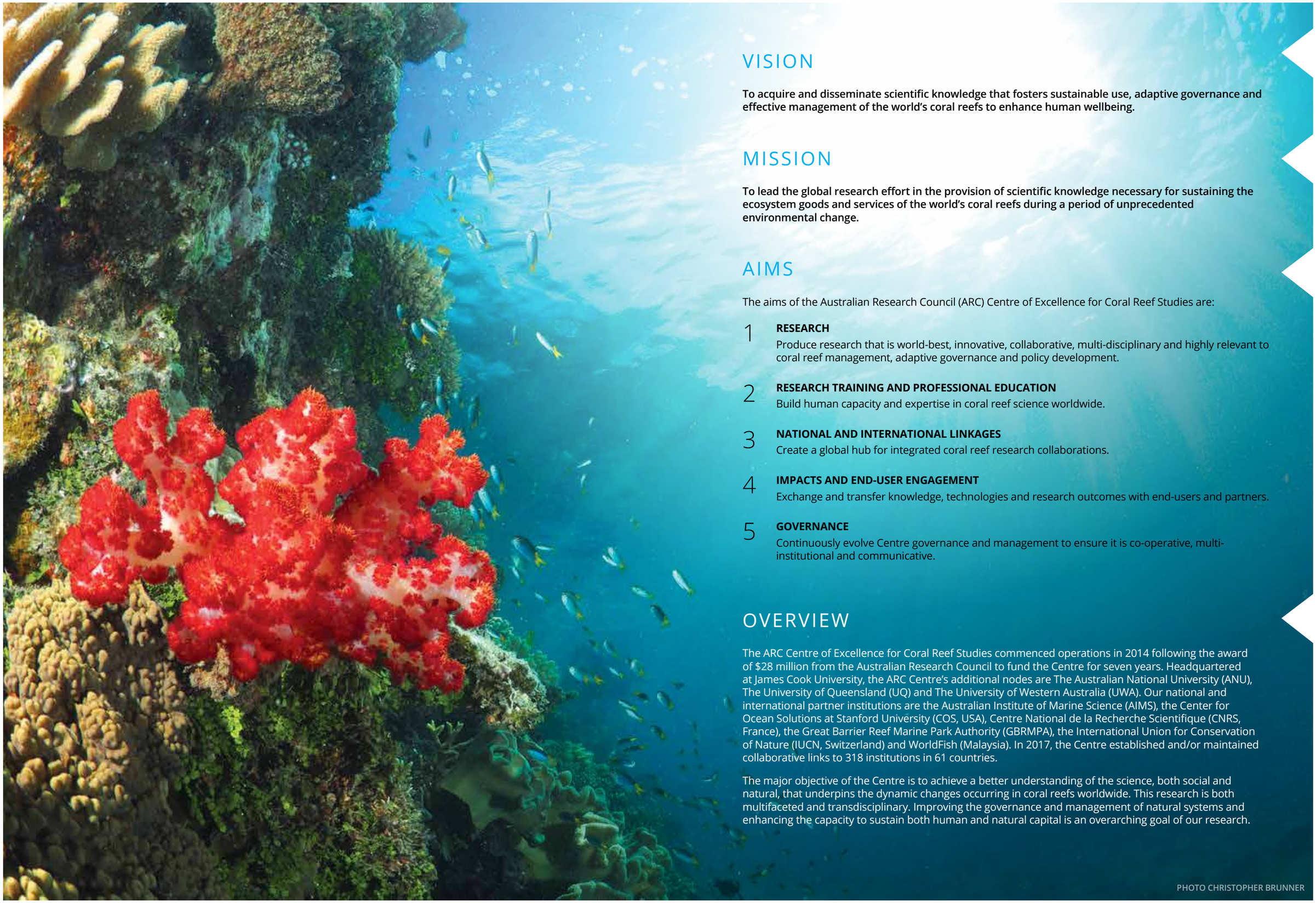
At the ARC Centre of Excellence for Coral Reef Studies we acknowledge the Australian Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the Traditional Owners of the lands and sea where we conduct our business. We pay our respects to ancestors and Elders, past, present and future. 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.

PHOTO MARK PRIEST



VISION

To acquire and disseminate 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:

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

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

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

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

5 **GOVERNANCE**
Continuously evolve Centre governance and 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 $28 million from the Australian Research Council to fund the Centre for seven years. Headquartered at James Cook University, the ARC Centre's 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 2017, the Centre established and/or maintained collaborative links to 318 institutions in 61 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 occurring in coral reefs worldwide. This research is both multifaceted and transdisciplinary. Improving the governance and management of natural systems and enhancing the capacity to sustain both human and natural capital is an overarching goal of our research.

PHOTO CHRISTOPHER BRUNNER

DIRECTOR'S REPORT

In the immediate aftermath of a multi-year global bleaching event, the need for coral reef research has never been greater. In 2017, we witnessed (and studied) the first back-to-back bleaching event on the Great Barrier Reef, resulting in unprecedented damage to two-thirds of this iconic World Heritage Area. Throughout the tropics, the global effort to improve governance and management of coral reefs is accelerating because of their importance to food security and human wellbeing. Our Centre's key goal is to provide and communicate the scientific knowledge that underpins sustainable use and stewardship of the world's coral reefs. This year's report includes a national priority case study of our research on the 2016 and 2017 bleaching events that exemplifies the uptake and impact of our research (p34).

Our ARC Centre was established with a 7-year funding cycle in 2014, and since then our research, publications, outreach and training activities have all grown very substantially. This year, 2017, we went through the important process of a mid-term review. This report documents our progress to date over our first four years of activities. At the end of 2017, the Centre's membership includes 68 Chief Investigators, Research Fellows and Associates; 28 Partner Investigators, resident international scholars and adjunct researchers; and 189 research students (p38).

In 2017, our fieldwork was undertaken in 28 tropical countries. In March, we published a cover article in *Nature* that summarised our aerial and underwater surveys of coral bleaching throughout tropical Australia. This work, co-authored by 46 authors from 11 institutions, was a huge effort that tested our capabilities to mobilize a small army of researchers across the country. In June, we published a second article in *Nature*, entitled 'Coral Reefs in the Anthropocene' (p16). Drawing on the social sciences, it provides a blueprint for better governance and management of reefs, and for coping with rapid change. The Centre's research program summaries on pp.10–32 provide many other examples of our recent and current activities at home and abroad.

Our Centre is the largest provider of graduate training in coral reef research in the world, and in 2017, our research students came to Australia from 41 countries (p38). The Centre's publication output reached a record 373 publications in 2017 (p68) – reaching our goal of one journal article each day. Since 2014, we have produced a total of more than 1,000 publications. Our collaborators in 2017 came from 318 institutions in 61 countries (p52).

The Centre's website is one of the major ways we communicate to a range of audiences around the world. In 2017, it received 14.1 million hits. The Centre's media coverage, boosted by the interest in our work on coral bleaching, has also continued to grow rapidly during 2017 (p58).

Centre members provided more than 120 briefings, workshops and consultancies during the year to governments, management agencies, non-government organisations (NGOs) and business organisations. Examples include Australian Commonwealth Departments, the Queensland and Western Australian governments, International Union for Conservation of Nature (IUCN), USA's National Oceanic and Atmospheric Administration (NOAA), Solomon Island Ministries, The Nature Conservancy (TNC), United Nations Educational, Scientific and Cultural Organization (UNESCO), USAid, and many more.

As we submit this report, we look forward to a highly productive 2018. Already we have two additional high profile papers accepted for publication in *Science* and *Nature* on the 2015/2016 and 2017 global bleaching events. In November 2017, we deployed recruitment panels along the length of the Great Barrier Reef, as our research turns now to addressing the slow recovery process that will unfold in coming years.

Lastly, I'd like to express my gratitude to our many other friends around the world for their contributions to an outstanding year, to the Centre's Advisory Board, and our research partners and end-users (particularly the Australian Institute for Marine Science, the Great Barrier Reef Marine Park Authority, and WorldFish). I am especially grateful to our Centre's Assistant Director, Alana Grech, and to our talented operations team – Jenny Lappin, Olga Bazaka, Viv Doherty, Catherine Naum and Janet Swanson – for their enthusiastic and friendly support.

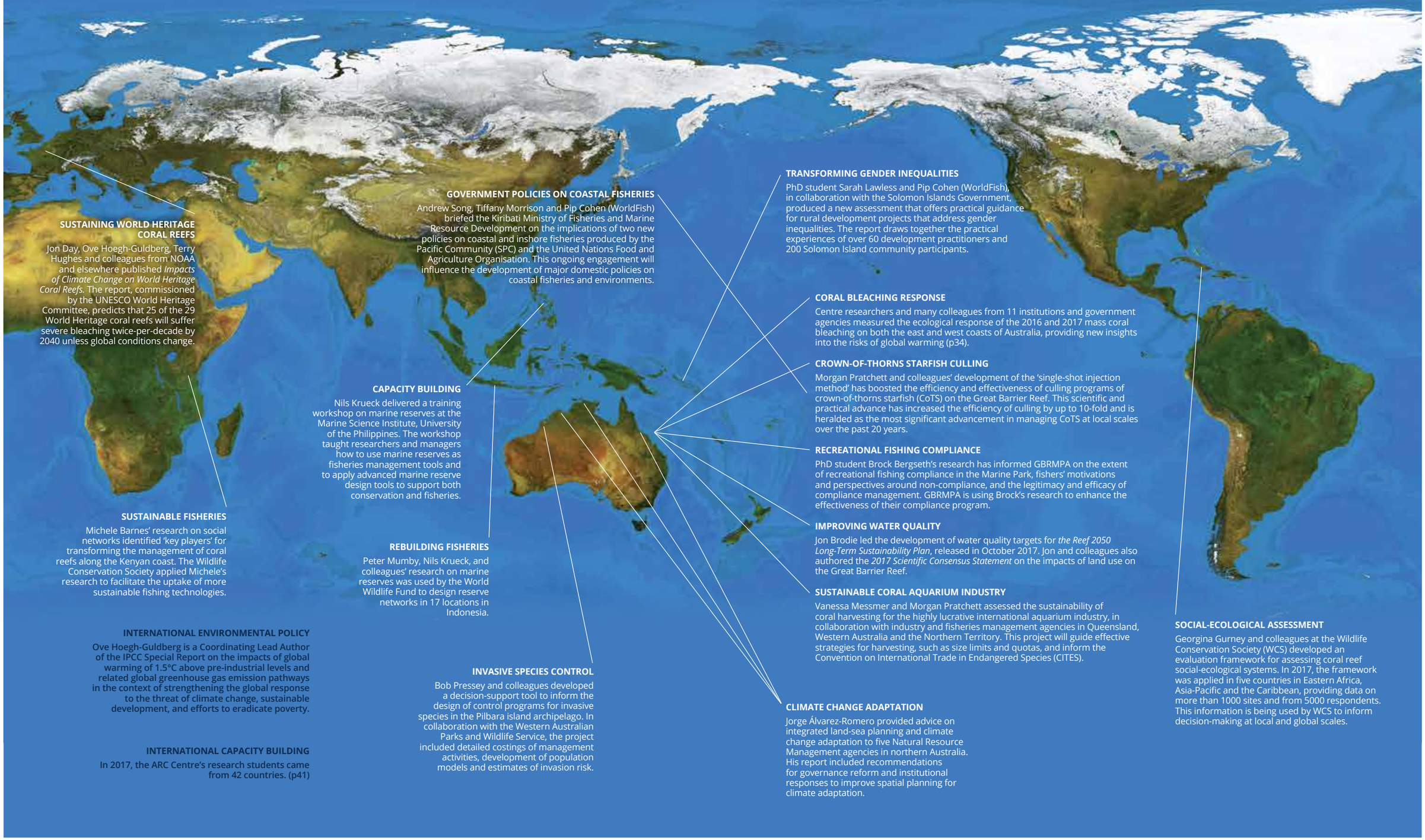
Terry Hughes
Director

PHOTO CHRISTOPHER BRUNNER

RESEARCH IMPACT AND ENGAGEMENT 2017

OPEN DATA

Digital data and metadata generated by the ARC Centre of Excellence is shared with the world via multiple platforms, including the JCU, UQ, ANU and UWA online data repositories that are syndicated with the Australian Research Data Commons, and made widely available via Research Data Australia. In 2017, over 140 individual datasets generated by Centre researchers were made accessible via Research Data Australia (https://researchdata.ands.org.au).



SUSTAINING WORLD HERITAGE CORAL REEFS

Jon Day, Ove Hoegh-Guldberg, Terry Hughes and colleagues from NOAA and elsewhere published *Impacts of Climate Change on World Heritage Coral Reefs*. The report, commissioned by the UNESCO World Heritage Committee, predicts that 25 of the 29 World Heritage coral reefs will suffer severe bleaching twice-per-decade by 2040 unless global conditions change.

GOVERNMENT POLICIES ON COASTAL FISHERIES

Andrew Song, Tiffany Morrison and Pip Cohen (WorldFish) briefed the Kiribati Ministry of Fisheries and Marine Resource Development on the implications of two new policies on coastal and inshore fisheries produced by the Pacific Community (SPC) and the United Nations Food and Agriculture Organisation. This ongoing engagement will influence the development of major domestic policies on coastal fisheries and environments.

TRANSFORMING GENDER INEQUALITIES

PhD student Sarah Lawless and Pip Cohen (WorldFish), in collaboration with the Solomon Islands Government, produced a new assessment that offers practical guidance for rural development projects that address gender inequalities. The report draws together the practical experiences of over 60 development practitioners and 200 Solomon Island community participants.

CORAL BLEACHING RESPONSE

Centre researchers and many colleagues from 11 institutions and government agencies measured the ecological response of the 2016 and 2017 mass coral bleaching on both the east and west coasts of Australia, providing new insights into the risks of global warming (p34).

CROWN-OF-THORNS STARFISH CULLING

Morgan Pratchett and colleagues' development of the 'single-shot injection method' has boosted the efficiency and effectiveness of culling programs of crown-of-thorns starfish (CoTS) on the Great Barrier Reef. This scientific and practical advance has increased the efficiency of culling by up to 10-fold and is heralded as the most significant advancement in managing CoTS at local scales over the past 20 years.

RECREATIONAL FISHING COMPLIANCE

PhD student Brock Bergseth's research has informed GBRMPA on the extent of recreational fishing compliance in the Marine Park, fishers' motivations and perspectives around non-compliance, and the legitimacy and efficacy of compliance management. GBRMPA is using Brock's research to enhance the effectiveness of their compliance program.

IMPROVING WATER QUALITY

Jon Brodie led the development of water quality targets for *the Reef 2050 Long-Term Sustainability Plan*, released in October 2017. Jon and colleagues also authored the *2017 Scientific Consensus Statement* on the impacts of land use on the Great Barrier Reef.

SUSTAINABLE CORAL AQUARIUM INDUSTRY

Vanessa Messmer and Morgan Pratchett assessed the sustainability of coral harvesting for the highly lucrative international aquarium industry, in collaboration with industry and fisheries management agencies in Queensland, Western Australia and the Northern Territory. This project will guide effective strategies for harvesting, such as size limits and quotas, and inform the Convention on International Trade in Endangered Species (CITES).

CAPACITY BUILDING

Nils Krueck delivered a training workshop on marine reserves at the Marine Science Institute, University of the Philippines. The workshop taught researchers and managers how to use marine reserves as fisheries management tools and to apply advanced marine reserve design tools to support both conservation and fisheries.

SUSTAINABLE FISHERIES

Michele Barnes' research on social networks identified 'key players' for transforming the management of coral reefs along the Kenyan coast. The Wildlife Conservation Society applied Michele's research to facilitate the uptake of more sustainable fishing technologies.

REBUILDING FISHERIES

Peter Mumby, Nils Krueck, and colleagues' research on marine reserves was used by the World Wildlife Fund to design reserve networks in 17 locations in Indonesia.

INTERNATIONAL ENVIRONMENTAL POLICY

Ove Hoegh-Guldberg is a Coordinating Lead Author of the IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

INTERNATIONAL CAPACITY BUILDING

In 2017, the ARC Centre's research students came from 42 countries. (p41)

INVASIVE SPECIES CONTROL

Bob Pressey and colleagues developed a decision-support tool to inform the design of control programs for invasive species in the Pilbara island archipelago. In collaboration with the Western Australian Parks and Wildlife Service, the project included detailed costings of management activities, development of population models and estimates of invasion risk.

CLIMATE CHANGE ADAPTATION

Jorge Álvarez-Romero provided advice on integrated land-sea planning and climate change adaptation to five Natural Resource Management agencies in northern Australia. His report included recommendations for governance reform and institutional responses to improve spatial planning for climate adaptation.

SOCIAL-ECOLOGICAL ASSESSMENT

Georgina Gurney and colleagues at the Wildlife Conservation Society (WCS) developed an evaluation framework for assessing coral reef social-ecological systems. In 2017, the framework was applied in five countries in Eastern Africa, Asia-Pacific and the Caribbean, providing data on more than 1000 sites and from 5000 respondents. This information is being used by WCS to inform decision-making at local and global scales.

RECOGNITION OF EXCELLENCE BY CENTRE RESEARCHERS

Highlights of the 42 awards ARC Centre researchers received in 2017.

Tracy Ainsworth was awarded the prestigious *Dorothy Hill Medal* from the Australian Academy of Science. Tracy's award was in recognition of her extraordinary contributions to understanding the responses of corals to heat stress and disease.

David Bellwood received the *Bleeker Award (Ecology)* at the 10th Indo-Pacific Fish Conference held in Tahiti. The award recognises David's extensive and innovative contributions to Indo-Pacific ichthyology. As the nomination states: "Bellwood's research has engendered a fundamental change in our understanding of reef fishes."

Michael Bode was awarded an ARC *Future Fellowship* to support research that combines innovative mathematical methods and new genetic data to predict the larval dispersal patterns of reef fish and corals.

Tom Bridge received a Queensland *Young Tall Poppy Science Award* for his research on deep coral reefs. This annual award recognises the achievements of Australia's outstanding young scientific researchers.

Josh Cinner received the *Elinor Ostrom Award for Young Scholars* for his work on co-managing coral reef fisheries. The award recognises and promotes the work of scholars in the field of the 'Collective Governance of the Commons'.

Peter Cowman was awarded an ARC *Discovery Early Career Researcher Award*.

Jennifer Donelson was awarded the *Early Career Researcher Award* by the Australian Society of Fish Biology in July.

Ove Hoegh-Guldberg was awarded the International Society for Reef Studies' *Eminence in Research Award*. The award acknowledges Ove's role as a leading scientist in the field of reef studies and his extraordinary contributions to the published literature over the past two decades.

Mike Kingsford was awarded the *K Radway Allen Award* by the Australian Society of Fish Biology in recognition of his extensive contributions to fish and fisheries research in Australasia.

Malcolm McCulloch was awarded the Geological Society of Australia's *AE Ringwood Medal*, for his exceptional research advances and internationally recognised expertise in fundamental earth processes.

Andrew Pomeroy was awarded a prestigious *Fulbright Postdoctoral Scholarship* by the Australian-American Fulbright Commission in March. The scholarship enabled Andrew to undertake research with the United States Geological Survey, in sediment transport processes within a range of reef environments.

Morgan Pratchett was appointed Editor-In-Chief of the journal *Coral Reefs*. In June, he received the *Mid-Career Scientist Award* from the International Society for Reef Studies. A month later, Morgan was elected to the National Council of the Australian Marine Sciences Association. He was also recognised, for the second time in his career, as the James Cook University *Advisor of the Year*, along with **Sean Connolly**.

2017 HIGHLY CITED RESEARCHERS

Three prominent members of the ARC Centre and two close affiliates are among the world's most highly cited researchers in the field of 'Environment and Ecology', according to the 2017 *Highly Cited Researchers* list, produced by Clarivate Analytics (formerly Thomson Reuters).

The *Highly Cited Researchers* list recognises the significant global impact of researchers within each of 21 fields of study, based on the level of citations their publications receive. According to Clarivate, "Citations serve as a testament to the utility and influence of given research, as judged by the scientists themselves. Authors who consistently produce highly cited work have earned distinction, embodying the most active, visible, and consequential research in their speciality areas".

Only 150 individuals worldwide were acknowledged for their contributions to the field of 'Environment and Ecology'. In 2017, the distinguished list includes Bob Pressey, Terry Hughes and Peter Mumby, along with adjunct researchers David Mouillot of the University of Montpellier (France) and Nicholas Graham of Lancaster University (UK).

Program Leader and Chief Investigator, **Bob Pressey**, has more than 28,000 citations, and is widely known for the quality and impact of his publications on conservation planning. Three of his papers on systematic conservation planning (in *Nature*), key principles for designing reserves (*Trends in Ecology and Evolution*), and the effectiveness of protected area networks (*Nature*), have each been cited over 1000 times.

Terry Hughes, Director of the ARC Centre, is one of the world's most highly cited coral reef scientists, with 47,000 citations. In 2017, his publications included two high profile articles in *Nature*. The first, in March, entitled 'Global warming and recurrent mass bleaching of corals' ranked in the top 1% of all research outputs, and was one of the Altmetric 'Top 100' research articles of 2017. The second *Nature* paper, published in June, entitled 'Coral Reefs in the Anthropocene', provides a transdisciplinary framework for sustaining reefs into the future. These two papers were co-authored by over 50 colleagues in the Centre, from eleven institutions in Australia, and by collaborators from Canada, the Netherlands, Saudi Arabia, the UK, and the USA

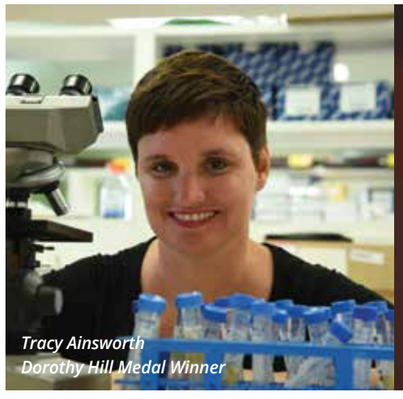
Peter Mumby is an award-winning marine ecologist and Chief Investigator at the ARC Centre, with 23,000 citations. His most cited paper, co-authored with Ove Hoegh-Guldberg and published in *Science,* focusses on rapid climate change and ocean acidification. A first-time recipient of the *Highly Cited* recognition, Peter acknowledges this recognition is a testament to the value of developing strong, diverse collaborators from around the world.

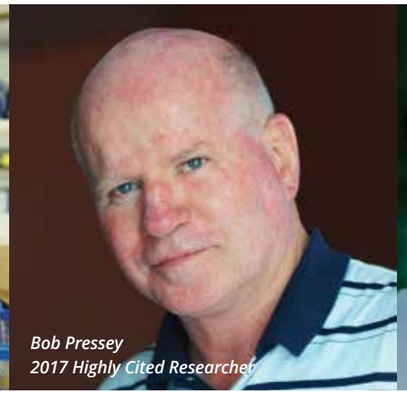
"I'm delighted with the news and I think it reflects the wonderful research collaborations I'm fortunate to have," said Peter. "We've really been focusing on processes of coral reef resilience over the last decade and trying to find practical solutions to help direct reef management and protection."

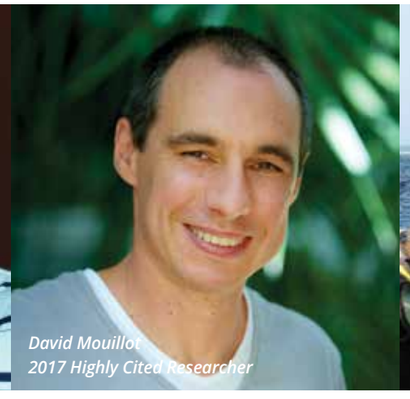
The ARC Centre is continually expanding its international collaborations, providing a global hub for coral reef research excellence. **David Mouillot** (University of Montpellier) is a frequent visitor to Australia and a long-term collaborator, and **Nick Graham** (now at Lancaster University) has strong ongoing collaborations with the Centre.

"My recognition as *Highly Cited Researcher* is clearly due to my close link with the ARC Centre of Excellence. My most cited publications are co-written with my colleagues in Australia," said David, a former Marie-Curie Fellow at the ARC Centre and a regular visiting scholar.

"I'm delighted to be recognised as a *Highly Cited Researcher*, and that my research, and that of my collaborators, is resonating so much with our peers," said Nick, who was research fellow in the ARC Centre from 2008 until 2015 (p48).


Tracy Ainsworth
Dorothy Hill Medal Winner


Bob Pressey
2017 Highly Cited Researcher


David Mouillot
2017 Highly Cited Researcher


Peter Mumby
2017 Highly Cited Researcher


Terry Hughes
2017 Highly Cited Researcher


Nick Graham
2017 Highly Cited Researcher

PHOTO JACQUELINE LAU

1 RESEARCH PROGRAM
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 a National Science Foundation 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* – 'Ten people who mattered this year.' In 2017, Terry was recognised as a Clarivate *Highly Cited Researcher*, ranking in the top 1% worldwide for citations in 'Environment and Ecology' (p9).

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 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. In 2017, Bob was recognised as a Clarivate *Highly Cited Researcher*, ranking in the top 1% worldwide for citations in 'Environment and Ecology' (p9).

ASSOCIATE PROFESSOR TIFFANY MORRISON

See full profile of new Program Leader, Associate Professor Tiffany Morrison on next page.

RESEARCHERS

Jorge Álvarez Romero, Neil Andrew, Michele Barnes, David Bellwood, Jessica Blythe, Michael Bode, Jon Brodie, Josh Cinner, Pip Cohen, Graeme Cumming, Alana Grech, Georgina Gurney, Laurence McCook, David Mills, John Pandolfi, Cristian Rojas, Garry Russ, Andrew Song, Fernanda Terra Stori, Rebecca Weeks.

PHOTO JACQUELINE LAU

PROGRAM LEADER PROFILE

ASSOCIATE PROFESSOR TIFFANY MORRISON

Associate Professor Tiffany Morrison is a political geographer, Chief Investigator and Program 1 Leader at the James Cook University node of the ARC Centre. Her unusual journey to reef governance began far from the marine environment. Tiffany grew up in Queensland with a love of the people and landscapes of the Australian bush, inspiring her pursuit of an undergraduate degree in environmental studies at Griffith University, Queensland. During her degree, Tiffany worked on the first Commonwealth Scientific and Industrial Research Organisation (CSIRO) experiment in regional environmental planning in Queensland's Central Highlands. In 2000, Tiffany was awarded a highly competitive Land and Water Australia PhD scholarship at The University of Queensland and a visiting fellowship at the University of Wisconsin-Madison. Her PhD thesis investigated decentralisation and regionalism in northeast Wisconsin and Queensland's Wet Tropics. After her initial experience of the social and institutional dimensions of regional environmental planning, Tiffany recalls that she "became deeply interested in environmental policy and administration in complex settings."

Tiffany was appointed lecturer at the School of Political and International Studies at Flinders University, South Australia, in 2004. Her new role enabled collaborations with global leaders in federalism and public choice theory, as well as a cohort of postgraduate students from south-east Asian countries, at the epicentre of the decentralisation wave. This environment provided the ideal springboard to advance understanding of the role of scale in different institutional settings, leading to Tiffany's career-defining interest in multi-scale governance. Her most noteworthy breakthrough in this period was to demonstrate that decentralised and regionalised environmental governance is not a simple reform and requires certain multi-scale preconditions in order to be effective. Tiffany's important contributions to the discipline of environmental governance were recognised by the award of a Visiting Fellowship at the University of Kyoto.

In 2008, Tiffany returned to The University of Queensland as a Senior Lecturer in the School of Geography, Planning and Environmental Management. While she was developing a group of excellent PhD students and postdoctoral research fellows, Tiffany extended her research focus to the rapidly transforming urban, island and coastal landscapes of Australia and south-east Asia. This new work demonstrated empirically that resilient regions depend on effective meta-governance, which is, in essence, 'the governance of governance'. Tiffany co-led a team of ecologists, geographers, planners, economists, and lawyers to test this concept, funded by an ARC Super Science award. This diverse group made several important conceptual advances in the study of climate adaptation policy. This period also led to Tiffany's increasing engagement with interdisciplinary research question on international climate mitigation, adaptation and resilience, in collaboration with colleagues at the University of Oregon and Stanford University. This ongoing work on the multi-scale design and implementation of environmental conventions has provided an important counterpoint to the 'bottom-up' emphasis in sustainability science.

Tiffany joined the ARC Centre in 2015 as Social Science Research Leader. She has since developed two research programs in coral reef studies: one on the polycentric governance of large-scale reef systems, and the other on the multi-scale governance of climate adaptation and conflict. Members of her team of postdoctoral research fellows and PhD students have diverse backgrounds in political science, development studies, geography, European studies, planning, and ecology, and include researchers with joint appointments at James Cook University, World Wildlife Fund, WorldFish, the National Climate Change Adaptation Research Facility, and Stockholm University. This research program has brought new skills and insights to the ARC Centre, and is setting new directions for research in political science, human geography and coral reef science.

PHOTO JOSH CINNER

REPORT

Research in Program 1 focusses on understanding the linkages between coral reef ecosystems, the goods and services they provide to people, and the wellbeing of human societies. The over-arching objective is to improve the governance and management of coral reefs worldwide. Key research questions include how levels of economic development, social capital, local history and culture influence resource use and governance systems. Program 1 places a high value on engagement with local communities, managers and policy makers, government agencies, and with non-government organisations. The conservation planning group led by Bob Pressey has the broad goal of providing decision-makers with more effective means of managing species and ecosystems by providing decision-support tools, guidelines for using information, and rigorous assessments of the adequacy of existing conservation measures.

In 2017, the geographic, social and ecological scope of Program 1's research was very diverse, with major projects in northern, eastern, and western Australia, and in Brazil, the Cook Islands, Costa Rica, Fiji, Indonesia, Kenya, Micronesia, Mexico, Papua New Guinea, the Philippines, the Solomon Islands, Tonga, and the USA. Program 1 continued to develop a productive relationship with researchers at WorldFish, headquartered in Malaysia (p52). In 2017, Research Fellow Pip Cohen convened a symposium on Resilient Small-Scale Fisheries in Penang, with participants from the ARC Centre and countries across Africa, Asia and the Pacific. David Mills also led an international workshop in Rome on the reporting and data methodologies of small-scale fisheries, co-convened by the Food and Agricultural Organization (FAO) of the United Nations.

Economist Cristian Rojas joined Program 1 as a new Research Fellow in 2017. Cristian is an environmental economist from Chile and the University of Wyoming, where he undertook his PhD research on the effect that markets for natural resources have on coastal communities in Papua New Guinea and South America. Research Fellow Jessica Blythe moved from the Centre's Townsville node during the year to the University of Waterloo, following the award of a prestigious Canadian Research Council Postdoctoral Fellowship, where she continues to collaborate with Program 1 researchers on social transformations in small-scale fisheries (p48).

Program 1 produced a record number of publications in 2017, including the following examples:

- Terry Hughes was lead-author of a major synthesis paper invited by *Nature*, entitled 'Coral reefs in the Anthropocene', co-authored with Tiffany Morrison, Graeme Cumming, Josh Cinner, Michele Barnes, David Bellwood and colleagues from the Netherlands and USA. The paper draws together insights from ecology, climate science, oceanography, and the social sciences to provide a blueprint for sustaining reefs into the future. PhD student Jon Day and Terry Hughes also contributed to a major UNESCO report on the impacts of climate change on World Heritage coral reefs, in collaboration with NOAA, UNESCO and others.

PHOTO JACQUELINE LAU

- Tiffany Morrison's latest research on power dynamics in environmental governance was published in 2017 in the *Proceedings of the National Academy of Sciences* (*PNAS)* and in *WIREs Climate Change,* with colleagues in Program 1 and at the University of Michigan, University of Exeter and Vrije Universiteit Amsterdam. The *PNAS* paper undertook a longitudinal analysis of the governance of the Great Barrier Reef, and its recommendations have already been adopted by the Australian Department of Environment and Energy. Georgina Gurney also led a 2017 article in *PNAS*, on the attachment of people to the Great Barrier Reef (p15). Her study was based on interviews with more than 5,000 individuals from 40 countries, and involved ongoing collaboration with the University of Exeter, CSIRO and GBRMPA.
- Bob Pressey, Georgina Gurney and Rebecca Weeks published an important perspective piece in *Biological Conservation*. Their paper synthesised and extended previous work to demonstrate the mismatch between the basic purpose of establishing protected areas and the measures used to underpin objectives and monitoring of progress. Bob also co-authored a paper in *Annual Review of Environment and Resources* on the outcomes attributable to systematic conservation planning around the world.
- Graeme Cumming published a key conceptual paper on resilience and the theory of ecological and social collapse, in *Trends in Ecology and Evolution*, co-authored with Garry Peterson from the Stockholm Resilience Centre. Graeme also led an invited concept paper for a special issue of the 20th volume of *Ecosystems*, co-authored with Terry Hughes and Tiffany Morrison. It focusses on spatial resilience, which is a subset of resilience theory that addresses processes which operate across multiple locations and spatial scales.
- Michele Barnes published a key paper in *Ecology and Society* on the social foundations of adaptation and transformation. Brock Bergseth, who submitted his PhD at the end of 2017, led a paper *Frontiers in Ecology and the Environment* on managing poaching in the Great Barrier Reef Marine Park (p7). Jessica Spijkers (a cotutelle PhD student with Stockholm University) also led a paper in *Regional Environmental Change*, on social conflict in fisheries.

Program 1 led over a dozen workshops and mentoring activities during the year. For example, the conservation planning group met with colleagues from Australia and the USA, to develop new ways of identifying how management interventions can have the most benefit for maintaining livelihoods. Michele Barnes convened an international workshop on network modelling, with collaborators from Hawaii and Sweden. In November, Graeme Cumming convened a research planning workshop in Townsville to develop a special issue of the journal *Biological Conservation,* covering diverse aspects of management of coral reefs.

Program 1 members gave numerous plenary addresses at international conferences in 2017. For example, Terry Hughes delivered a keynote talk at the *International Congress of the Society for Ecological Restoration* in Brazil, Tiffany Morrison gave a keynote presentation to the *Stockholm Environment Institute* on environmental governance of the Great Barrier Reef, and Graeme Cumming gave a plenary address at the *International Long Term Ecological Research Conference*, in France. Josh Cinner also gave a keynote talk on co-managing reef fisheries at the *International Commons Conference* in the Netherlands, when he received the prestigious 2017 *Elinor Ostrom Award for Young Scholars* (p8).

PHOTO TERRY HUGHES

PHOTO JOSH CINNER

PHOTO MATT CURNOCK

MEDIA RELEASE | **5 SEP 2017**

GLOBAL 'COMMUNITY' RALLIES FOR THE REEF

Who cares about the Great Barrier Reef? Many people, and according to a paper published today in the journal *Proceedings of the National Academy of Sciences*, some of the most passionately connected individuals can come from faraway places, across the globe.

The study, led by Dr Georgina Gurney of the ARC Centre of Excellence for Coral Reef Studies at James Cook University, involved interviews with more than 5,000 people from 40 countries and found that where you live, doesn't necessarily determine what you care about. In fact, the data suggests that people living near or far from the Reef can develop equally strong feelings of attachment to the large and iconic World Heritage site.

This is good news for the Reef. Blighted by bleaching, the Great Barrier Reef needs all the help it can get. The findings published today suggest that resource managers should draw on the support of the global community, not only locals living adjacent to the Reef, when engaging the public.

"It's widely acknowledged that successful environmental management requires strong community engagement and support, but current approaches tend to only target locals. Our findings reveal that this view is too narrow," says Dr Gurney.

For the many ecosystems that are increasingly affected by global-scale threats, such as climate change, these results are empowering.

"We need to look beyond our backyards for solutions to protect the Great Barrier Reef. Climate change, for example, is one of the biggest threats to the Reef and tackling it requires the support of the global community, not only those living close to the Reef."

The study redefines the meaning of 'community' and, in doing so, identifies four new sub-communities, each with a different form of attachment to the Reef.

"Our study includes interviews with a diverse group of people – from fishers to international tourists. We found there are generally four types of communities who express 'attachment' for the Great Barrier Reef," says co-author, Professor Neil Adger of the University of Exeter, UK. "For example, we identified an 'Armchair Enthusiast' community. This group of individuals unexpectedly exhibits strong emotional bonds with the Reef, despite the fact that many live outside the Reef region and even outside of Australia."

The authors say that the evidence suggests new types of bonds between people and iconic natural places are emerging that transcend traditional geographic boundaries. If targeted effectively, these bonds may be useful in building the transnational support required for successfully protecting the Reef.

"Modern-day problems, need modern-day solutions," says co-author Dr Nadine Marshall of the Commonwealth Science and Industry Research Organisation (CSIRO). "Addressing global-scale threats requires engaging people from all over the world who care about the Reef through modern communication channels, such as social media."

"Our results show that declines in the Reef's health may affect people across the globe. So, we suggest that resource managers consider the untapped potential of emerging transnational communities to build broad public support for protecting the Reef."

Gurney, GG, Blythe, J, Adams, H, Adger, WN, Curnock, M, Faulkner, L, James, T, and Marshall, NA (2017). Redefining community based on place attachment. *Proceedings of the National Academy of Sciences* 114(38): 10077-10082.

MEDIA RELEASE | **1 JUN 2017**

PHOTO JOSH CINNER

A BRAVE NEW WORLD FOR CORAL REEFS

The future of the world's coral reefs hangs in the balance, but it is not too late to save them, according to a major study published today in the prestigious journal *Nature*.

Scientists say that the reefs we know today are changing rapidly as they struggle to cope with the combined impacts of global warming, overfishing and pollution.

"The reefs of the future will be radically different from today or 30 years ago," says Professor Terry Hughes, Director of the ARC Centre of Excellence for Coral Reef Studies (Coral CoE). He led the study on reef futures and their capacity for rapid shifts. "But, if we take the right steps immediately, we can – and must – secure a future for reefs, recognising that the possibility of restoring them to their former condition is no longer possible."

"Current approaches to protecting coral reefs are failing because too often we ignore the real reasons for their decline," says co-author Professor Josh Cinner, also from the Coral CoE. "We need to understand why they are declining, and encourage changes in human behaviour to sustain reefs for the future."

"It's death by a thousand cuts," remarked co-author Professor Jeremy Jackson, from the Smithsonian Tropical Research Institute. "Reefs suffer simultaneously from dredging, overharvesting, pollution, sewage, sediments, and steadily increasing temperatures."

These combined elements are transforming reefs into new configurations, where the mix of species is rapidly changing. According to the scientists, navigating this transition will require radical shifts in the science, management and governance of reefs worldwide.

"We can't save every species or turn back history," Prof Hughes explained. "The challenge now is to steer reefs into the future, to ensure that they remain fully functional, and to retain their ability to support the livelihoods and wellbeing of the 100s of millions of people who depend on them."

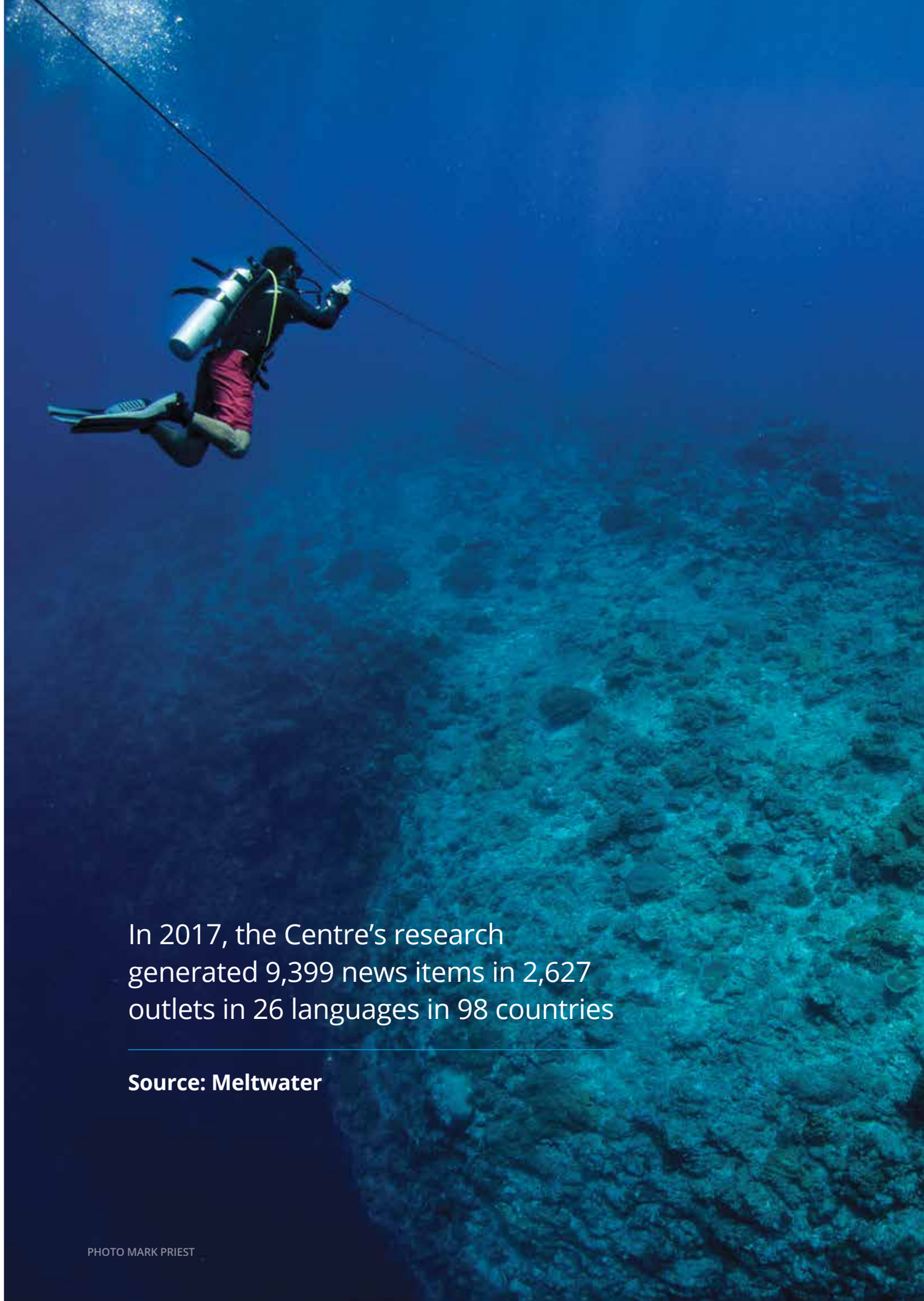
Professor Steve Palumbi, Director of Stanford University's Hopkins Marine Station, adds, "Coral species themselves are changing, evolving, adapting at a huge scale. Their ability to change rapidly is an asset for us – the corals that live on warmer reefs now may be better prepared for future conditions. And every asset we have is important to use," he said.

"The window of opportunity to save reefs remains open, but it is closing rapidly," the scientists say. "One degree of average global warming has already caused three global coral bleaching events, so +1.5 or +2C will radically change reefs for centuries to come."

The scientists base their future vision on the COP21 Paris agreement. Reefs will run the gauntlet of climate change over coming decades as ocean temperatures continue to climb. However, some areas will warm less than others, and under the COP21 Paris Agreement, the most extreme future temperature rises and severe impacts of ocean acidification will be avoided.

Prof Hughes is emphatic about the importance of COP21 to reefs: "They'll be different, but recognisable as coral reefs. However, if COP21 fails badly, coral reefs as we know them today will be destroyed."

Hughes, TP, Barnes, M., Bellwood, DR, Cinner, JE, Cumming, GS, Jackson, JBC, Kleypas, J, van de Leemput, IA, Lough, JM, Morrison, TH, Palumbi, SR, van Nes, EH, and Scheffer, M (2017). Coral reefs in the Anthropocene. *Nature* 546(7656): 82-90.



In 2017, the Centre's research generated 9,399 news items in 2,627 outlets in 26 languages in 98 countries

Source: Meltwater

PHOTO MARK PRIEST

PHOTO CHRISTOPHER BRUNNER

2 RESEARCH PROGRAM 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 ARC (2013-2016). He was recently elected as a Fellow in both the International Society for Reef Studies (2015) and The Paleontological Society (2016).

DR VERENA SCHOEPF

See full profile of new Program Leader, Dr Verena Schoepf, on next page.

RESEARCHERS

Kristen Anderson, Andrew Baird, David Bellwood, Pim Bongaerts, Michael Bode, Yves-Marie Bozec, Tom Bridge, Jon Brodie, Peter Cowman, Graeme Cumming, April Hall, 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, Serge Planes, Morgan Pratchett, George Roff, Garry Russ, Eugenia Sampayo, Greg Torda, Sue-Ann Watson.

PHOTO CHRISTOPHER BRUNNER

PROGRAM LEADER PROFILE

DR VERENA SCHOEPF

Dr Verena Schoepf is a Research Fellow and Program Leader at The University of Western Australia node of the ARC Centre. Verena spent her childhood in the Austrian Alps, where her passion for marine environments was cultivated through watching documentaries by the Austrian underwater pioneer, Hans Hass. Verena spent time snorkelling on coral reefs in the Red Sea as a teenager. She recalls "it was here, in the Red Sea, that I decided my future would be spent studying these fascinating underwater cities".

Verena completed an undergraduate and Masters degree in biology and zoology at the University of Innsbruck, Austria. Her desire to study marine biology led her to the University of Vienna, where she studied the corallivorous gastropod *Drupella cornus* in the northern Red Sea with Professor Martin Zuschin. This project enabled Verena to finally get her feet wet. "I was lucky to have the opportunity to go diving every day, and it didn't take very long until I started seeing corals and *Drupella* as soon as I closed my eyes. I even dreamed about them!"

In 2009, Verena moved to Ohio State University (USA) to pursue a PhD on the physiology and biogeochemistry of corals under climate change. Ohio is, of course, thousands of kilometres from the nearest coral reef, but her research activities included several months in the Mexican Caribbean. Verena even brought 'coral reefs' to Ohio when she conducted an ocean acidification experiment in partnership with a local coral farm. Verena won a range of awards during her PhD, including the Geological Society of America's *Gretchen L Blechschmidt Award*, and Ohio State University's most prestigious research student award, the *Presidential Fellowship*.

Verena joined the UWA node of the ARC Centre when she was awarded a postdoctoral research fellowship to work with Centre Deputy Director, Malcolm McCulloch. Her current research investigates mechanisms of heat and pH tolerance in reef-building corals using physiological and novel geochemical techniques. Verena's discovery of the naturally heat-resistant 'super-corals' of the Kimberley region was featured in the 2016 documentary *Verena Schoepf – Super Corals* as part of the German/French broadcaster ZDF/ARTE television series, *Ocean Heroines*. She took a lead role in coordinating research by the National Coral Bleaching Taskforce at The University of Western Australia, and conducted extensive bleaching monitoring throughout Western Australia during the 2016 mass bleaching event. Verena is also a passionate science communicator. She regularly writes for *The Conversation*, and served as ship-based Outreach Officer during the 2015 Perth Canyon Research Cruise.

Verena had a very successful 2017. Her research was published in *Science*, *Nature* and *Scientific Reports*. She also led a study, published in the *Proceedings of the Royal Society B*, which revealed the calcification mechanisms that underlie the resistance and adaptive responses of corals to ocean acidification. Together with her colleagues at Stanford University, Verena received a *Research Collaboration Award* to explore mechanisms of heat tolerance in corals from the Kimberley region. The outputs of Verena's recent research were covered extensively during the year by media outlets in Australia and overseas, including *The Guardian, ABC News, The Australian, The Age, Deutsche Welle* and *Der Standard* (Germany) and *The New York Times*. Verena's outstanding contributions to coral reef science were recognised by the ARC Centre in 2017 with her new appointment as Program Leader.

PHOTO MARK PRIEST

REPORT

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 linked social-ecological 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 use those findings to inform and improve 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. This promotes understanding of how reefs can recover from disturbances such as bleaching events. 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 2017, Program 2 made significant contributions to assessing the impacts of climate and environmental change on coral reefs and linked human societies. In a landmark paper in the journal *Nature*, Terry Hughes led a team including 18 other Centre researchers to document the unprecedented scope of the 2016 mass coral bleaching on the Great Barrier Reef (p34). This work resulted in over 403 news stories and reached a Twitter audience of 3.9 million, making it one of the Altmetric 'Top 100' articles in 2017. In addition, Verena Schoepf showed in *Proceedings of the Royal Society B* that corals can modulate the chemistry of the calcifying fluid inside their tissues, promoting resistance to ocean acidification.

Program 2 researchers also provided new evidence of long-term shifts in the status of coral reefs. In *Proceedings of the National Academy of Sciences (PNAS)*, John Pandolfi, George Roff and Laurence McCook co-authored a paper that measured the historic mortality and recovery dynamics of coral communities on the Great Barrier Reef. They found a dramatic loss of resilience in ecologically important branching *Acropora* corals at a regional scale over the last century. Similarly, John Pandolfi and Jeremy Jackson used the presence of "ghost reefs" in historical nautical charts to demonstrate in *Science Advances* the large spatial scale of near-shore coral reef loss in the Caribbean over the last 240 years (p57).

Sean Connolly, Terry Hughes and David Bellwood published a high-profile paper in *Ecology Letters* that presented a new unified model which explains commonness and rarity of corals and fishes on coral reefs. Also in *Ecology Letters*, PhD student Jessica Zamborain-Mason, along with Garry Russ and Sean Connolly, showed that accounting for node self-connections in network analysis significantly improves the prediction of metapopulation persistence, which has important implications for the design of marine reserve networks. In addition, Peter Mumby co-authored a paper in *PloS Biology* that proposes a new modelling framework for identifying areas of natural

PHOTO CHRISTOPHER BRUNNER

resilience and recovery potential on the Great Barrier Reef.

In *Current Biology*, PhD student Victor Huertas and David Bellwood reported a remarkable lip specialisation in tube-lip wrasses that offers these coral-eating fish protection from the stinging cells and sharp skeletons of their prey (p33). In another paper published in *Current Biology*, Andrew Baird and colleagues investigated why many taxa, including corals, do not pass on symbionts to their offspring. Their research showed that the absence of symbionts may allow coral larvae to avoid harm during fertilisation.

This year, Program 2 produced a new series of cutting-edge papers on coral reef conservation and management. For example, Peter Mumby co-authored a paper in *Nature,* on the performance of marine protected areas that found the biggest driver of success is not biological design, but the level of capacity and investment. Michael Bode and colleagues reported in *PNAS*, that the timing of when conservation funds are spent is critical to maximising investment benefits. Graeme Cumming led a review in *Conservation Letters* on social dilemmas, social-ecological traps and cooperation in conservation and natural resource management.

Program 2 researchers made important contributions to policy and management in 2017 (p6), and played a key role in communicating and advising government and industry on the impacts of the 2016 and 2017 mass bleaching events in Australia (p34). For example, Andrew Hoey provided evidence to the Australian Government's Senate Inquiry into the impacts of climate change on marine fisheries and biodiversity. Hugo Harrison formed a Collaborative Research Agreement with the Australian Director of National Parks on coral bleaching in the Coral Sea Commonwealth Marine Reserve. Laurence McCook was awarded a *President's Visiting International Expert Fellowship* from the Chinese Academy of Sciences. During his time in China, Laurence met with regional fisheries management agencies, marine reserve offices, the State Ocean Administration and various science agencies. He also accompanied John Pandolfi in an invited workshop, designed to assess reefs of the South China Sea, held on Hainan Island in January 2017.

PHOTO MARK PRIEST

PHOTO SOFIA SCHLAEPFER

PHOTO GEMMA GALBRAITH

MEDIA RELEASE | 16 FEB 2017

DEEP REEFS OFFER NO 'LIFELINE' FOR SHALLOW CORAL

PHOTO ED ROBERTS,TETHY IMAGES

A new study argues we should not count on deep coral reefs as a 'lifeline' for shallow reefs.

Often highlighted as important ecological refuges, deep sections of coral reefs (30-60 m depth) can offer protection from the full force of climate change-related impacts, such as intensifying storms and warm-water bleaching. However, new research questions their role in acting as a source of new corals for damaged shallow reefs.

Dr Pim Bongaerts, a Research Fellow at the ARC Centre of Excellence for Coral Reef Studies and The University of Queensland, and lead author of the study published in *Science Advances*, said deep reefs share coral species with the shallow reef, which has led to the idea that deep reefs could be an important source of larvae and help to 'reseed' shallow reefs.

"We argue that this concept of deep coral populations 'reseeding' their shallow-water counterparts may be relevant to some species, but is ultimately unlikely to aid more broadly in the recovery of shallow reefs," he said.

Given the impossibility of tracking the movements of individual coral larvae on the reef, understanding the connectivity between shallow and deep coral populations relies on methods that assess the genetic similarity between coral populations.

The team focused on the relatively isolated reef system of Bermuda in the Western Atlantic where they screened the genomes of more than 200 individual coral colonies from shallow and deep water, belonging to two coral species with similar depth distributions on the reef.

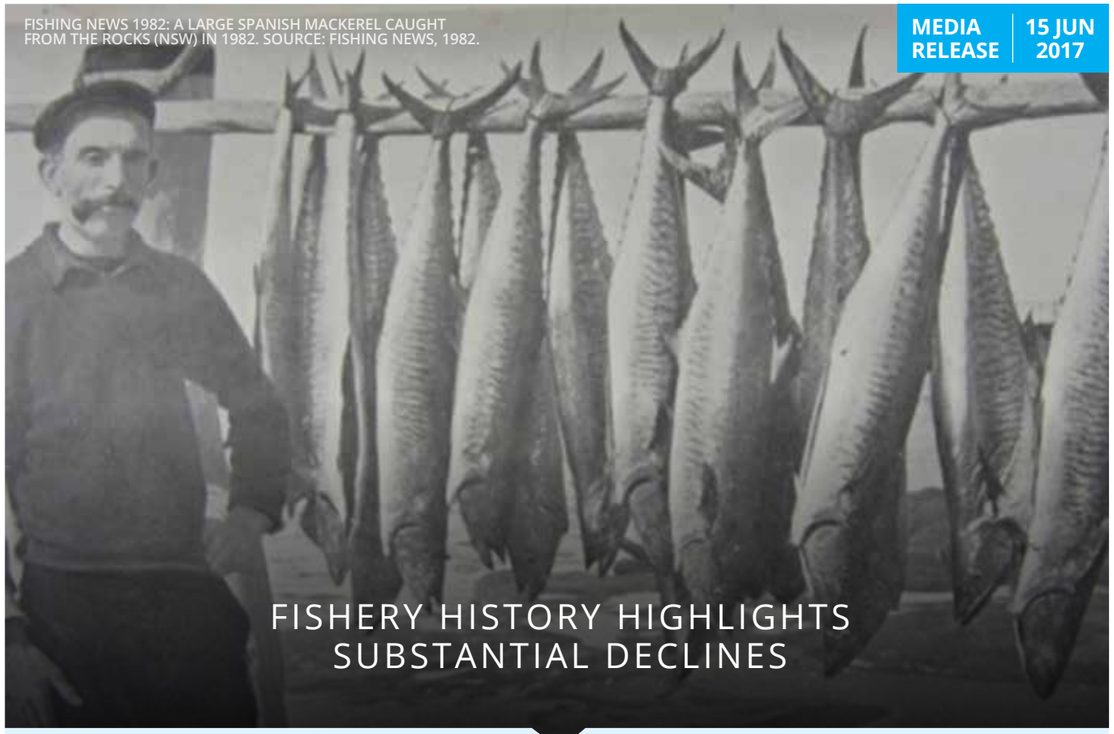
The study demonstrates that the extent of connectivity between shallow and deep populations can differ greatly between species on a reef, and can be strongly affected by natural selection processes that vary across shallow and deep reef environments.

Co-author, Professor Ove Hoegh-Guldberg also from the ARC Centre of Excellence said deep coral reefs have been highlighted as holding hope for shallow reefs that are badly damaged by bleaching events.

"Our results, however, contribute to a growing body of evidence, that the role of deep reefs in shallow reef recovery is likely to be very limited," he said.

According to Dr Bongaerts, the study once again highlights that under the increasing disturbances that coral reefs continue to face, they are unlikely to just 'sort themselves out.' "Instead, the responsibility for their future lies with us. If we want to have any chance of preserving these unique and diverse ecosystems, it is crucial that we start curbing our emissions and divest from fossil fuels," he said.

Bongaerts, P, Riginos, C, Brunner, R. Englebert, N, Smith, SR, and Hoegh-Guldberg, O (2017). Deep reefs are not universal refuges: reseeding potential varies among coral species. *Science Advances* 3(2): e1602373.



FISHING NEWS 1982: A LARGE SPANISH MACKEREL CAUGHT FROM THE ROCKS (NSW) IN 1982. SOURCE: FISHING NEWS, 1982.

MEDIA RELEASE | **15 JUN 2017**

FISHERY HISTORY HIGHLIGHTS SUBSTANTIAL DECLINES

A new study has ingeniously reconstructed a 103-year record of the Queensland east coast Spanish Mackerel spawning fishery, and revealed that catch rates have declined by 70 per cent over the past 80 years.

The ARC Centre of Excellence for Coral Reef Studies (Coral CoE) and University of Queensland (UQ) study documented the decline by combining data from historical newspapers with fisher memories.

Lead author and Coral CoE PhD graduate Dr Sarah Buckley, now at the Sea-Fisheries Protection Authority in Ireland, said the decline has had substantial consequences. “For the past 20 years the Cairns fishery has been commercially extinct and the Townsville spawning aggregations have remained completely offshore,” she said.

Co-author Professor John Pandolfi of Coral CoE and the School of Biological Sciences at UQ said the conservation of spawning aggregations of fish was one of a suite of management tools that could contribute to healthy fish populations.

“Managers need to consider increased protection of Spanish Mackerel during this critical time if it is hoped that catch rates can be increased,” Professor Pandolfi said.

Spanish Mackerel are large and important recreational and commercial fish found in Queensland and northern New South Wales waters.

Annually they form huge aggregations for breeding purposes at discrete locations for a confined period of time in the Great Barrier Reef.

Although this fishery commenced over 100 years ago, official commercial catch and effort were not recorded by the government until the 1980s, leaving large gaps in our understanding of long-term changes in the fish spawning aggregations, some of which disappeared undetected.

The scientists interviewed commercial fishers about their memories of changes to catch, gear and technology and locations fished, to reconstruct a valuable and comprehensive record.

Co-author Dr Ruth Thurstan said Spanish Mackerel fishers were able to recall fishing from as early as the 1940s, providing a wealth of knowledge that could be used to plug these historical data gaps.

Preventing decline and loss of fish spawning aggregations is a priority for the Great Barrier Reef Marine Park Authority. These data are currently being used by the Queensland government to inform stock assessment, demonstrating the valuable knowledge that is held by long-term fishers and in our local archives.

Buckley, SM, Thurstan, RH, Tobin, A and Pandolfi, JM (2017). Historical spatial reconstruction of a spawning-aggregation fishery. *Conservation Biology* 31(6): 1322–1332.

Centre researchers **Bob Pressey**, **Peter Mumby** and **Terry Hughes** along with two Centre adjuncts **Nick Graham** and **David Mouillot** were named as 2017 Clarivate Analytics *Highly Cited Researchers* in the field of ‘Environment and Ecology’. During the last decade, they produced multiple highly cited papers ranking in the **top 1% by citations**.

PHOTO KATIE SIEVERS

3 RESEARCH PROGRAM
RESPONDING TO A CHANGING WORLD

PHOTO KRISTEN BROWN

RESEARCH PROGRAM LEADERS

ASSOCIATE PROFESSOR MIA HOOGENBOOM

Associate Professor 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 James Cook University and, during 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 physiology and ecology, and her research establishes mechanistic links between environmental change, physiology, and population and community dynamics. Mia's research is multi-disciplinary and collaborative. Over 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, Nature* and *Global Change Biology*. She has supervised 26 postgraduate and honours students since 2010, and actively participates in educational outreach programs that provide authentic marine biology field and laboratory experiences for secondary school students. Her ecotoxicology research informs strategies for managing the impacts of environmental contaminants on coastal marine ecosystems.

PROFESSOR RYAN LOWE

Professor Ryan Lowe, from The University of Western Australia (UWA) within the UWA Oceans Institute, is co-leader of Research Program 3. Ryan's research involves the study of how oceanic and atmospheric forcing drives the circulation, distribution of wave energy, and water level variability within the coastal zone, with a particular focus on processes that occur along coral reef coastlines. Major areas of his research focus on: understanding how ocean dynamics drive physical and other environmental variability within coral reefs; how these dynamics influence a range of complex biophysical processes, and finally, how these processes can be numerically predicted and accurately forecast into the future. Ryan received his PhD in Civil and Environmental Engineering in 2005 from Stanford University and has been based at UWA since 2007. He has authored over 90 papers in leading international journals, as well as numerous technical reports for government and industry. Ryan is the Editor for the *Journal of Geophysical Research*. In 2012, he received a four-year ARC Future Fellowship. In 2014 he was the recipient of the UWA Vice Chancellor's *Mid-Career Researcher Award.*

ASSOCIATE PROFESSOR MAJA ADAMSKA

See full profile of new Program Leader, Associate Professor Maja Adamska, on next page.

RESEARCHERS

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

PHOTO KRISTEN BROWN

PROGRAM LEADER PROFILE

ASSOCIATE PROFESSOR MAJA ADAMSKA

Associate Professor Maja Adamska joined The Australian National University node of the ARC Centre as Program Leader and Chief Investigator in 2017. Maja has been fascinated by nature since she was a child living in the high-rise neighbourhood of Silesia, a coal-mining region of Poland. She remembers her "favourite book was about an amoeba dreaming of evolving into a human. I wondered how it happened, and hoped I could investigate it one day." At 17, Maja moved to Krakow to pursue an undergraduate and Masters degree in biology at Jagiellonian University, Poland's oldest university. Soon after finishing her degrees, she realised "there was no way I could use any of the modern molecular techniques I was reading about in papers if I stayed in Poland because of the financial realities of Polish universities at that time." Instead, Maja moved to Germany, where she was awarded a *Boehringer Ingelheim Fellowship* to study homeobox genes at the Technical University Braunschweig.

After completing her PhD, Maja moved to the USA to pursue her first postdoctoral fellowship at the University of Michigan. It was here that Maja discovered a transgene that severely decreases the expression of Dickkopf, an important gene that activates the Wnt signalling pathway (one of the systems used in cell communication in animals). Maja's second postdoctoral fellowship at The University of Queensland enabled her to gain further insight into the evolutionary history of the Wnt pathway and "spend more time outdoors looking at simple animals, something I wanted to do since childhood". In the second year of her postdoctoral fellowship, Maja was awarded an ARC Discovery Project to support her growing research program. At the same time, her colleague Professor Bernie Degnan convinced the Joint Genome Institute in California, USA to sequence the first Australian animal, the Great Barrier Reef sponge, *Amphimedon queenslandica*. Maja used *Amphimedon* to investigate the major developmental signalling pathways of Wnt, TGF-Beta and hedgehog. After spending many months at the Heron Island Research Station, Maja thought that "the mystery I have been pondering since childhood was solved: clearly, complex animals evolved from protists, through simple intermediates – like sponges – by evolving more and more complex developmental toolkits. But I was in for a big surprise."

In 2007, Maja was recruited to lead a research group at the Sars International Centre for Marine Molecular Biology at the University of Bergen, Norway. Maja used this opportunity to explore whether "the inner layer of sponges is the evolutionary ancestor of the animal gut, as postulated by E. Haeckel in the 19th century." To address this question, her group sequenced a local sponge species, *Sycon ciliatum*. They found that developmental signalling pathways and transcription factors were much more complex in *Sycon* than *Amphimedon*. Maja recalls that "some genes which we thought evolved after sponges diverged from the lineage leading to higher animals were also present in *Sycon*, a finding we published in *Nature.*" Her group's research addressing potential homology of body layers and axes between sponges and cnidarians (and thus other animals) suggests that Haeckel was quite likely right. This study, published in *Nature Communications*, led to Maja's current research program and ARC Future Fellowship at The Australian National University node of the ARC Centre.

Maja says she is "very fortunate to be following my childhood dreams. My research with the ARC Centre allows me to address the evolutionary steps leading from protists, through sponge-like ancestors, to the more complex animals as cnidarians and then vertebrates. The story is not as simple as we originally thought, but that only makes it so much more interesting." Supported by the ARC Centre, and employing cutting-edge technologies such as single cell transcriptome sequencing, Maja is also investigating mechanisms of sponge and coral regeneration, with important implications for the evolutionary, medical and environmental sciences.

PHOTO MARK PRIEST

REPORT

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 for coral reef ecosystems, and the capacity of coral reef organisms to adapt to a changing world. Such knowledge is key to understanding the future sustainability of coral reefs and the ecosystem services they provide to societies and economies.

In the aftermath of the 2016 and 2017 mass bleaching events on the Great Barrier Reef, Program 3 researchers undertook novel research to understand the implications of ocean warming on multiple levels of biological functioning. A high-impact collaborative publication in *Nature Climate Change,* led by Greg Torda and co-authored by eight other Centre researchers, examined the adaptive responses of coral reefs to climate change and identified key knowledge gaps (p31). In *Frontiers in Marine Science*, Mia Hoogenboom and several PhD students documented microhabitat features that reduce the severity of bleaching in corals. Bill Leggat and *the late* Sylvain Forêt investigated changes in gene expression in response to thermal stress in *Frontiers in Plant Science*.

In 2017, Program 3 continued its ground-breaking research on the mechanisms that influence calcification by reef-associated organisms. Combining computational and molecular techniques, Maja Adamska co-authored a paper in *Scientific Reports* that identified novel genes involved in the formation of calcium carbonate spicules in calcifying sponges. Chris Cornwall, Malcolm McCulloch, and Steeve Comeau documented changes in pH at the site of calcification for coralline algae in *Global Change Biology*. They also investigated the impacts of recent climate-driven marine heat waves on coral reef calcification in *Scientific Reports*. Sue-Ann Watson led a paper in *Science Advances* on latitudinal differences in the cost of shell production, from the tropics to the poles. She found that shell cost may play only a small role in influencing skeleton size across latitudes relative to other ecological factors, such as predation in present-day oceans.

Philip Munday led a Special Feature in *Biology Letters* on new perspectives in ocean acidification research. The nine Special Feature papers address cutting-edge questions and emerging topics in ocean acidification research, across the taxonomic spectrum from plankton to top predators. Mark McCormick published two papers in *Global Change Biology* and *Scientific Reports* that found the ongoing habitat degradation of coral reefs alters the efficacy of alarm cues and prevents an alarm odour response in fishes. In *Nature Communications*, Malcolm McCulloch, Juan Pablo D'Olivio, James Falter and Michael Holcomb used newly developed geochemical proxies to show that *Porites* corals from natural reef environments exhibit a close antithetic relationship between dissolved inorganic carbon (DIC) and pH of the corals' calcifying fluid (p32). These novel findings show that

PHOTO KRISTEN BROWN

calcification occurs largely independently of changes in seawater carbonate chemistry, and hence ocean acidification, but is highly vulnerable to thermally induced stress from global warming.

Tracy Ainsworth led a paper in *Trends in Microbiology* that outlined the roles of eukaryotic microbes in marine systems, and their contribution to ecosystem change. In *Fish and Fisheries*, Jodie Rummer and Philip Munday explored the evolutionary history of reef fishes and how their history has shaped their physiological adaptations to environmental temperatures and pCO_2. In *Global Change Biology*, Jennifer Donelson and Philip Munday considered how the detection of plasticity across generations (transgenerational plasticity or TGP) in climate change experiments is affected by the predictability of environmental variation, as well as the timing and magnitude of environmental cues.

New research by Program 3 in 2017 revealed the impacts of changes to local environmental conditions, including declining water quality, on coral reefs. Collaborative research in *Microbiome* by PhD student Martina Prazeres, Tracy Ainsworth, John Pandolfi and Bill Leggat, used molecular techniques to uncover how the interactions between benthic foraminifera and their associated microbes change along environmental gradients. In a paper published in *Marine Pollution Bulletin*, PhD student Kathryn Berry led research that quantified the effects of exposure to small coal particles on coral reproduction.

In 2017, Program 3 explored fundamental processes of cellular development and phylogeny to provide new insight into the evolution of coral reefs. In a major collaborative paper in *Trends in Neurosciences*, David Miller and colleagues compared the nervous systems of corals and their relatives, to improve understanding of the fundamental features of nervous system structure and function. Peter Cowman led a novel paper in *Biological Reviews* that showed how assemblage structure and tropical provinciality of tropical reef fishes has changed through time as lineages have evolved.

Outreach and engagement activities by Program 3 researchers in 2017 successfully delivered the Centres' scientific research to a wider audience (p58). For example, Maja Adamska gave a public lecture on Darwin Day at Questacon in Canberra about the evolution of animals. Mia Hoogenboom also delivered a public lecture on marine debris at the Asian Civilisations Museum in Singapore. Ove Hoegh-Guldberg performed the role of Chief Scientific Advisor in the production of the film *Chasing Coral*, which has been screened in more than 90 countries around the world. Ryan Lowe signed a Memorandum of Understanding with Dutch research institution Deltares to establish new research programs focusing on the management of coral reef coastlines in the Indian Ocean. Multiple Centre researchers, including Jon Brodie and Partner Investigator Janice Lough, contributed to the *2017 Scientific Consensus Statement*, which synthesises the scientific findings quantifying the influence of land-based contaminants on the Great Barrier Reef. Also, Ove Hoegh-Guldberg and Terry Hughes provided advice during 2017 to the Queensland and Commonwealth governments, through their membership of the Expert Advisory Panel for the *Reef 2050 Plan*.

PHOTO MARK PRIEST

PHOTO SAMUEL PAYET

PHOTO CATHERINE KIM

PHOTO GREG TORDA

MEDIA RELEASE | 1 SEP 2017

CAN CORAL REEFS SURVIVE CLIMATE CHANGE

A group of international scientists have issued advice that more research is urgently required to determine whether corals can acclimatise and adapt to the rapid pace of climate change.

The team of coral experts, led by Dr Greg Torda from the ARC Centre of Excellence for Coral Reef Studies (Coral CoE) at James Cook University and the Australian Institute of Marine Science (AIMS), have delivered recommendations for future research.

As the Great Barrier Reef faces unprecedented coral mortality from back-to-back mass bleaching in 2016 & 2017, rising carbon dioxide and other natural and human-induced pressures, scientists advise more research is urgently needed into the poorly-understood mechanisms that corals might use to survive in a rapidly warming world.

"There is still a lot to understand about corals," says Dr Torda. "While our only real chance for their survival is to reverse climate change, a nugget of hope exists – that the corals may be able to adapt to their changing environment," he says.

"However, there are major knowledge gaps around how fast corals can adapt or acclimatise to changes in their environment, and by what mechanisms they might use to achieve this," adds co-author Professor Philip Munday of Coral CoE.

"For example," explains Dr Jenni Donelson, co-author at Coral CoE,"recent studies show that fish can acclimatise to higher water temperatures when several generations are exposed to the same increased temperature, but whether corals can do the same, and how they might achieve this, is largely unknown."

Eight research recommendations are published today in the prestigious journal *Nature Climate Change* and arise from a workshop with a team of experts composed of 22 biologists from 11 institutions in five different countries.

The team agrees that further research identifying how corals respond to climate change is critical, as the Earth undergoes an unprecedented rate of environmental change.

Co-authors Professor Timothy Ravasi and Dr Manuel Aranda from King Abdullah University of Science and Technology (KAUST) warn that the clock is ticking. "The Great Barrier Reef has suffered substantial losses of coral over the past two years. Understanding the mechanisms that could enable corals to cope with ocean warming is becoming increasingly important if we want to help these ecosystems," they say.

The paper is focused on stony, reef-building corals, which are the 'ecosystem engineers' of tropical coral reefs. These corals build the frameworks that provide shelter, food and habitat for an entire ecosystem. When corals are lost, the diversity and abundance of other reef organisms declines, until ultimately the ecosystem collapses.

"Predicting the fate of coral reefs under climate change is subject to our understanding of the ability of corals to mount adaptive responses to environmental change," says Dr Torda. "Our paper sets out key research objectives and approaches to address this goal."

"The time to act is now, as the window of opportunity to save coral reefs is rapidly closing," he concludes.

Torda, G, Donelson, JM, Aranda, M, Barshis, DJ, Bay, L, Berumen, ML, Bourne, DG, Cantin, N, Forêt, S, Matz, M, Miller, DJ, Moya, A, Putnam, HM, Ravasi, T, van Oppen, MJH, Thurber, RV, Vidal-Dupiol, J, Voolstra, CR, Watson, SA, Whitelaw, E, Willis, BL and Munday, PL (2017). Rapid adaptive responses to climate change in corals. *Nature Climate Change* 7(9): 627-636.

PHOTO CIEMON CABALLES

MEDIA RELEASE | 15 JUN 2017

THE ACHILLES HEEL OF CORAL GROWTH IS HIGH TEMPERATURES, NOT OCEAN ACIDIFICATION

The Achilles heel of coral growth is high temperatures, not ocean acidification, according to researchers from the ARC Centre of Excellence for Coral Reef Studies and The University of Western Australia.

The researchers say that corals will find it increasingly difficult to build strong skeletons as the world's oceans rapidly warm. Global-scale coral bleaching events are becoming more frequent and intense, potentially compromising the future of coral reefs.

In recent studies, Professor Malcolm McCulloch from the ARC Centre of Excellence for Coral Reef Studies and The University of Western Australia found that under ocean acidification, corals can still build skeletons, or 'calcify'. However, they lose this ability when they bleach under the extreme heat events that now characterise global warming.

Professor McCulloch said coral calcification, a process vital for building reefs, was dependent on a partnership between coral and their photosynthetic algae (zooxanthellae).

"Corals fine-tune their internal pH to maximise the supply of carbon and energy from their zooxanthellae. This can then lead to calcification, or skeleton-building," Professor McCulloch said.

"However when there are abrupt increases in seawater temperatures this relationship breaks down; the corals become stressed and expel their zooxanthellae. This leaves them with little energy to survive. Unless the temperature drops and the zooxanthellae are able to recolonise in the coral, the coral may die."

Stony corals build the iconic tropical coral reef networks that dominate many shallow-water environments, harbouring more than one-third of the oceans' biodiversity. Professor McCulloch examined massive *Porites* corals collected from the Great Barrier Reef (GBR) and from Coral Bay Ningaloo Reef. A coral core collected from the GBR was used to look directly at the impacts of the global bleaching event of 1998 – which is still the warmest summer on record for the central section of the GBR.

One of Professor McCulloch's studies concludes that, "the increasing frequency and intensity of coral bleaching events due to CO_2-driven global warming constitutes the greatest immediate threat to the growth of shallow-water reef-building corals, rather than the closely associated process of ocean acidification."

D'Olivo, JP and McCulloch, MT (2017). Response of coral calcification and calcifying fluid composition to thermally induced bleaching stress. *Scientific Reports* 7(1): 2207.

McCulloch, MT, D'Olivo, JP, Falter, J, Holcomb, M and Trotter, JA (2017). Coral calcification in a changing world and the interactive dynamics of pH and DIC upregulation. *Nature Communications* 8: 15686.

NATIONAL GEOGRAPHIC

ARTICLE | 5 JUN 2017

Why Slimy Fish Lips Are the Secret to Eating Stinging Coral

The tubelip wrasse has evolved a strategy for preying on an animal most reef creatures avoid.

By **Mary Bates**
PUBLISHED JUNE 5, 2017

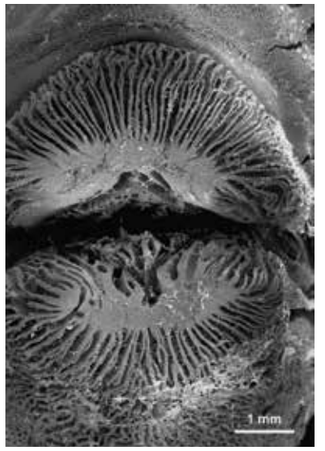
Fish lips may be a fixture of the selfie generation, but for one tropical fish, a fleshy pout helps them survive.

The tubelip wrasse (Labropsis australis) relies on self-lubricated lips to eat stinging corals in the Indian Ocean and western Pacific, a new study says.

Corals may look soft and innocuous, but the animals are actually a challenging meal: Their razor-sharp skeletons are protected by mucus-covered flesh laden with stinging cells. For that reason, many fish avoid eating them.

Not the tubelip wrasse, which has "distinct fleshy lips that stick out, and they are shaped like a tube when the mouth is closed," study co-author David Bellwood, of Australia's James Cook University, says by email.

"A closer look shows that the lips are like the gills of a mushroom but covered in slime."



This close-up image shows the self-lubricating lips of the tubelip wrasse, which the fish uses to feast on corals.

PHOTOGRAPH BY VICTOR HUERTAS AND DAVID BELLWOOD

FISH FACES

Bellwood and his colleague, Víctor Huertas, used an electron scanning microscope to examine the mouths and lips of tubelip wrasse and a non-coral-eating wrasse species in incredible detail.

While the species' teeth and jaw bones were similar, their lips were wildly different: Tubelip wrasse lips have numerous thin membranes arranged outward from the center, while the other species has narrow, smooth lips without membranes.

Next, Bellwood and Huertas produced extremely thin cross-sections of tubelip wrasse lips to peek into their internal structure. The lips were loaded with mucus-secreting cells, according to the study, published June 5 in the journal *Current Biology*.

Finally, the researchers analyzed high-speed video images of tubelip wrasses feeding on corals in the lab at James Cook University. The fish feed by briefly placing their lips against the coral before delivering a powerful suck, or "kiss"—often accompanied by an audible tuk sound.

Rather than grabbing onto the coral, the fish appear to create a seal with their mouths over a small area, presumably to more efficiently suction off coral mucus and flesh.

LIP SERVICE

Bellwood and Huertas suggest that the tubelip wrasse's slimy lips may provide a protective coat between the fish and the coral's stinging cells while also facilitating suction feeding.

While plausible, these ideas will be difficult to test, so for now it is a "wonderful mystery," said Peter Wainwright, a fish biologist at the University of California, Davis, who was not involved in the research.

"This paper significantly extends our knowledge of how fish eat coral—one of the rarest feeding habits found among reef fish," Wainwright says in an email.

The next step, the authors say, is to delve more into the "magic of the mucus," and find how exactly the substance aids tubelips in eating coral.

Studying coral predators like the tubelip may help conservationists in evaluating threats toward coral reefs, says Bellwood. Coral reefs are declining worldwide due mainly to ocean warming and acidification.

"Hopefully," he says, "these tubelip wrasses are more like irritating mosquitoes than vampire bats slowly draining the coral's bodily fluids."

NATIONAL PRIORITY CASE STUDY

SECURING THE FUTURE OF THE GREAT BARRIER REEF

PHOTO GREG TORDA

Worldwide, coral reefs support the livelihoods and food security of hundreds of millions of people, yet increasingly reefs everywhere are threatened by anthropogenic climate change. In March 2017, we published the cover article in *Nature*, entitled 'Global warming and recurrent mass bleaching of corals'. The paper documents the geographic footprint of coral bleaching in 2016 on Australia's coral reefs, and shows that satellite-derived metrics of heat exposure explain the severity and location of recurrent bleaching on the Great Barrier Reef in 1998, 2002 and 2016. The study, which is coauthored by 46 people, was achieved through the coordinated efforts of the ARC Centre, in partnership with AIMS, GBRMPA, NOAA and other institutions. Already, the article has been cited 200 times, and according to Altmetrics, it was the most highly publicised paper on climate change in 2017. The study generated intense media coverage and policy debate about climate change and stewardship of vulnerable ecosystems and related-industries. In response to our research findings, the Queensland and Commonwealth governments have launched several new initiatives, including an accelerated review of the targets of the *Reef 2050 Plan*. UNESCO, the world body with responsibility for World Heritage Areas (WHA), also commissioned Centre researchers to provide a report on the vulnerability of coral reef WHAs to global warming.

In June 2017, Centre researchers and colleagues published a major synthesis in *Nature*, entitled 'Coral Reefs in the Anthropocene'. As the title infers, this trans-disciplinary paper addresses a key question – what do we have to do to ensure that coral reefs can still flourish in 50 to 100 years from now? We explored first the implications for coral reefs of global action to shift away from business-as-usual emissions of greenhouse gasses, as envisaged by the COP21 Paris Agreement. We showed that the 2°C global average target translates into another 0.5°C of warming of shallow tropical waters, which allowed us to re-assess the future threat of global warming and ocean acidification to reef biodiversity. We argued that the scenario of 600-1000 ppm of atmospheric CO_2, which underpins most of the scientific literature on the projected impacts of rising temperatures and ocean acidification on coral reefs, is no longer realistic, even if the Paris Agreement fails to fully meet its targets. The most likely future scenario is that emissions of greenhouse gasses will soon peak and then decline, creating a centuries-long period that we termed 'the climate gauntlet'. We will still have reefs at the end of this century, but the mix of species will be very different from today. One conclusion from our study is that extreme climate change that would irreparably damage reefs is avoidable, and that physiological experiments need to be re-calibrated to better imitate near-future trajectories in temperature and pH.

We also scrutinised the strengths and weaknesses of current scientific approaches to understanding the cumulative, interacting effects of multiple stresses – climate change, overfishing and pollution, on the future trajectories of coral reefs. We offered a new conceptual and modelling framework for understanding cumulative impacts, and their effects on both coral reefs and the people who depend on them. Finally, drawing on the social sciences, we developed a suite of future options for governance and management of novel and unfamiliar coral reef ecosystems. We concluded that "*Sustaining reef biodiversity will require us to shift conceptually from the current emphasis on protection, conservation or restoration of stable ecosystems at equilibrium, to a new reality where ecosystems are more dynamic and patchier, and increasingly different from anything that has been encountered before. Embracing this confronting paradigm shift will require a transformation in the governance and management of these high-diversity ecosystems*."

A week before the *Nature* review was published, Centre Director, Terry Hughes, presented these findings to the Expert Advisory Committee for the *Reef 2050 Plan*. Key elements of this study have already been incorporated into policy shifts that are unfolding in response to back-to-back bleaching of the Great Barrier Reef in 2016 and 2017. Ove Hoegh-Gulberg, Andrew Hoey, Terry Hughes, and Peter Mumby attended the Great Barrier Reef Summit and contributed to the development of a new Reef Blueprint released in December 2017 by the Great Barrier Reef Marine Park Authority, aimed at ensuring a resilient reef, empowering people and fostering change.

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BY CAMERON LAIRD PHOTOGRAPHY, 2017

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PHOTO MICHELLE ACHLATIS

FEATURE

The Guardians of the Great Barrier Reef

Australia's scientists are working against time and climate change politics to save their beloved coral reef.

BY KATE MACKENZIE

DECEMBER 21, 2017

On a hot, still day in March, Terry Hughes climbed aboard a single-engine Cessna in the tropical Australian port of Cairns.

The world's most-cited coral reef researcher, Hughes was with James Kerry, a marine biologist, and a local pilot. In seven hours' time, they would arrive in the remote Aboriginal community of Lockhart River, but the purpose of the journey was not to reach that destination. It was to spend the time crisscrossing the 3,000 coral shoals and pinnacles of the Great Barrier Reef to look for traces of what they most feared to see: coral bleaching.

This kind of survey work is gruelling, demanding constant concentration amid intense heat and engine noise. The scientists spend hour after hour peering out the plane's small windows, calling out and recording numbers to score the condition of the coral of each individual reef, using spare moments to take photographs and video footage.

Just minutes after the plane buzzed northward over the turquoise and sapphire waters of the reef, Hughes and Kerry saw it: bone-white spots scattered among the smaller reefs that comprise the Great Barrier Reef — the telltale sign of mass coral bleaching. From the plane's height, the pale patches were so large that to the untrained eye they might resemble stretches of white sand or surf breaking over the fringes of cays. As the plane flew so low that the two scientists could see turtles and crocodiles in patches of deeper water, there was no mistaking the white coral of the damaged reefs among the greens, purples, and pinks.

"There are other circumstances in which flying over the length and breadth of the Great Barrier Reef would be a fantastic adventure," says Hughes, a phlegmatic Dubliner with tousled hair and a reluctant smile who directs the Australian Research Council's Centre of Excellence for Coral Reef Studies at James Cook University. But this trip was "confronting."

Coral bleaching occurs when excessively warm water kills off the algae that sustain tropical coral, causing it to turn white. The bleaching that struck the Great Barrier Reef in 2016 was the worst episode on record, killing off nearly 30 percent of the reef's coral. Bleaching plagued the reef again in February and March [2017], extending the cumulative damage to almost half of its coral cover.

Even where coral death is widespread, reefs can recover over the course of years and decades. But if the bleaching blows come too close together, the chances of revival diminish. Ironically, some bleached corals appear to flourish at first as their already bright reds, purples, greens, and pinks take on a striking fluorescence. But fluorescent corals are deathly sick, and within a few days, the coral turns bone white. If they die, the harder corals become murky looking and mossy as seaweed colonizes them, while softer ones will rapidly disintegrate altogether.

The realization of just how profound a threat climate change poses to reefs is a fairly recent one. That first mass coral bleaching that occurred off the coast of Panama in 1982 and 1983 was initially believed to be the result of chemical spills. It wasn't until 1984 that scientists finally identified warmer waters brought by an El Niño pattern as a key contributor. But it took almost two more decades before the scientific community began to seriously consider what global warming might mean. Ove Hoegh-Guldberg, deputy director of the Centre of Excellence for Coral Reef Studies, was one of the first scientists to study how climate change could make bleaching more common. His study, published in 1999, was the first to link the rapid improvements in climate modeling with the developing science on bleaching to predict that global warming could become a global catastrophe for reefs. "[M]ost indicators point to the fact that mortality rates are likely to rise within the next few decades to levels that may approach almost complete mortalities," he wrote.

Almost immediately, Hoegh-Guldberg found himself in the spotlight, attacked by conservative media commentators and politicians. His early work on climate change received some scathing peer reviews and "so-called friends were sometimes not so friendly," his wife, Sophie Dove, who is also a marine biologist, recounted in a 2009 documentary.

"Most of the other researchers in the 1990s, and even into this millennium, were poo-pooing the idea that climate change was a significant threat to coral reefs," Hoegh-Guldberg says of that period.

And though the link between climate change and bleaching is more widely accepted now than it was in the late 1990s, it can still be risky for coral reef scientists in Australia to discuss their findings, as that kind of public commentary puts them in the middle of the country's bitter debates about climate change and fossil fuels.

This year, Hughes began training Great Barrier Reef Marine Park Authority officials in aerial bleaching survey techniques on the basis that "in the not-too-distant future they're going to have to be routine monitoring."

But at this point, hope may be the only way forward — and Hughes isn't ready to give up.

"It comes down the psychology of the message," Hughes says. "Do you tell people reefs are doomed? I genuinely don't believe that's the case if we take action. I prefer the approach [that] says we have a narrow window of opportunity to save reefs. And we better get on with saving them."

PHOTO MIA HOOGENBOOM

FP

ARTICLE | 21 DEC 2017

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http://foreignpolicy.com/2017/12/21/the-guardians-of-the-great-barrier-reef-australia-climate-change/

GRADUATE AND EARLY CAREER TRAINING

PHOTO MARK PRIEST

The ARC Centre aims to build human capacity and expertise in coral reef science worldwide. To achieve this objective, we have created an exciting and multi-disciplinary intellectual environment, with a major focus on training and mentoring the next generation of coral reef researchers, enhancing Australia's research capability and human capital.

In 2017, the ARC Centre provided supervision and research funding to 189 research students at James Cook University, Australian National University, University of Queensland, and University of Western Australia. Of these students, 148 are enrolled in PhDs, with the remainder pursuing Honours or Masters degrees. Forty eight new students enrolled in graduate degrees in 2017, and 51 graduated. The Centre also supports 34 Early Career Researchers (ECRs), who are within 5 years of their PhD.

The ARC Centre is a global leader in coral reef research and attracts students and ECRs from around the world. In 2017, 137 international students came from 41 countries. Similarly, 79% of ECRs in the Centre have come to Australia from overseas.

The ARC Centre provides extensive mentoring and training to research students and ECRs on a range of generic and specific topics. Key among these is training to support the development of quantitative and technical skills. In February 2017, 30 students and ECRs attended a two-week intensive course on statistics in R, hosted by the ARC Centre and Murray Logan, biostatistician at the Centre's Partner Organisation, the Australian Institute of Marine Sciences (AIMS). Peter Cowman also hosted a training workshop in the software *Geneious,* to enhance skills in bioinformatics.

In 2017, the ARC Centre continued to support the development of manuscript and grant writing, communication and employment skills. Research students and ECRs were provided training by ARC Centre researchers on getting published (Josh Cinner), effective scientific presentations (Michele Barnes and Michael Bode), and online profiles and social media (Alana Grech and Jodie Rummer). In August 2017, the ARC Centre hosted a half-day workshop for over 25 students and ECRs on writing a Curriculum Vitae, cover letter, research statement and response to selection criteria. The ARC Centre also provided mentoring in the ethical conduct of research, including training on the appropriate management of research data and materials.

As part of our goal to train outstanding coral reef researchers and scientists more broadly, the ARC Centre offers a range of mentoring activities to all graduate students attending the annual Australian Coral Reef Society Conference – regardless of their affiliation with the Centre. The theme of the 2017 National Student Mentoring Day was 'Careers and Communication'. More than 30 students attended the event sponsored by the ARC Centre, which include guest speakers from the AIMS, CSIRO, Port of Townsville, Queensland Museum, and Cinematic Science, as well as members of the ARC Centre.

The ARC Centre has developed a highly successful strategy for the communication of our research findings to a diverse audience. We provide media training and one-to-one coaching to ARC Centre members, including students and ECRs. Communications Manager Catherine Naum coordinates media training and supports the outreach activities of ECRs, research students and senior researchers across the ARC Centre's nodes.

The Centre hosts a weekly seminar series to share the latest research of members, including students and ECRs, and leading researchers from across the world. Seminars are video-conferenced among the four University nodes and uploaded onto the ARC Centre's You Tube channel. We are grateful to Centre Research Fellows Sofia Fortunato, Andrew Song and Tracy Ainsworth, who co-ordinated the seminar series in 2017.

The Centre sponsors two committees in support of research students and ECRs. Each committee is allocated funding and logistic support to enhance training, mentoring and leadership activities during the year. We thank the Student Committee which, in 2017, was chaired by Laura Richardson and Eva McClure. Other members were Brock Bergseth, Oda Waldeland, and Ed Sacre (JCU), Michelle Achlatis, Catherine Kim, Veronica Radice, and Laura Puk (UQ) and Rebecca Green (UWA). The student and ECR committees are supported by Graduate Co-ordinator Olga Bazaka, Chief Operations Officer Jennifer Lappin and Assistant Director Alana Grech.

An important focus of the two committees is the design and implementation of the research student and ECR retreats, held each year to coincide with the ARC Centre's Annual Symposium. Almost 90 students attended the 2017 student retreat in Canberra, which focused on resilience training, including mindfulness, meditation and mental health. The ECR retreat featured speakers from the Australian Research Council who discussed the new emphasis on research impact. The student and ECR committees also organised multiple social events across the four nodes, enhancing the ARC Centre's collaborative and supportive culture.

Awards to ARC Centre students in 2017 included:

- Tania Kenyon and Molly Scott received Great Barrier Reef Marine Park Authority *Science for Management Awards*.
- Catherine Kim received a *Winifred Violet Scott Grant* and was a finalist in the Women in Technology *Life Sciences Young Achiever Award*.
- Ian Bouyoucos was awarded travel and research grants from the British Ecological Society, Oceania Chondrichthyan Society, Europcar Polynesia Company and The Company of Biologists Limited.

- Michael Jarrold and Laura Richardson were awarded travel and research grants from the Fisheries Society of the British Isles.
- Renato Morais and Jennifer Wilmes received research funding from the Lizard Island Reef Research Foundation.
- Carrie Sims was awarded a *Holsworth Wildlife Research Endowment Grant* from the Ecological Society of Australia.
- Katie Sambrook was awarded multiple grants to support her research, including a *Jill Landsberg Trust Fund Scholarship* by the Ecological Society of Australia and a *Michael Hall Student Innovation Award* by the Australian Society for Fish Biology.
- Molly Scott, Samuel Matthews and Thomas Roberts were each awarded prestigious *TropINTERN scholarships*, which supported five month fully funded internships at the Great Barrier Reef Marine Park Authority and Museum of Tropical Queensland, Townsville.
- Rachel Spinks and Molly Scott were both awarded research grants from the Sea World Research and Rescue Foundation.
- Brock Bergseth and Jon Day both received the 2017 *Glenn Almany Memorial Prize* for their research on the Great Barrier Reef. This prize is awarded to graduate students who publish an outstanding paper on research that required them to work with people beyond traditional academic boundaries, made a difference, or which has the potential to influence policy, management or practice. The publications awarded in 2017 were:
  - Bergseth BJ, Williamson DH, Russ GR, Sutton SG and Cinner JE (2017). A social-ecological approach to assessing and managing poaching by recreational fishers. *Frontiers in Ecology and the Environment.* 15: 67–73.
  - Day JC (2017). Effective public participation is fundamental for marine conservation – lessons from a large-scale MPA. *Coastal Management.* 45(6): 470–486.
- The ARC Centre's annual *Virginia Chadwick Awards* for outstanding first-authored publications by research students was awarded in 2017 to Renee Gruber, Tessa Hempson, Sybille Hess, Laura Richardson and Jessica Zamborain-Mason. The top papers were:
  - Gruber RK, Lowe RJ and Falter J (2017). Metabolism of a tide-dominated reef platform subject to extreme diel temperature and oxygen variations. *Limnology and Oceanography* 62(4): 1701–1717.
  - Hempson TN, Graham NAJ, MacNeil MA, Hoey AS and Wilson SK (2017). Ecosystem regime shifts disrupt trophic structure. *Ecological Applications* 28(1): 191–200.
  - Hess S, Prescott LJ, Hoey AS, McMahon SA, Wenger AS and Rummer JL (2017). Species-specific impacts of suspended sediments on gill structure and function in coral reef fishes. *Proceedings of the Royal Society B* 284: 20171279.
  - Richardson LE, Graham NAJ and Hoey AS (2017). Cross-scale habitat structure driven by coral species composition on tropical reefs. *Scientific Reports* 7: 7557.
  - Zamborain-Mason J, Russ GR, Abesamis RA, Bucol AA and Connolly SR (2017). Network theory and metapopulation persistence: incorporating node-self connections. *Ecology Letters* 20(7): 815–831.

PHOTO MARK PRIEST

2017 PHD STUDENTS IN THE ARC CENTRE OF EXCELLENCE

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
Michelle Achlatis	UQ	The Netherlands	Bioeroding sponges in a time of change: insights into the physiology and cell biology of a photosymbiotic coral-eroding sponge. (PhD)	S Dove, O Hoegh-Guldberg
Siham Afatta Kemal Taruc	UQ	Indonesia	An assessment of the sustainability and resilience of livelihoods within an Indonesian marine social-ecological system. (PhD)	O Hoegh-Guldberg
Mariana Alvarez Noriega	JCU	Mexico	Coexistence-promoting mechanisms in reef-coral communities. (PhD)	S Connolly, A Baird, M Hoogenboom
Natalia Andrade Rodriguez	JCU	Ecuador	Transcriptomic analysis of competitive interactions between soft and hard corals. (PhD)	D Miller, A Moya
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
Anne Bauer-Civiello	JCU	USA	From people to reef, marine debris and plastic pollution in north Queensland. (PhD)	M Hoogenboom
Brock Bergseth	JCU	USA	Socio-economic drivers of poaching behaviours in marine protected areas. (PhD)	J Cinner, D Williamson, G Russ
Kathryn Berry	JCU, AIMS	Canada	Effects of coal contamination on tropical marine organisms. (PhD awarded)	M Hoogenboom
Teressa Bobeszko	JCU	Australia	Characterisation of carbonic anhydrase in the symbiotic dinoflagellate *Symbiodinium.* (PhD awarded)	B Leggat, D Yellowlees
Chloë Boote	JCU	United Kingdom	The larval development, microbiome, and stress response of the mushroom coral *Heliofungia actiniformis*. (PhD)	D Miller, A Moya
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	The dynamics of coral-algal interactions on coral reef ecosystems. (PhD)	S Dove, O Hoegh-Guldberg
Christopher Brunner	JCU, AIMS	Germany	Cumulative impacts of water quality and climate change (sea surface temperature warming and ocean acidification) on important reef species. (PhD)	M Hoogenboom
Ramona Brunner	JCU	Germany	The function and ligands of g-protein coupled receptors (gpcrs) in coral larvae settlement. (PhD)	D Miller, A Moya
Dominic Bryant	UQ	Australia	The effects of global and local disturbance towards spatial patterns of coral in the central Indian Ocean. (PhD)	O Hoegh-Guldberg, S Dove
Patrick Buerger	JCU, AIMS	Germany	Viruses: contributors to and mitigators of black band disease in corals. (PhD awarded)	M van Oppen, B Willis
Ciemon Caballes	JCU	Philippines	Environmental influences on the reproductive biology and early life history of the crown-of-thorns starfish. (PhD awarded)	M Pratchett, A Hoey
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 abundance and diversity on host coral dynamics. (PhD)	M Hoogenboom, M Pratchett
Sivee Chawla	JCU	India	Understanding ecosystem service choices made by individual actors and their implications for social-ecological interactions. (PhD)	G Cumming, T Morrison

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
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
Harry Clarke	UWA	Australia	Resolving the impacts of ocean warming and dredging in coral cores collected from the NW shelf of Australia. (PhD)	M McCulloch, J P D'Olivo Cordero
Mia Theresa Bullecer Comeros	JCU	Philippines	Strengthening catchment to sea connections by evaluating the impacts of water quality on parrotfishes and surgeonfish assemblages in American Samoa. (PhD)	A Hoey, G Russ
Mario Conde-Frias	UWA	Colombia	Investigating the sediment dynamics within submerged canopies for unidirectional and oscillatory flows. (PhD)	R Lowe
Zara-Louise Cowan	JCU	United Kingdom	Predation on the early life stages of the crown-of-thorns starfish (*Acanthaster cf. solaris*). (PhD awarded)	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	United Kingdom	Presence and effects of microplastics in coastal environments. (PhD)	M Hoogenboom, A Grech
Michael Cuttler	UWA	USA	Timescales and mechanisms of sediment transport and shoreline morphodynamics in a fringing reef system. (PhD awarded)	R Lowe, M McCulloch, J Falter
Madeline Davey	UQ	Australia	Identifying marine reserve implementation strategies that are economically and ecologically achievable. (PhD)	P Mumby
Jonathan Day	JCU	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
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
Adam Downie	JCU	Canada	How do coral reef fish develop into athletes? (PhD)	J Rummer, P Cowman
Edwin Drost	UWA	The Netherlands	The impact of tropical cyclone forcing on Australia's northwestern coastal system. (PhD awarded)	R Lowe
Ameer Ebrahim	UQ, U. Sunshine Coast	Seychelles	The role of rabbitfish in a marine environment, and their contribution towards the resilience of tropical coral reefs. (PhD)	P Mumby
Michael Emslie	JCU	Australia	Effects of habitat versus fisheries management on spatio-temporal variation in fish assemblages on the Great Barrier Reef. (PhD awarded)	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
Nicolas Evensen	UQ	United Kingdom	Bottlenecks of coral recovery on degraded reefs. (PhD)	P Mumby

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
Eric Fisher	JCU, AIMS	Australia	Spawning aggregation sites on tropical reefs. (PhD)	M McCormick
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 hybridization. (PhD awarded)	G Jones
Gemma Galbraith	JCU	United kingdom	Submerged pinnacle coral reefs; reef fish ecology and functional connectivity. (PhD)	G Jones, M McCormick
Anjani Ganase	UQ	Trinidad and Tobago	Patterns and drivers that determine the structure and composition of typical Caribbean seascapes. (PhD)	O Hoegh-Guldberg, S Dove, P Mumby
Sarah Gierz	JCU	Australia	Thermal acclimation and light-harvesting complex expression in *Symbiodinium.* (PhD awarded)	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
Ruby Grantham	JCU	United Kingdom	The temporal dynamics of reef fisheries as part of diversified coastal livelihoods. (PhD)	G Cumming, D Mills
Rebecca Green	UWA	United Kingdom	Investigating biogeochemical responses to hydrodynamic processes at Scott Reef, a remote atoll off Western Australia. (PhD)	R Lowe
Mila Grinblat	JCU	Russia	Sex change and gene expression in *Fungia fungites* coral. (PhD)	D Miller, P Cowman
Renee Gruber	UWA	USA	Metabolism, particle uptake, and nutrient fluxes on a tide-dominated fringing reef. (PhD awarded)	R Lowe, J Falter
Rodrigo Gurdek	JCU, AIMS	Uruguay	Spatial and temporal connectivity dynamics on the Great Barrier Reef Marine Park using genomics and biophysical modelling. (PhD)	H Harrison
Nataly Gutierrez Isaza	UQ	Colombia	Ecological stoichiometry of corals, symbionts and macroalgae along the latitudinal gradient in eastern Australia. (PhD)	J Pandolfi
Vanessa Haller	JCU, AIMS	Germany	Ecosystem modelling to evaluate multiple uncertain threats on coral reefs. (PhD)	M Bode, G Russ, R Pressey
Kelly Hannan	JCU	USA	The mechanisms underpinning maintained or enhanced performance of coral reef fishes under elevated carbon dioxide conditions. (PhD)	J Rummer, P Munday
Margaux Hein	JCU, GBRMPA	Monaco	Investigating the socio-ecological benefits of coral restoration to support reef resilience. (PhD)	B Willis
Christopher Hemingson	JCU	USA	The evolution, biogeography and ecological significance of colour in coral reef fishes. (PhD)	D Bellwood, P Cowman
Tessa Hempson	JCU, AIMS, U.Lancaster	South Africa	Coral reef mesopredator trophodynamics in response to reef condition. (PhD awarded)	N Graham, A Hoey, G Jones, G Almany
Alejandra Hernandez-Agreda	JCU	Venezuela	Coral core micorbiome: composition, microhabitat distribution, host influence and response to environmental change. (PhD)	T Ainsworth, B Leggat, P Bongaerts, A Hoey
Sybille Hess	JCU	Switzerland	The effects of suspended sediments on the physiology and behaviour of coral reef fishes. (PhD)	J Rummer, A Hoey
Tessa Hill	JCU	United Kingdom	Direct and indirect effects of ocean acidification on reef corals. (PhD)	M Hoogenboom, B Willis, S-A Watson

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
Victor Huertas Martin	JCU	Spain	Feeding ecology of corallivorous reef fishes. (PhD)	D Bellwood, S Connolly
Sofia Jainschlaepfer	JCU	Canada	Assessment of the effects of boat noise on coral reef fish in their larval stage. (PhD)	G Jones, M McCormick
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
Johanna Johnson	JCU	Australia	Development and implementation of a vulnerability assessment tool to inform decision-making in socio-ecological systems. (PhD)	M Kingsford, H Marsh
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 and biological dynamics of post-disturbance coral reef rubble fields. (PhD)	P Mumby, S Dove
Sun Kim	UQ	South Korea	Evolution and ecology of coral range dynamics. (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	Ecological dynamics of Pleistocene corals. (PhD)	J Pandolfi
Alyson Kuba	JCU	USA	Effects of ocean warming on coral reproduction and transgenerational effect: comparison of genetic and epigenetic mechanisms of resilience. (PhD)	A Baird, M Hoogenboom
Felicity Kuek	JCU, AIMS	Malaysia	Dimethylsulfoniopropionate (DMSP) metabolism within the coral holobiont. (PhD)	D Miller, A Moya
Chao-Yang Kuo	JCU	Taiwan	Adaptive strategies in reef-building corals. (PhD awarded)	A Baird, T Hughes, M Pratchett
Vivian Lam (p51)	UQ	Hong Kong	Operationalising resilience: from metrics to measurement. (PhD awarded)	P Mumby
Marie Lapointe	JCU	Canada	Understanding ecosystem service preferences and wellbeing benefits along a rural-urban gradient. (PhD)	G Cumming, G Gurney
Jacqueline Lau	JCU, U.Lancaster	Australia	Winners and losers in marine conservation: investigating access to coral reef ecosystem services. (PhD)	J Cinner, C Hicks, G Gurney
Sarah Lawless	JCU	Australia	The diffusion of meta-norms in natural resource governance. (PhD)	T Morrison, P Cohen, A Song
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
Zoe Loffler	JCU	Australia	Influence of canopy-forming macroalgae on key reef processes. (PhD)	A Hoey, M Pratchett
Chancey Macdonald	JCU	New Zealand	Depth patterns in coral reef fish distributions and microhabitat associations: are deep reefs a refuge? (PhD)	G Jones, T Bridge
Eva Maire	JCU, U. Montpellier	France	How heterogeneity of socio-economic and ecological factors affect the facets of biodiversity in coral reef ecosystems? (PhD)	J Cinner, A Hoey
Estefania Maldonado Villacis	JCU	Ecuador	Biological conservation planning for multiple species habitat restoration in Ecuador. (PhD)	R Pressey
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

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
Robert Mason	UQ, NOAA	Australia	Coral responses to temperature, irradiance and acidification stress: linking physiology to satellite remote sensing. (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	Diffusion of a gear-based conservation innovation in coral reef fisheries. (PhD)	J Cinner, T Morrison, M Barnes
Eva McClure	JCU	Australia	The impact of typhoons on the effectiveness of marine reserve networks in the Coral Triangle. (PhD)	G Russ, A Hoey
Shannon McMahon	JCU	Australia	Effects of rising water temperature and food availability on predatory reef fish. (PhD)	J Donelson, P Munday
Michael McWilliam	JCU	United Kingdom	Coral reef resilience – learning from the past. (PhD)	T Hughes, M Hoogenboom
Matheus Antonio Mello Athayde	UQ	Brazil	*Porites cylindrica* (Dana, 1846), a resilient coral found on the Great Barrier Reef: present and future coral physiology. (PhD)	S Dove
Thane Militz	JCU	USA	A review of the Papua New Guinea marine aquarium fishery. (PhD awarded)	M McCormick
Meira Mizrahi	JCU	Australia	Maximizing potential impact of marine protected area placement: an integrated socio-economic perspective. (PhD)	R Pressey, R Weeks
Jose Montalvo Proano	JCU, AIMS	Ecuador	Mechanisms involved in the potential acclimation of corals to future environmental conditions. (PhD)	P Munday , M van Oppen
Stefano Montanari	JCU, AIMS	Italy	Hybridisation in reef fishes: ecological promoters and evolutionary consequences. (PhD)	M Pratchett
Renato Morais Araujo	JCU	Brazil	Habitat effects on coral reef fish growth and biomass production. (PhD)	D Bellwood, S Connolly
Katie Motson	JCU	United Kingdom	The impacts of coral reef health on fish-parasite interactions. (PhD)	A Hoey
Tiffany Nay	JCU	USA	Physiological and behavioural strategies used by fish to mitigate the effects of ocean warming. (PhD)	A Hoey, M Pratchett
Nery Contti Neto	UWA	Brazil	Field observations of sediment dynamics within coastal benthic ecosystems (PhD)	R Lowe
Katia Nicolet	JCU	Switzerland	Vectors and environmental drivers of coral disease dynamics on the Great Barrier Reef. (PhD awarded)	M Hoogenboom, B Willis, M Pratchett
Jessica Nowicki	JCU	USA	Neural and ecological basis of pair bonding in butterflyfishes (family Chaetodontidae). (PhD awarded)	M Pratchett
Maria Palacios Otero	JCU	Colombia	Controlling mesopredators: importance of intraguild behavioural interactions in trophic cascades. (PhD awarded)	M McCormick, G Jones
Samuel Payet	JCU	Australia	The role of hybridisation in the evolution of coral reef fishes. (PhD)	H Harrison, G Jones, M Pratchett
Katie Peterson	JCU	USA	Ecological drivers of community stability in space and time. (PhD)	T Hughes, S Connolly
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	Germany	Population dynamics of the brown macroalga *Lobophora sp.* and its control by herbivorous fish. (PhD)	P Mumby

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
Kate Quigley	JCU, AIMS	Spain	Genetic and environmental basis for *Symbiodinium* specificity in the coral-dinoflagellate symbiosis. (PhD awarded)	B Willis, B Leggat
Veronica Radice	UQ	USA	Trophic ecology and microbial communities of shallow and deep reef-building corals of the Maldives, Indian Ocean. (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
Jeremy Raynal	JCU	USA	The roles of culture, governance and ecology in natural resource management: interpreting standards in marine protected area design and management in order to enhance application in unique local contexts. (PhD)	R Weeks, R Pressey
Tries Razak	UQ, AIMS	Indonesia	The effect of temperature variability and life-history strategy in coral response to long-term increase in sea surface temperature. (PhD awarded)	P Mumby
Laura Richardson	JCU, U.Lancaster	United Kingdom	Influence of coral species composition on coral reef ecosystem structure and function. (PhD)	A Hoey, N Graham, M Pratchett
Johan Risandi	UWA	Indonesia	Investigating the hydrodynamics and morphodynamics of a reef-fringed pocket beach. (PhD)	R Lowe
Thomas Roberts	JCU, AIMS	Australia	Depth distribution patterns in reef-building corals. (PhD)	A Baird, T Bridge, G Jones
Claire Ross	UWA	Australia	Environmental and biological controls on the growth and physiology of high latitude corals in Western Australia. (PhD)	M McCulloch, V Schoepf, T DeCarlo
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
Netramani (Netra) Sagar	UWA	India	Reconstructing climate and anthropogenic signals on the Indian Ocean margins using geochemistry of marine calcifiers. (PhD)	M McCulloch, A Sadekov
Katie Sambrook	JCU	United Kingdom	Beyond the reef: the influence of seascape structure on fish communities and ecological processes on reefs. (PhD)	A Hoey, G Cumming
Jodie Schlaefer	JCU	Australia	Determining the population structures of cubozoan jellyfishes with biophysical modelling. (PhD)	M Kingsford
Molly Scott	JCU, AIMS	Australia	Mechanisms of behavioural thermoregulation in coral trout on the Great Barrier Reef, Australia. (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 awarded)	R Lowe
Katherine Sievers	JCU	USA	The influence of multiple habitat types on no take marine reserve performance, fish community structure, and demographics of important fishery species. (PhD)	G Russ, G Jones
Tiffany Sih	JCU, AIMS	USA	Fisheries for deep sea snappers. (PhD)	M Kingsford
Carrie Sims	UQ	Australia	Community ecology of corals and their symbionts. (PhD)	J Pandolfi
Alexandre Siqueira Correa	JCU	Brazil	Regulators of coral reef diversity through space and time. (PhD)	P Cowman, D Bellwood
Patrick Smallhorn-West	JCU	Canada	Efficacy of community-based marine management in the Kingdom of Tonga. (PhD)	G Jones, T Bridge, R Pressey, G Gurney

STUDENT NAME	UNIVERSITY	COUNTRY	THESIS TITLE	ARC CENTRE ADVISERS
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	USA	The effects of projected near-future CO_2 on cephalopod behaviours and physiology. (PhD)	S-A Watson, P Munday
Leanne Sparrow	JCU	Australia	Key factors influencing the occurrence and frequency of ciguatera. (PhD awarded)	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	Keeping up with climate change: the evolutionary potential of coral reef fishes to rising sea temperature. (PhD)	P Munday, J Donelson
Robert Streit	JCU	Kenya	Spatial ecology and space use in browsing herbivorous reef fishes: ecological drivers and effects on ecosystem function. (PhD)	D Bellwood, G Cumming
Tullia Isotta Terraneo	JCU, KAUST	Italy	Species boundaries in the coral genus *Porites*: an integrated approach. (PhD)	A Baird, D Miller
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	Wave-driven hydromechanics and sediment dynamics under the influence of coastal canopies in marine ecosystems (PhD)	R Lowe
Francisco Vidal Ramirez	UQ	Chile	Effects of past, present and possible future seawater environments on sea cucumbers and the sediments they process. (PhD)	S Dove
Peter Waldie	JCU, TNC	Australia	Investigating spatial aspects of the community-based management of a small-scale artisanal grouper fishery. (PhD awarded)	J Cinner, R Hamilton, G Almany
Melissa Walsh	JCU	USA	Marine conservation finance: strategies and finance mechanisms to improve the amount and efficacy of investment into marine conservation. (PhD awarded)	R Pressey
Donald Warren	JCU	USA	Influence of elevated temperature on juvenile damselfish performance and their scope for adjustment through developmental plasticity. (PhD awarded)	M McCormick, P Munday, J Donelson
Casey Whalen	JCU	USA	Coral mediation of associated microbial community. (PhD)	D Miller, A Moya
Adam Wilkinson	JCU	United kingdom	The identification of potential links between fibropapillomatosis prevalence in green sea turtles (*Chelonia mydas*) and toxic metal contamination along the Great Barrier Reef, Australia. (PhD)	J Brodie
Jennifer Wilmes	JCU	Belgium	Spatial variation in the density and demography of newly settled crown-of-thorns starfish (*Acanthaster cf. solaris*). (PhD)	M Pratchett, A Hoey, V Messmer
Gundula Winter	UWA	Germany	Hydrodynamics in complex nearshore rocky reef environments. (PhD awarded)	R Lowe
Jessica Zamborain Mason	JCU	Spain	Towards the sustainability of coral reef fisheries: a functional approach. (PhD)	S Connolly, J Cinner
Karin Zwiep	UQ	The Netherlands	Using eDNA to reconstruct past coral reef ecosystems. (PhD)	J Pandolfi

CAREER DEVELOPMENT AND ALUMNI

PHOTO CHRISTOPHER BRUNNER

A research degree from the ARC Centre prepares students for rewarding careers in many disciplines and sectors. Since 2014, 52% of the Centre's PhD graduates have been awarded positions at universities in Australia and overseas, including the Institute of Marine Research (Norway), Pennsylvania State University (USA), University of Neuchatel (Switzerland), Cornell University (USA), Naturalis Biodiversity Centre (The Netherlands) and Simon Fraser University (Canada). Centre alumni have also been awarded prestigious fellowships in New Zealand and the United Kingdom.

Over 20% of our PhD graduates are now employed by government organisations, including the Great Barrier Reef Marine Park Authority, Australian Institute of Marine Science and the Seychelles Fishing Authority. An additional 5% are employed by NGOs and 11% are now working in industries such as fisheries and environmental consultancies.

Since 2014, 26 researchers have completed postdoctoral fellowships at the ARC Centre. Almost 75% of these researchers were subsequently appointed by universities in Australia and overseas, with over half to tenured or tenure-track positions. Other researchers have gained employment in industry and at our Partner Organisations, the Great Barrier Reef Marine Park Authority and the Australian Institute of Marine Science.

RESEARCHERS FROM THE ARC CENTRE ARE IN HIGH DEMAND, CREATING A GLOBAL NETWORK OF COLLABORATIONS THAT INCREASES CAPACITY AND EXPERTISE IN CORAL REEF SCIENCE WORLDWIDE. THE FOLLOWING EXAMPLES ILLUSTRATE THE CAREER PATHS OF RECENT ALUMNI OF THE CENTRE:

Adrian Arias completed his PhD at the James Cook University (JCU) node of the ARC Centre in 2016, under the supervision of Bob Pressey. Following his studies, Adrian was appointed as Program Manager of *Oceans 5*, an international funders' collaborative that supports projects and campaigns to eliminate overfishing, and to establish marine protected areas. His role is to develop and manage *Oceans 5* projects in Latin America and the Caribbean.

Chris Cornwell recently completed his postdoctoral fellowship at The University of Western Australia node of the ARC Centre, which resulted in numerous publications in high impact journals, including *Global Change Biology* and *Nature Climate Change.* Chris was awarded a prestigious five-year *Rutherford Discovery Fellowship* by the New Zealand Royal Society in 2017. The award will enable him to further develop his research on the influence of climate change on the physiological and environmental controls of calcification by coralline algae, at the Victoria University of Wellington.

Christina Hicks graduated from the JCU node of the ARC Centre with a PhD in environmental social science in 2013. She was subsequently appointed to a joint postdoctoral fellowship, co-funded by the ARC Centre and Stanford University (USA), before moving to her current position in 2015 as a tenured lecturer at Lancaster University (UK). Christina has published research in *Nature*, *Science*, *Proceedings of the National Academy of Sciences* and *Nature Climate Change*. She was also awarded a $2.3 million grant in 2017 by the European Research Council.

Jessica Blythe completed a 3-year postdoctoral fellowship at JCU in 2017, co-funded by the ARC Centre and Partner Organisation, WorldFish. In her next career move, Jessica has returned to Canada to undertake a *Social Sciences and Humanities Research Council (SSHRC) Postdoctoral Fellowship,* focussing on environmental governance and small-scale fisheries, at the University of Waterloo.

Joleah Lamb graduated from JCU in 2014 with a PhD in coral health and disease, under the supervision of Bette Willis. Joleah was awarded a *NatureNet Fellowship* at Cornell University (USA) and The Nature Conservancy in 2015. In 2017, Joleah published a first-author and cover article in *Science* on the capacity of seagrasses to reduce human exposure to bacterial pathogens. In January 2018, she published another first-authored article in *Science,* on the effect of plastic pollution on coral reefs.

Martina de Freitas Prazeres graduated from The University of Queensland node of the ARC Centre with a PhD in 2016, under the supervision of John Pandolfi. In 2017, Martina was awarded a highly competitive $380,000 *Innovational Research Incentives Scheme Veni* postdoctoral fellowship, at the Naturalis Biodiversity Centre, funded by the Netherlands Organisation for Scientific Research.

Nick Graham was awarded an ARC *Postdoctoral Fellowship*, *Discovery Early Career Researcher Award* and a *Queensland Smart Futures Fellowship* at the JCU node of the Centre. He joined Lancaster University (UK) in 2015 as a Royal Society University Professorial Fellow, and Chair in Marine Ecology. He is recognised as a 2017 *Highly Cited Researcher* (p9) and was recipient of a Queensland *Young Tall Poppy Science Award, Scopus Young Researcher Award*, and Australian Coral Reef Society *Early Career Researcher Medal*.

Peter Waldie graduated from the JCU node of the ARC Centre in 2017, under the supervision of Glenn Almany and Josh Cinner. During his candidature, Peter developed a collaborative relationship with *The Nature Conservancy* (TNC). He is now employed as a Coastal Fisheries Scientist with TNC and continues his important work on community-based management of fisheries in Micronesia and Melanesia.

Ruth Thurstan conducted her postdoctoral fellowship at The University of Queensland node of the ARC Centre, resulting in numerous publications on sustainable fisheries in high impact journals including *Fish and Fisheries* and *Conservation Letters*. Ruth was appointed by the University of Exeter (UK) as a tenured lecturer in 2017. Following her appointment, she was awarded a *Marie Skłodowska-Curie Actions Research Fellowship*, funded by the European Union.

Tracy Ainsworth was promoted to Principal Research Fellow at the JCU node of the ARC Centre in 2016, and in the same year published two first-author articles in *Science*. She won numerous awards during her postdoctoral fellowships at the ARC Centre, including an ARC *Postdoctoral Fellowship* and *Super Science Research Fellowship*, the Australian Academy of Science *Dorothy Hill Medal* (p8) and the L'Oreal-UNESCO *for Women in Science Australia and New Zealand Fellowship*. Tracy was awarded a prestigious *Scientia Fellowship* by the University of New South Wales in 2017.

"Just wanted to send some brief feedback on the recent professional development workshops: both sessions were fantastic and I definitely hope that they continue in the Centre in future. Some really useful insights and advice for a wide range of early PhD/ mid career scientists – the content was really well tailored and the presenters did a great job elaborating on specific questions/issues. The relaxed and informal setting made it accessible and easy to participate…All in all, another example of the amazing resources available to us at the CoE."

Gemma Galbraith | PhD Candidate

PHOTO DAVID WILLIAMSON

GRADUATE PROFILE

DR VIVIAN LAM

Dr Vivian Lam grew up in the concrete jungle of Hong Kong. Despite her surroundings, she developed a deep passion for nature conservation. She remembers wanting to "learn about the diversity of animals, be it cute and cuddly, or hard and ugly". This passion led Vivian to pursue an undergraduate degree in environmental science at the University of Hong Kong (HKU), where she was awarded the *Peter Thrower Prize in Biological Sciences* for graduating top of her class. During her studies, Vivian became increasingly aware that although Hong Kong is small in area, it is a key driver of global patterns in seafood trade and consumption. "When I found out that shark fisheries were practically undocumented in Hong Kong, as most research focused on its trade or fins, I wanted to do something about it."

Vivian's Masters thesis at the Swire Institute of Marine Science, HKU, investigated historical shark fisheries in southern China. Her research revealed the extent of shark declines, previously unknown due to the lack of information in the region. To increase the impact of her research, Vivian pursued opportunities to generate public awareness of the unsustainable consumption of shark fins. Her outreach activities included working as a scientific adviser in the award-winning short film *Fin*, and interviews with international media, including *The Washington Post* reporter, Juliet Eilperin.

To gain practical experience in linking science to international policy, Vivian became an intern at the United Nations in Bonn, Germany. There, she assisted in the development of a Memorandum of Understanding to protect global shark populations, under the terms of the Convention for Migratory Species. Vivian's next appointment took her to Washington D.C. (USA), where she worked at the International Union for Conservation of Nature (IUCN) on the Global Coral Reef Monitoring Network (GCRMN) under the guidance of ARC Centre Partner Investigator, Professor Jeremy Jackson. This role involved liaising with over 300 scientists to amass unprecedented quantities of data for the key report *Status and Trends of Caribbean Coral Reefs: 1969-2012.*

With a vast amount of data at her fingertips, Vivian saw a need to learn more about statistical modelling. She moved to Brisbane in 2013 to undertake a PhD at The University of Queensland under the supervision of Peter Mumby, whom she met whilst working at the IUCN. Vivian's goal was to improve retrospective analyses of data to inform management objectives. She trialled state-of-the-art methods for extracting ecological information from monitoring data collected by the ARC Centre's Partner Institution, the Australian Institute of Marine Science. Her research found that "inshore and offshore reefs in the Great Barrier Reef are both largely governed by episodic localised disturbances – storms and floods in inshore reefs, and storms and crown-of-thorns starfish in the mid- and offshore reefs". The results of Vivian's research provide information to guide current reef monitoring programmes and deliver practical solutions that improve future monitoring and resilience assessments in the region.

Vivian relocated back to Hong Kong after submitting her thesis in July 2017. Shortly after her return, she was offered a position with the Hong Kong Government in the Agriculture, Fisheries and Conservation Department. She will be working in the planning and management division to develop consistent monitoring programmes for capture fisheries and to assist in the development of fisheries protection areas. Vivian has "always been interested in how science transfers to policy and legislation," and she reports, "I am very excited about this opportunity to contribute to the management of marine resources back home."

NATIONAL AND INTERNATIONAL LINKAGES

The ARC Centre has hundreds of ongoing collaborations and interactions with Australian and international researchers and institutions. These collaborations continue to grow in 2017, consolidating the global hub for coral reef research at the Centre. The Centre's international linkages create novel collaborations leading to multi-institutional publications, international working groups and workshops, and are exemplified by visits to overseas institutions, and international visitors to the Centre's nodes. Since 2014, the Centre's international research profile and reputation has attracted 146 new international graduate students to Australia. In 2017, 69% of our 2017 new graduate enrolments were international (p38).

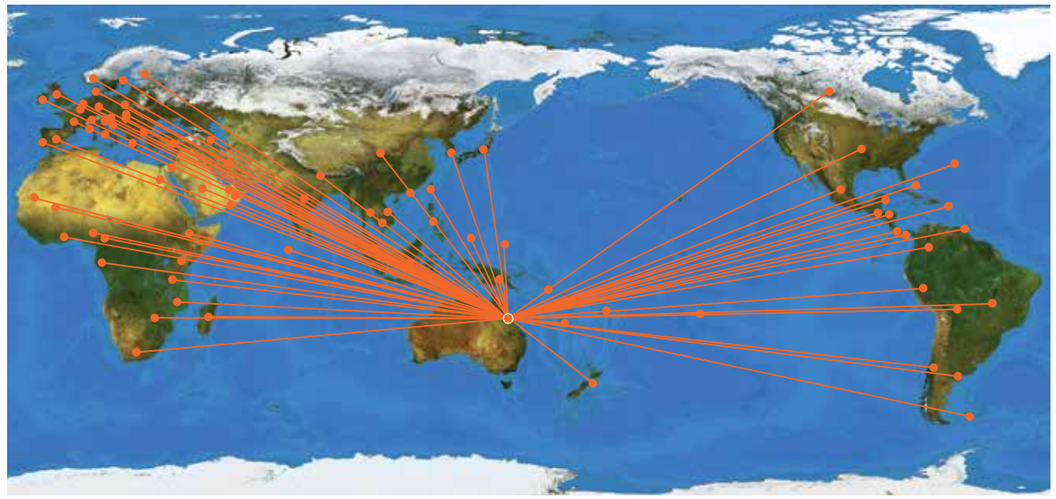
In 2017, Centre researchers published 315 journal articles with cross-institutional co-authorship, involving researchers from 318 institutions in 61 countries. ARC Centre researchers convened 23 international working groups and workshops, involving 254 external researchers and stakeholders. Across the four nodes of the ARC Centre, we hosted 76 international visitors from 24 countries, while Centre personnel visited international collaborators at 123 laboratories and research facilities in 37 countries.

Centre personnel are actively involved on many editorial boards of international journals. We undertake research worldwide, and our outreach is global (p58). 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. Five Centre research leaders are Fellows of the Australian Academy of Science: David Bellwood, Ove Hoegh-Guldberg, Terry Hughes, Malcolm McCulloch and Bob Pressey. Malcolm McCulloch is also a Fellow of The Royal Society (UK).

The ARC Centre currently has four 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 researchers also collaborate extensively with three international non-government organisations (NGOs) – The Nature Conservancy (TNC), the Worldwide Fund for Nature (WWF) and Conservation International (CI). These collaborations result in tangible outputs and impacts, including the development of multiple trans-disciplinary research projects, cotutelle PhDs, exchange of researchers, recruitment of co-funded postdoctoral fellows, and enhanced engagement and uptake of our research by end-users around the world. These links are reinforced by the Centre's governance structure, and are measured by specific performance targets.

PHOTO MARK PRIEST

The map below shows the locations of the Centre's international collaborators.



CASE STUDY: FRANCE

Strengthening bilateral science cooperation on research is a longstanding priority for France, and they have a globally-significant program of coral reef research centred at field laboratories and other research facilities in French Polynesia, New Caledonia, the Indian Ocean and the Caribbean. In 2014, the ARC Centre established a formal Partner Organisation agreement with Centre National de la Recherche Scientifique (CNRS), France's largest governmental research organisation, with Serge Planes as a Partner Investigator. Since then, the ARC Centre's research collaborations with France have flourished, generating >190 journal articles. The Institut de Recherche pour le Développement (IRD) and CNRS lead the list of 41 institutions in France with which the Centre collaborates, highlighting the interdisciplinarity and breadth of those collaborations. These links were further strengthened in August 2017 with several researchers from the Centre joining their French counterparts in Sydney to attend a workshop organised by the Embassy of France on the *Protection of coral reefs*. In December, Terry Hughes spoke in Canberra on bilateral cooperation in marine science and coral reef protection at the Australian-French Association for Research and Innovation (AFRAN) Forum at the invitation of the French Embassy. A number of French/Centre working groups meetings were held during 2017 to progress high profile research outcomes. In March, Josh Cinner hosted a workshop on 'Bright Spots' with David Mouillot in Chamonix, France while Michael Bode hosted a workshop with the Centre for Synthesis and Analysis of Biodiversity in Aix-en-Provence. In August, Malcolm McCulloch, Aleksey Sadekov and Steeve Comeau presented talks at the Goldschmidt Conference in Paris, where they ran a series of geochemistry-focussed workshops with their French colleagues. In October, Michael Bode and Jodie Rummer co-hosted two working group meetings with CNRS colleagues in Moorea, French Polynesia. Jodie's group focussed on genomic evidence for adaptation of marine fishes to ocean acidification with Michael and Serge Planes pursuing the research challenge of matching connectivity models to larval dispersal data in coral reef fishes.

WORLDFISH, MALAYSIA

WorldFish is one of the ARC Centre's longest standing and productive international partners. WorldFish is a non-profit research organisation headquartered in Malaysia, engaged in research in Africa, Asia and the Pacific to improve the lives for the 800 million people globally who depend on fisheries and aquaculture. 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 David Mills and Pip Cohen are based in the ARC Centre at the Townsville node, and the Centre and WorldFish have co-funded two postdoctoral researchers since 2014. Pip Cohen was appointed as a Partner Investigator in the ARC Centre in 2017 following Dr Neil Andrew's move from WorldFish to the Australian National Centre for Ocean Resources and Security (University of Wollongong). During 2017, CGIAR announced that WorldFish and the ARC Centre had been awarded funding for implementation of the FISH CRP flagship focussed on small-scale fisheries in which the ARC Centre leads the coastal fisheries program. FISH CRP will facilitate collaborative projects in this research focus for five years (2018–2022), and ARC Centre leaders have attended a number of early planning meetings in Penang. In September, Centre PhD students Sarah Lawless, Ruby Graham and Jacqui Lau and a number of

Centre research fellows attended the WorldFish Resilient Small-Scale Fisheries Symposium in Penang, which offered valuable opportunities to strengthen research collaborations between our organisations. Sarah, Ruby and Jacqui are co-supervised by WorldFish researchers. 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 2017, Centre Director, Terry Hughes, re-visited KAUST as a member of the Advisory Board of KAUST's Red Sea Research Centre where he also gave the Keynote address at the Red Sea Research Center Open Science Conference. The ARC Centre hosted six visitors from KAUST associated with two large collaborative projects, entitled *Genomic evidence for adaptation of marine fishes to ocean acidification*, and *Transcriptional program and the epigenome of transgenerational acclimation to climate change in reef fishes*. Two of the ARC Centre's research fellows, Heather Veilleux and Jennifer Donelson, were recruited for these projects and are funded through this partnership. ARC Centre and KAUST team members presented results from these projects at various conferences in 2017, including the Society for Experimental Biology Annual Meeting and the 10th Indo-Pacific Fishes Conference. Tim Ravasi (KAUST) and Philip Munday also hosted a collaborative workshop for team members in conjunction with the Indo-Pacific Fishes Conference. Two papers from the collaboration with KAUST were published in *Nature* journals during 2017, including an article in *Nature Climate Change,* led by ARC Centre research fellow Greg Torda (p31), on the potential for rapid adaptive responses to climate change and corals. Greg's position in the Centre is co-funded by the Australian Institute of Marine Science.

GREAT BARRIER REEF MARINE PARK AUTHORITY

GBRMPA, the Australian government agency with the primary responsibility of protecting and managing the Great Barrier Reef, is the ARC Centre's most important end-user in Australia. Their task is to assess, inform, and implement government policies to maintain the environmental quality of the Great Barrier Reef. Our research goals are strongly aligned with the scientific information needs of GBRMPA. Consequently, GBRMPA's partnership with the ARC Centre provides them with direct access to the ARC Centre's expertise. GBRMPA is embedded within the ARC Centre's governance arrangements, to facilitate research planning and the exchange of information and data. GBRMPA's Chair is a member of the Centre's Advisory Board, and the Authority's Chief Scientist sits on the Centre's Scientific Management Committee. GBRMPA managers receive regular updates, advice and briefings on the Reef from ARC Centre researchers. For example, in 2017, findings from the Centre's aerial surveys of coral bleaching were used on a daily basis by GBRMPA as they responded to the event. Ove Hoegh-Guldberg, Andrew Hoey, Terry Hughes, and Peter Mumby attended the GBRMPA *Reef Summit* in May to advise GBRMPA on their response to mass coral bleaching and cumulative impacts on the Great Barrier Reef. During 2017, Centre researchers David Williamson, Garry Russ and Geoff Jones continued to deliver findings to GBRMPA on their assessment of the ecological effects of zoning of fishing effort on inshore reefs of the GBR. The Centre is also a major contributor to technical courses, workshops, and training. For example, in March this year, the Centre provided hands-on training to GBRMPA personnel in aerial bleaching surveys. In November, Centre researchers Terry Hughes, Bette Willis, and Sam Matthews joined 27 GBRMPA managers for presentations, information exchange and discussions in GBRMPA's Pre-Summer Reef Health Workshop, a forum for planning and coordinating upcoming monitoring and research activities.

THE AUSTRALIAN INSTITUTE OF MARINE SCIENCE

The Australian Institute of Marine Science is the ARC Centre's major Australian research partner outside of the University sector. AIMS undertakes a range of research on tropical marine environments and aquaculture, is responsible for the long-term monitoring of the Great Barrier Reef, and increasingly provides 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 ARC Centre welcomes Dr Paul Hardisty who was appointed as the new AIMS Chief Executive Officer in 2017 and we look forward to a productive relationship with him through his role as a member of the Centre's Advisory Board. In 2017, we farewelled Professor Madeleine van Oppen as a long serving Partner Investigator in the Centre. AIMS' senior principal scientist, Janice Lough has been a very active Partner Investigator in the Centre in 2017, working closely with the coral bleaching research team and publishing two papers in *Nature* in March and June. AIMS and the ARC Centre also share valuable infrastructure, co-supervise graduate students (37 in 2017) and co-fund two postdoctoral fellows: Greg Torda and Kristen Anderson. AIMS and ARC Centre researchers co-authored 49 papers in 2017.

INTERNATIONAL VISITORS IN 2017

In 2017, 76 international visitors were hosted by one or more of the four nodes of the ARC Centre of Excellence.

NAME	OVERSEAS INSTITUTION	COUNTRY
Dr Rene Abesamis	Silliman University	Philippines
Dr Manuel Aranda	King Abdullah University of Science and Technology	Saudi Arabia
Dr Paul Armsworth	University of Tennessee	United States
Dr Andrew Bauman	National University of Singapore	Singapore
Dr Maria Beger	University of Leeds	United Kingdom
Dr Moisés Bernal	King Abdullah University of Science and Technology	Saudi Arabia
A/Prof Michael Berumen	King Abdullah University of Science and Technology	Saudi Arabia
Dr Dhanya Bhaskar	Azim Premji University	India
Prof Kate Brown	University of Exeter	United Kingdom
James Carouso	Senior Foreign Service	United States
Prof Allen Chen	Academia Sinica	Taiwan
Dr Steven Cooke	University of Ottawa	Canada
Dr Emily Darling	University of Toronto	Canada
Jason deCaires Taylor	Underwater Artist	United Kingdom
Dr C Mark Eakin	National Oceanic and Atmospheric Administration	United States
Estradivari Estradivari	WWF	Indonesia
Dr David Feary	University of Nottingham	United Kingdom
Valerie Fowler	US Consular General	United States
Dr Pedro Frade	University of Algarve	Portugal
Prof Ruth Gates	University of Hawai'i at Mānoa	United States
Sylvain Govan	Aquarium des Lagons Nouvelle-Calédonie	New Caledonia
Prof Nick Graham	Lancaster University	United Kingdom
Prof Martin Grosell	University of Miami	United States
Prof Alan Hastings	University of California	United States
Dr Missaka Hettiaraarchichi	University of Moratuwa/WWF	Sri Lanka
Dr Rachael Heuer	University of Miami	United States
Dr Ann Holbourn	University of Kiel	Germany
Wouter Holleman	South African Institute for Aquatic Biodiversity	South Africa
Dr Björn Illing	University of Hamburg	Germany
Bob Inglis	Eco Right Movement	United States
Mary Anne Inglis	Eco Right Movement	United States
Luca Joppa	Microsoft	United States
Maria Jung	Bremen University	Germany
Prof Wolfgang Kiessling	University of Erlangen	Germany
Dr Danika Kleiber	Pacific Island Fisheries Science Center	United States
Prof Nancy Knowlton	Smithsonian Institution	United States
Anna Krien	Nature Journal	United States

NAME	OVERSEAS INSTITUTION	COUNTRY
Prof Wolfgang Kuhnt	University of Kiel	Germany
Rita Kumar	WWF Global Oceans Practice	United States
Timothy Lewis	Columbia University and New York City Department of Education	United States
Prof Jon Lloyd	Imperial College	United Kingdom
Muhammad Lukman	Coral Triangle Initiative for Coral Reef and Food Security Secretariat	Indonesia
Bruna Luz	University of São Paulo	Brazil
Simon Mahood	Wildlife Conservation Society	Cambodia
Dr Laurence McCook	Chinese Academy of Sciences	China
Pauli Merriman	WWF Global Oceans Practice	Sweden
Alison Munro	King Abdullah University of Science and Technology	Saudi Arabia
Kanji Nakagawa	Kyoto University	Japan
Melissa Naugle	Internship	United States
Dr David Obura	CORDIO East Africa	Kenya
Prof Stephen Palumbi	Stanford University	United States
Dr Darren Parsons	National Institute of Water and Atmospheric Research	New Zealand
Dr Angus Paterson	South Africa Institute of Aquatic Biodiversity	South Africa
Sheetal Patil	Axim Premjo University	India
Samantha Peterson	WWF Global Oceans Practice	South Africa
Prof Richard Pollnac	University of Rhode Island	United States
Prof Widi Pratikto	Coral Triangle Initiative for Coral Reef and Food Security Secretariat	Indonesia
Dr Nigel Preston	WorldFish	Myanmar
Susanna Primavesi	Università degli Studi di Milano-Bicocca	Italy
Prof Timothy Ravasi	King Abdullah University of Science and Technology	Saudi Arabia
Dr Willem Renema	Naturalis Biodiversity Center	Netherlands
Dr Riccardo Rodolfo-Metalpa	Institut Research Pour le Developpement	New Caledonia
Dr Pablo Saenz	Universidad of Austral de Chile	Chile
Prof Michael Sarnthein	University of Kiel	Germany
Dr Celia Schunter	King Abdullah University of Science and Technology	Saudi Arabia
Tom Shlesinger	Tel Aviv University	Israel
Dr William Skirving	National Oceanic and Atmospheric Administration	United States
Dr Mark Spalding	University of Siena	Italy
Prof Simon Sprecher	University of Fribourg	Switzerland
Dr Fernanda Terra Stori	University of São Paulo	Brazil
Raisa Vieira	Federal University of Goiás	Brazil
Prof Gangjian Wei	Chinese Academy of Sciences	China
Dr Sally Wood	University of Bristol	United Kingdom

Australian GEOGRAPHIC

ARTICLE | 7 SEP 2017

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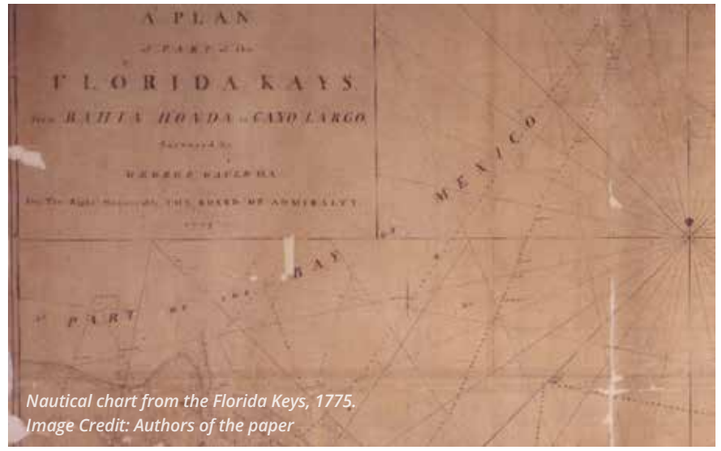
http://www.australiangeographic.com.au/news/2017/09/centuries-old-nautical-maps-reveal-coral-loss-much-worse-than-we-thought

Centuries-old nautical maps reveal coral loss much worse than we thought

BY ANGELA HEATHCOTE | SEPTEMBER 07, 2017

Scientists say it's possible we could use nautical maps to understand coral loss across our own shores.



Nautical chart from the Florida Keys, 1775. Image Credit: Authors of the paper

EIGHTEENTH CENTURY nautical maps of the Florida Keys area, which include a stunning amount of ecological information, have for the first time revealed large amounts of coral loss previously unimaginable to scientists.

By comparing these centuries-old nautical maps to satellite images of modern coral habitats across the Florida Keys, the team of researchers from the US and Australia discovered coral reefs that no longer exist, and were thus previously ignored.

When researchers added this coral loss to their current estimates, the percentage of coral loss over the past two and half centuries surged to almost 90 per cent in some locations, leading researchers to believe that the new study, published in *Science Advances* last week, will have dramatic consequences for the conservation of our coral reefs.

"Usually we monitor coral loss through time by going to reefs where we know there are corals or coral habitat and then measuring the decline in percent of coral cover through time. However, our work shows that there are abundant places where reefs used to exist but we would never even think to monitor coral cover there because they are not reef habitats anymore," co-author of the paper, John Pandolfi told Australian Geographic.

"These reefs used to exist and they exist no longer, adding to our understanding of the scale of coral and reef decline. Adding a new kind of loss that we were generally unaware of... without studies such as ours, we risk having overly optimistic views of the current conservation status of Caribbean reefs."

Using nautical charts to map coral reef change

The role of nautical charts in mapping changes across the world's coral reefs is yet to be fully realised as they typically contained very little ecological information up until the 18th century.

"18th century British imperial mapping of overseas territories marked the first global effort to collect high-resolution spatial data on coastal areas; these charts often contained substantial amounts of ecological information, with coral of particular interest as a navigational hazard," the paper reads.

"The degree of biologically relevant information recorded varied by cartographer, but the best of these British maps describes the depth, shape, and color of shallow-water corals and distinguishes them from other hard structures such as rocks."

John explained that it's possible that nautical charts could be used to map the loss of coral habitat across Australian shores, and that this is something they will continue looking into.

This research was led by the ARC Centre visiting scholar, A/Prof Loren McClenachan of Colby College, USA.

COMMUNICATION, MEDIA AND PUBLIC OUTREACH

The ARC Centre's research expertise is sought after continuously from across the globe – from the Discovery Channel to international organisations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) – creating invaluable outreach opportunities for the Centre and its members. In 2017, the ARC Centre interacted with a range of audiences through a diverse range of mechanisms and activities – social media, briefings and workshops, public talks, articles in *The Conversation*, plenary addresses, visits to schools, and a highly active online presence. The ARC Centre Symposium and Public Forum is an annual event designed to bring together members, graduate students and partners to share new ideas and plan for the future. In 2017, the *Coral Reef Futures Symposium* was held in Canberra at the iconic Shine Dome, and attended by more than 150 researchers. This year's Public Forum, hosted by media personality Dr Karl Kruszelnicki, was a highly successful event for engaging with the public. The ARC Centre's website continues to grow in popularity – in 2017, the total number of webhits grew to 14.1 million. This year we re-designed the website, adding substantial new content for a diverse global audience.

SOCIAL MEDIA

Social media is a key communication strategy for the ARC Centre. On Facebook, the Centre increased its posts by 20 per cent and subsequently grew its 'Page Likes' by more than 70 per cent. In 2017, the ARC Centre also initiated a strategic partnership with the Australian Academy of Science to deliver a series of popular video posts promoting research outputs, with a viewership reaching over 150,000. In 2017, the number of Twitter users following the Centre's account grew by more than 2000, and our 600 posts earned over a million impressions. Social media has become a crucial platform for broadly communicating the Centre's newly published research findings. Through mechanisms like Altmetric, we can better assess the online attention of the Centre's research outputs. For example, according to Altmetric the paper 'Global warming and recurrent mass bleaching of corals' published in *Nature* in March 2017 generated 1813 tweets from 1348 users, reaching 4.1 million Twitter followers.

BRIEFINGS AND WORKSHOPS

Providing tailored advice, training and information to key stakeholders is a vital role of the ARC Centre. In 2017, researchers engaged in 121 briefings to policy and decision-makers in both the public and private sectors. In May, Ove Hoegh-Guldberg briefed the Minister for the Environment and Energy, Josh Frydenberg, on climate change impacts on coral reefs. Sean Connolly met with members of the Australian Parliament as part of the *ARC-Science and Technology Australia Research Showcase* in September, and Andrew Hoey represented the ARC Centre at the annual *Science Meets Parliament* event hosted in Canberra in March. A number of ARC Centre researchers including Terry Hughes, Tiffany Morrison, Jon Brodie, Alana Grech and Jon Day provided expert advice to the Australian Academy of Science (AAS) to inform their submissions on government policy reviews relating to the Great Barrier Reef. Rebecca Weeks briefed dignitaries

at the Chuuk Department of Marine Resources in Micronesia on the design and management of marine protected areas and complementary fisheries management strategies.

The Centre supported Traditional Owners and their Sea Country through a range of briefings held in 2017. Alana Grech briefed the GBRMPA Indigenous Reef Advisory Committee on how to mitigate controversy associated with traditional harvesting of dugong in the Great Barrier Reef and Torres Strait. Chris Cornwall and Verena Schoepf met with the Bardi Jawi Indigenous Rangers in One Arm Point, located in the far north of Western Australia, to discuss the mass bleaching event in the Kimberley. The ARC Centre is also a key supporter of the Aboriginal and Torres Strait Islanders in Marine Science (ATSIMS) and the Deadly Science Getaway programs. ATSIMS empowers Indigenous secondary students in North Queensland to pursue study and careers in marine science and management. The Deadly Science Getaway program seeks to engage and inspire young Aboriginal and Torres Strait Islander women (13- to 18-year-olds) from remote communities to pursue careers in marine science through field work at the James Cook University's Orpheus Island Research Station.

PUBLIC TALKS AND SCHOOLS

ARC Centre members across the four nodes delivered a total of 58 public talks in 2017. For example, Maja Adamska gave her lighthearted talk 'Was your great-great-grandmother a sponge?' as part of *Darwin Day* celebrations at Questacon, in Canberra. Aleksey Sadekov delivered his talk 'Broadening horizons of palaeoclimate studies', at a public event hosted by The Royal Society of Western Australia. Thomas Bridge presented at two events associated with the World Science Festival hosted in Brisbane: 'Cool Jobs', which aims to inspire schoolchildren about careers in science, and 'Let's Talk', a seminar where he was able share his research with over 2300 members of the public. In December, Verena Schoepf delivered her TEDx Talk 'Super-Corals and the Future of Coral Reefs' at The University of Western Australia.

Researchers at the ARC Centre also actively engage in public outreach with schools and special interest groups. For instance, Andrew Hoey engaged with our Partner Organisation GBRMPA for the annual *Reef Guardians Youth Summit*, to celebrate and inspire the next generation of Reef Guardians. Tracy Ainsworth helped students of all ages celebrate Australia's National Science Week as part of the *Catch a Rising Star: Women in Queensland Science* program. Tracy gave four presentations throughout the week reaching hundreds of children, including members of the local U3A, Townsville State High School and Magnetic Island State School. This year, Jodie Rummer and PhD student Ian Bouyoucos also gave a series of talks on their research, to local communities on the island of Moorea, French Polynesia.

THE CONVERSATION

The ARC Centre actively publishes original research-based articles and commentary through the popular online media resource, *The Conversation*, which has an audience of up to 35 million readers. In 2017, 11 ARC Centre researchers published 9 articles. Topics ranged from coral bleaching to the burgeoning blue economy. The most widely read article during 2017 was led by Terry Hughes and Joshua Cinner, with close to 10,000 recorded reads. The article, entitled 'The world's coral reefs are in trouble, but don't give up on them yet', was published on 31 March and subsequently re-published by *Australian Geographic*, yielding a total audience reach of 161,000. Other examples of *The Conversation* articles published in 2017:

Ove Hoegh-Guldberg. *The Western Indian Ocean's blue economy can thrive. Here's how*, 26 January 2017. https://theconversation.com/the-western-indian-oceans-blue-economy-can-thrive-heres-how-71734

Terry Hughes. *Year-on-year bleaching threatens Great Barrier Reef's World Heritage Status*, 15 March 2017. https://theconversation.com/year-on-year-bleaching-threatens-great-barrier-reefs-world-heritage-status-74606

Tiffany Morrison. *The Great Barrier Reef's safety net is becoming more complex but less effective*, 6 April 2017. https://theconversation.com/the-great-barrier-reefs-safety-net-is-becoming-more-complex-but-less-effective-75053

Terry Hughes and James Kerry. *Back-to-back bleaching has now hit two-thirds of the Great Barrier Reef*. 12 April 2017. https://theconversation.com/back-to-back-bleaching-has-now-hit-two-thirds-of-the-great-barrier-reef-76092

Jon C. Day. *The UN is slowly warming to the task of protecting World Heritage sites from climate change*, 11 July 2017. https://theconversation.com/the-un-is-slowly-warming-to-the-task-of-protecting-world-heritage-sites-from-climate-change-80270

Jon Brodie, Alana Grech, Laurence McCook. *The new Great Barrier Reef pollution plan is better, but still not good enough*, 1 September 2017. https://theconversation.com/the-new-great-barrier-reef-pollution-plan-is-better-but-still-not-good-enough-83233

PLENARY TALKS

In 2017, Centre researchers gave 43 keynote addresses around the world. For example, alongside esteemed colleagues and dignitaries, Ove Hoegh-Guldberg delivered an invited panelist speech at the high visibility conference *Our Ocean 2017* held in Malta. In September, Terry Hughes delivered an invited address to more than 1,500 delegates at the *7th World Conference on Ecological Restoration* held in Brazil, before traveling to Saudi Arabia to participate and deliver the opening keynote speech at KAUST's *Open Science Conference 2017* hosted by the Red

PHOTO MICHAEL MCWILLIAM

Sea Research Center. Jodie Rummer also delivered an invited keynote address, alongside National Geographic editor-in-chief Susan Goldberg and other prominent female role models at the USA-based Gills Club in Boston, USA.

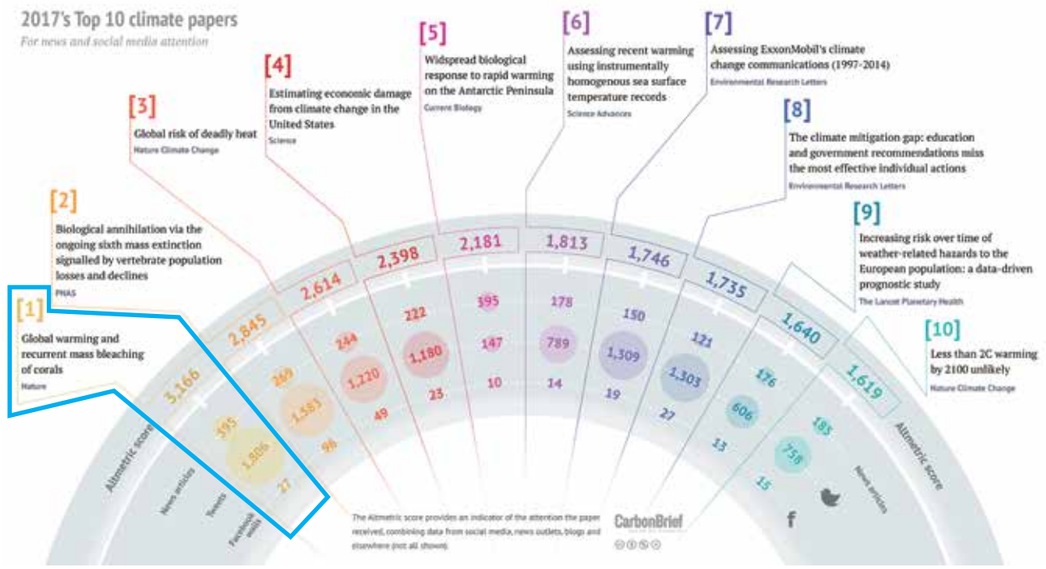
MEDIA RELEASES

In 2017, the ARC Centre distributed 26 media releases, which generated 9,399 news items and commentaries in all forms of mass media – radio, television, digital and print, including uptake by the world's most prestigious and influential outlets such as the *The New York Times, National Public Radio, Le Monde, Der Spiegel* and the *BBC*. The ARC Centre's research also resonated with trendsetting digital news outlets including *Mashable*, *MotherJones*, *IFLScience* and *BuzzFeed,* with a young audience reach of up to 48 million.

The two biggest stories in 2017 arose from the media releases 'Scientists mobilise as bleaching resumes on Great Barrier Reef' (16 March 2017) and 'Two-thirds of the Great Barrier Reef hit by back-to-back bleaching' (10 April 2017). These two releases generated close to 4,000 commentaries.

According to Altmetric, the Centre's March 2017 *Nature* paper 'Global warming and recurrent mass bleaching of corals', was one of the world's most talked about papers of 2017– garnering 395 news stories in 245 outlets, including *The Guardian*, *The Washington Post*, and *Daily Mail*. The paper also generated tremendous dialogue across social media platforms including Twitter and Facebook, yielding 1806 tweets and 27 posts, respectively. In November, the paper was listed in the Altmetric 'Top 100 Most Important Papers of 2017', at number 21, and was identified as #1 in CarbonBrief's listing of '2017's Top 10 Climate Papers'.

The 10 April 2017 media release 'Two-thirds of the Great Barrier Reef hit by back-to-back bleaching' reported on preliminary findings of the Centre's comprehensive aerial surveys along the entire length of the Great Barrier Reef. *The Washington Post*'s page-one article alone reached an audience of 39 million, with additional news articles appearing in *National Geographic*, *New Scientist*, *The Guardian* and *Le Monde*, as well as many other major media outlets. The map of bleaching released by the Centre has been reproduced in a wide range of communication materials – from textbooks and magazine articles, to CNET's widely popular 'Rebooting the Reef' multimedia series.



The Centre's March* Nature *paper 'Global warming and recurrent mass bleaching of corals' was ranked by CarbonBrief as the Number One climate paper in the world in 2017. (Highlighted in blue)
https://www.carbonbrief.org/analysis-the-climate-papers-most-featured-in-the-media-in-2017

Additional media highlights for 2017 include:

Seven TV News – *JCU researchers have discovered a new weakness in the potentially deadly cone snail*, S Watson, P. Munday, 1 February 2017

SBS News – *New study finds reef won't heal on its own*, P Bongaerts, 17 February 2017 https://www.sbs.com.au/news/new-study-finds-reef-won-t-heal-on-its-own

The Washington Post – *The Great Barrier Reef is bleaching yet again, and scientists say only swift climate action can save it*, T Hughes, 15 March 2017 https://www.washingtonpost.com/news/energy-environment/wp/2017/03/15/the-great-barrier-reef-is-bleaching-yet-again-and-scientists-say-only-swift-climate-action-can-save-it

ABC Radio National – Breakfast *Back-to-back mass bleaching confirmed for GBR*, T Hughes, 23 March 2017 http://www.abc.net.au/radionational/programs/breakfast/back-to-back-mass-bleaching-confirmed-for-gbr/8379318

60 Minutes, 9Now – *Great Barrier Grief*, T Hughes, 26 March 2017 https://www.9now.com.au/60-minutes/2017/episode-8

Australian Geographic – *Great Barrier Reef suffers severe bleaching for second year running,* T Hughes, J Kerry, 10 April 2017 http://www.australiangeographic.com.au/news/2017/04/great-barrier-reef-suffers-second-year-of-bleaching

The Age, Melbourne – *Great Barrier grief: coral bleaching far worse than thought,* T Hughes, 10 April 2017

ABC TV News – Evenings with Grandstand – Interview: *Two-thirds of the Great Barrier Reef has been devastated by severe coral bleaching*, S Connolly, 10 April 2017

ABC Radio – The World Today – *Coral bleaching events on Great Barrier Reef leaves marine scientists devastated and horrified,* J Kerry, 10 April 2017 http://www.abc.net.au/worldtoday/content/2016/s4651203.htm

New Scientist – *Barrier Reef's worsening plight,* T Hughes, 15 April 2017 https://doi.org/10.1016/S0262-4079(17)30702-9

BBC News – *Coral reefs can be saved but change is inevitable, scientists say*, T Hughes, 1 June 2017 http://www.bbc.com/news/world-australia-40115716

Reuters – *With a sloppy 'kiss', intrepid fish enjoys perilous feast*, D Bellwood, V Huertes, 6 June 2017 http://af.reuters.com/article/oddlyEnoughNews/idAFKBN18W2QN

Scientific American – *Coral reef fish suck up meals with slime-covered lips,* D Bellwood, 6 June 2017 https://www.scientificamerican.com/article/coral-reef-fish-suck-up-meals-with-slime-covered-lips

BuzzFeed – *Global coral reefs are in huge trouble, and we're not doing enough to save them,* J Day, 24 June 2017 https://www.buzzfeed.com/robstott/global-coral-reefs-are-in-huge-trouble-and-were-not-doing

Netflix – *Chasing Coral*, O Hoegh-Guldberg, P Bongaerts, M Gonzalez-Rivero, 14 July 2017 https://www.youtube.com/watch?v=b6fHA9R2cKI

Comedy Central – The Jim Jefferies Show – *Climate change and conspiracy theories at the Great Barrier Reef*, T Hughes, 18 July 2017 http://www.comedycentral.com.au/the-jim-jefferies-show/videos/climate-change-and-conspiracy-theories-at-the-great-barrier-reef-uncensored

Discovery Channel – Daily Planet – *Shark Week – 'Weird Sharks' – Epaulette sharks are cute but tough!* J Rummer, 24 July 2017 https://twitter.com/dailyplanetshow/status/888470431346249728

ICI Radio-Canada – *The Great Barrier Reef in Australia: Interview with Dr. Aurélie Moya,* A. Moya, 27 July 2017 http://ici.radio-canada.ca/premiere/emissions/midi-info

NPR USA – *Coral Reef fish are more resilient than we thought, study finds,* P Munday, M Jarrod, 1 September 2017 https://www.npr.org/sections/thetwo-way/2017/08/31/547606153/coral-reef-fish-are-more-resilient-than-we-thought-study-finds

IFLScience – *300-year-old nautical maps reveal something disturbing off the coast of Florida,* J Pandolfi, L McClenachan, 7 September 2017 http://www.iflscience.com/environment/18thcentury-maps-reveal-floridas-long-lost-coral-reefs/

Readers Digest – *Battle for survival: is the Great Barrier Reef really dying?* T Hughes, 1 October 2017 https://www.readersdigest.com.au/true-stories-lifestyle/animal-kingdom/battle-survival-%E2%80%93-great-barrier-reef-really-dying

ABC TV Catalyst – *Can we save The Reef?* T Hughes, M van Oppen, 3 October 2017 http://www.abc.net.au/catalyst/stories/4743446.htm

CNET – *Mother Nature can save the Great Barrier Reef… if we help her,* V Schoepf, 22 October 2017 https://www.cnet.com/news/help-mother-nature-save-the-great-barrier-reef/

The Sydney Morning Herald – *Coral bleaching damages more WA reefs,* V Schoepf, 6 November 2017 http://www.smh.com.au/wa-news/coral-bleaching-damages-more-wa-reefs-20171106-gzfojf.html

Seven TV News – *GBR could face third bleaching event,* G Torda, 10 November 2017 https://twitter.com/7NewsTownsville/status/929850513922732032

Phys.org – *Study urges global-change researchers to embrace variability,* S Comeau, C Cornwall, 15 November 2017 https://phys.org/news/2017-11-urges-global-change-embrace-variability.html

Cosmos Magazine – *Can the Great Barrier Reef regenerate?* P Mumby, 2 December 2017 https://cosmosmagazine.com/geoscience/can-the-great-barrier-reef-regenerate

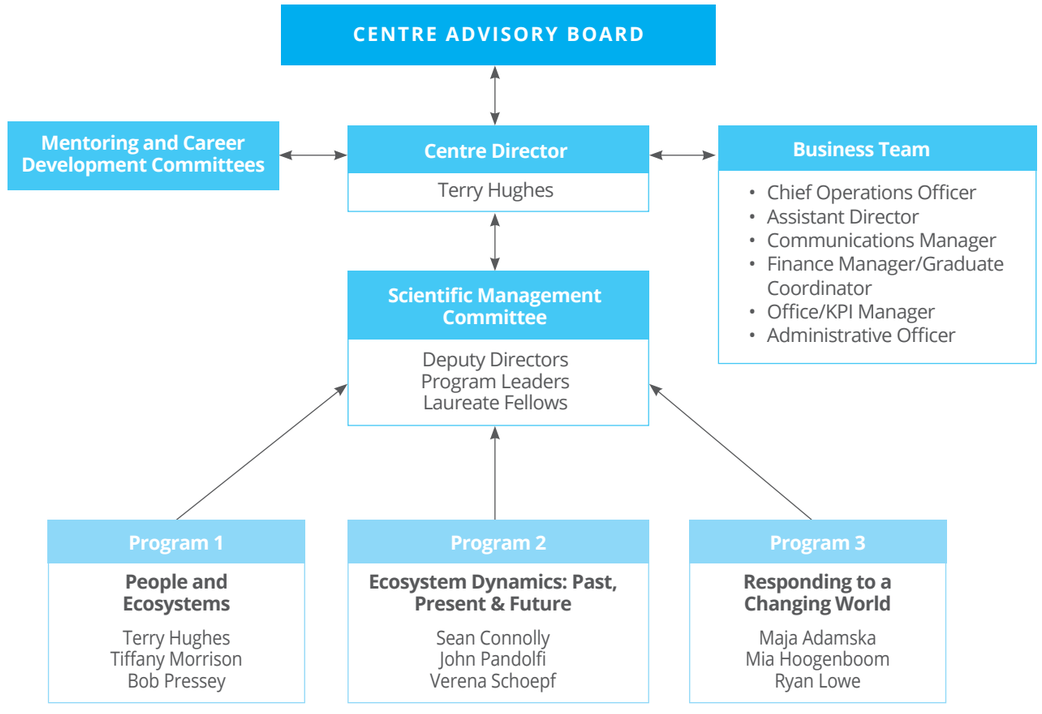
BBC 4 Radio – Inside Science – *The future of coral reefs,* M Pratchett, 14 December 2017 http://www.bbc.co.uk/programmes/b09hp2sj

GOVERNANCE

The ARC Centre has a clearly defined and effective governance structure that reflects its research themes and engages stakeholders in planning and management. James Cook University is the Administering Organisation with Centre Director, Terry Hughes, reporting directly to the Senior Deputy Vice-Chancellor, Chris Cocklin. Operations are managed by the Chief Operations Officer, Jenny Lappin, in consultation with the Centre Director and Assistant Director, Alana Grech.

The diagram below shows the governance structure of the Centre. The Centre Director oversees the Centre's research programs and liaises regularly with the two Deputy Directors, Ove Hoegh-Guldberg (UQ) and Malcolm McCulloch (UWA). Chief Investigators are located across three Divisions at James Cook University, and at The Australian National University, The University of Queensland and The University of Western Australia. Partner Investigators are based at the Australian Institute of Marine Science, the Great Barrier Reef Marine Park Authority and in leading overseas research institutions (p52). Adjunct researchers (p67) based in institutions across the globe 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 and provided with the support of Jennifer Lappin as Secretary. The Centre also supports two additional committees run by Centre graduate students and ECRs. The committees are tasked with promoting career development of these two integral components of the Centre's personnel and the organisation of annual retreats and training workshops, and contributing to career development and mentoring (p38). An informal group, comprising all of the Centre's female staff, also provides mentoring and general support to female ECRs and students.



CENTRE ADVISORY BOARD

The Centre Advisory Board provides high-level strategic advice for the Centre, and also facilitates and advises on improved linkages between the Centre, stakeholders, government and industry. The Centre Director and Chief Operations Officer provide the link between the Centre Advisory Board, the Scientific Management Committee (SMC) and Centre operations.

Distinguished international researcher Professor Brian Walker *FAA,* is Chair of the Board. Brian brings enormous experience and knowledge of interdisciplinary research as a former Chief of Australia's CSIRO Division of Wildlife and Ecology. Membership of the Centre's Board reflects the Centre's strong multi-disciplinary research activities and includes the Chief Executive Officer of AIMS, the Chair of the Great Barrier Reef Marine Park Authority, a senior representative from WorldFish and an independent senior University leader.

The Board met formally twice in 2017, on 14th June in Canberra and on 7th December in Brisbane. A key focus for the Board during 2017 was preparing the Centre for its formal mid-term review to be conducted by the ARC in June 2017 and providing advice on new research partners for the Centre's future. We sincerely thank the members of the Board for generously sharing their time, expertise and advice.

MEMBERSHIP OF THE CENTRE ADVISORY BOARD:

Dr Brian Walker FAA (Chair)
Fellow
CSIRO Ecosystem Sciences

Dr Neil Andrew
Regional Director
WorldFish
Malaysia

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

Margaret Johnson
General Manager, Policy and 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 Dr Paul Hardisty, 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 and planning for its scientific research program is the responsibility of the SMC. Distinguished international environmental social scientist and pioneer of interdisciplinary research, Professor Kate Brown from University of Exeter, UK, is the Chair. Other members are the leaders of each of the Centre's research programs, the Centre's Laureate Fellows and the Chief Scientist of the Great Barrier Reef Marine Park Authority. Membership of the SMC is continually evolving. In 2017, Malcolm McCulloch stepped down and was replaced by Ryan Lowe as a leader of Program 3. To further support strong succession planning and gender balance, Tiffany Morrison (p12), Verena Schoepf (p20) and Maja Adamska (p28) also became Program Leaders.

The SMC met formally three times in 2017, twice in Townsville and once in Canberra. A number of additional informal meetings were held leading up to the Centre's Mid-Term Review and later in the year to prepare a 2018 bid for Centre of Excellence funding from 2020. The back-to-back bleaching on the Great Barrier Reef (p34) was the SMC's major focus in 2017, and 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*. Other priorities for each meeting have included establishing and maintaining the objectives and operations for the Centre's research programs, and recruiting high-quality postdoctoral fellows and students.

Each Program Leader manages their research program through regular meetings with the research and student members of their program. Budgetary allocations for the research programs are agreed by the SMC. The SMC reallocates program-level funds in view of the Centre's changing research and activity priorities.

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

Associate Professor Tiffany Morrison
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

Dr Verena Schoepf
Leader, Research Program 2
University of Western Australia

Associate Professor Maja Adamska
ARC Future Fellow and Leader, Research Program 3
Australian National University

Associate Professor Mia Hoogenboom
Leader, Research Program 3
James Cook University

Professor Ryan Lowe
Leader, Research Program 3
University of Western Australia

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

Dr David Wachenfeld
Chief Scientist
Great Barrier Reef Marine Park Authority

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MEMBERSHIP

In 2017, the Centre's membership comprised: 68 Chief Investigators, Research Fellows and Associates; 28 Partner Investigators, resident international scholars and adjunct researchers; and 189 research students (p41). Thirteen of the Centre's Research Fellows were funded by ARC awards (Laureate, Future Fellow and DECRA), and one by an Advance Queensland Fellowship.

In 2017, the Centre welcomed 12 new Research Fellows and Associates: Maja Adamska, Michele Barnes, Michael Bode, Thomas DeCarlo, Alana Grech, April Hall, Björn Illing, Andrew Pomeroy, Cristian Rojas, Aleksey Sadekov, Fernanda Terra Stori and Julie Vercelloni. For the second consecutive year, the Centre achieved its 50:50 gender equity recruitment goal.

We also farewelled a number of our researchers who have taken up new positions elsewhere, extending the Centre's network of alumni collaborators (p49): Tracy Ainsworth, Bridie Allan, Jessica Blythe, Karen Chong-Seng, Steeve Comeau, James Falter, Manuel González-Rivero, Mélanie Hamel, Andreas Kubicek, Bill Leggat, Chiara Pisapia and Madeleine van Oppen. 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

Associate Professor Maja Adamska
ARC Future Fellow
Australian National 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
Chief Investigator
James Cook University

Dr Michele Barnes
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 Center, Malaysia

Dr Michael Bode
ARC Future Fellow
James Cook University

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

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

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
Discovery Early Career Researcher Award (DECRA)
James Cook University

Professor Graeme Cumming
Research Fellow
James Cook University

Dr Thomas DeCarlo
Research Fellow
University of Western Australia

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

Dr Jennifer Donelson
Research Fellow
James Cook University

Associate Professor Sophie Dove
Chief Investigator
University of Queensland

Dr François Dufois
Research Fellow
University of Western Australia

Dr James Falter
Research Fellow
University of Western Australia

Dr Sofia Fortunato
Research Fellow
James Cook University

Dr Manuel González-Rivero
Research Fellow
University of Queensland

Dr Alana Grech
Research Fellow
James Cook University

Dr Georgina Gurney
Research Fellow
James Cook University

Dr April Hall
Advance Queensland 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

Associate Professor 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

Associate Professor Bill Leggat
Research Fellow
James Cook University

Professor Ryan Lowe
Chief Investigator
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

Associate Professor 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

Dr Andrew Pomeroy
Research Fellow
University of Western Australia

Professor Morgan Pratchett
Chief Investigator
James Cook University

Professor Bob Pressey
Research Fellow
James Cook University

Dr George Roff
Research Fellow
University of Queensland

Dr Cristian Rojas
Research Fellow
James Cook University

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

Professor Garry Russ
Chief Investigator
James Cook University

Dr Aleksey Sadekov
Research Fellow
University of Western Australia

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 Center, Malaysia

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

Dr Heather Veilleux
Research Fellow
James Cook University

Dr Julie Vercelloni
Research Associate
University of Queensland

Dr Sue-Ann Watson
Research Fellow
James Cook University

Dr Rebecca Weeks
Research Fellow
James Cook University

RESIDENT INTERNATIONAL SCHOLARS

Dr Michele Barnes
National Science Foundation Research Fellow (to August 2017)

Dr Pip Cohen
Research Fellow
WorldFish, Malaysia

Dr Mélanie Hamel
Centre National de la Recherche Scientifique, France

Dr Björn Illing
Deutscher Akademischer Austauschdienst (DAAD), German Academic Exchange Service scholar, Germany

Dr Laurence McCook
South China Sea Institute of Oceanology, China

Dr David Mills
Research Fellow
WorldFish, Malaysia

Dr Fernanda Terra Stori
Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) scholar, Brazil

PARTNER INVESTIGATORS AND ADJUNCT RESEARCHERS

Dr Vanessa Adams
Macquarie University

Dr Neil Andrew
WorldFish, Malaysia

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

Professor Eldon Ball
Australian National University

Dr Line Bay
Australian Institute of Marine Science

Dr Mary Bonin
Great Barrier Reef Marine Park Authority

Dr Ciemon Caballes
Ultra Coral Australia

Dr Guillermo Diaz-Pulido
Griffith University

Dr Louisa Evans
Exeter University, United Kingdom

Professor Nick Graham
Lancaster University
United Kingdom

Dr Alison Green
The Nature Conservancy

Dr Richard Hamilton
The Nature Conservancy

Dr Christina Hicks
Lancaster University
United Kingdom

Professor Jeremy Jackson
International Union for Conservation of Nature, USA

Professor Janice Lough
Australian Institute of Marine Science

Dr Aaron MacNeil
Australian Institute of Marine Science

Dr Tim McClanahan
Wildlife Conservation Society, Kenya

Professor Madeleine van Oppen
Australian Institute of Marine Science

Professor David Mouillot
Université Montpellier 2 Sciences et Techniques, France

Professor Stephen Palumbi
Stanford University, USA

Dr Serge Planes
University of Perpignan, France

Dr David Wachenfeld
Great Barrier Reef Marine Park Authority

Dr Peter Waldie
The Nature Conservancy

GRADUATE STUDENTS

(see page 41)

RESEARCH SUPPORT STAFF

Dr Rene Abesamis
James Cook University

Dr Nitin Bhatia
James Cook University

Carlin Bowyer
University of Western Australia

Dr Dani Ceccarelli
James Cook University

Eric Fakan
James Cook University

Dr Maria Gomez-Cabrera
University of Queensland

Dr David Hayward
Australian National University

Cindy Huchery
James Cook University

Mizue Jacobson
James Cook University

Dr James Kerry
James Cook University

Anton Kuret
University of Western Australia

Joanne Moneghetti
James Cook University

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University of Western Australia

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Dr Maya Srinivasan
James Cook University

Dr Annamieke Van Den Heuvel
University of Queensland

Cassy Thompson
James Cook University

Dr David Williamson
James Cook University

BUSINESS TEAM

Jennifer Lappin
Chief Operations Officer
James Cook University

Dr Alana Grech
Assistant Director
James Cook University

Olga Bazaka
Finance Manager and Graduate Coordinator
James Cook University

Vivian Doherty
Events Co-ordinator and KPI Officer
James Cook University

Rosanna Griffith-Mumby
Administrative Officer
University of Queensland

Catherine Naum
Communications Manager
James Cook University

Janet Swanson
Administrative Officer
James Cook University

Karen van Staden
Administrative Officer
University of Western Australia

Hayley Ware
Project Officer
University of Queensland

PUBLICATIONS

In 2017, researchers from the ARC Centre of Excellence produced 373 publications, including 356 journal articles, 8 book chapters, and 9 reports, an overall increase of 15% from 2016. Since 2014 journal articles publications have increased 25%.

Centre researchers published 160 articles in journals with Impact Factors greater than four, including 31 in prestige journals – *Nature* and other *Nature* journals, *Science*, the *Trends* journals, *Annual Review of Marine Science*, *PLoS Biology*, *Ecology Letters* and *Proceedings of the National Academy of Sciences*. The average Impact Factor for all 358 journal articles in 2017 was 5.1. The Centre's research outputs were published in a total of 123 journal titles, spanning many fields of research and reflecting the multidisciplinary breadth of the Centre's activities.

According to Scopus, Centre researchers were cited 39,813 times in 2017, 24 researchers were cited more than 500 times and 13 had more than 1000 citations in the last 12 months.

The six articles that received the highest Altmetric scores for ARC Centre publications in 2017 were:

Hughes T, Kerry J, Álvarez-Noriega M, Alvarez-Romero J, Anderson K, Baird A, Babcock R, Beger M, Bellwood D, Berkelmans R, Bridge T, Butler I, Byrne M, Cantin N, Comeau S, Connolly S, Cumming G, Dalton S, Diaz-Pulido G, Eakin C, Figueira W, Gilmour J, Harrison H, Heron S, Hoey A, Hobbs J, Hoogenboom M, Kennedy E, Kuo C, Lough J, Lowe R, Liu G, McCulloch M, Malcolm H, McWilliam M, Pandolfi J, Pears R, Pratchett M, Schoepf V, Simpson T, Skirving W, Sommer B, Torda G, Wachenfeld D, Willis B and Wilson S (2017) Global warming and recurrent mass bleaching of corals. *Nature* 543(7645): 373-377.
Altmetric 3174 (picked up by 403 news outlets, tweeted by 1813, ranked #21 of 2.2 million articles published in 2017 across all disciplines)

Gill, DA, Mascia, MB, Ahmadia, GN, Glew, L, Lester, SE, Barnes, M, Craigie, I, Darling, ES, Free, CM, Geldmann, J, Holst, S Jensen, OP, White, AT, Basurto, X, Coad, L, Gates, RD, Guannel, G, Mumby, PJ, Thomas, H, Whitmee, S, Woodley, S, and Fox, HE (2017). Capacity shortfalls hinder performance of marine protected areas globally. *Nature* 543(7647): 665–669.
Altmetric 678 (tweeted by 1023)

Hughes T, Barnes M, Bellwood D, Cinner J, Cumming G, Jackson J, Kleypas J, van de Leemput I, Lough J, Morrison T, Palumbi S, van Nes E and Scheffer M (2017). Coral reefs in the Anthropocene. *Nature* 546(7656): 82–90.
Altmetric 568 (picked up by 37 news outlets, tweeted by 649)

McClenachan, L, O'Connor, G, Neal, BP, Pandolfi, JM, and Jackson, JBC (2017). Ghost reefs: Nautical charts document large spatial scale of coral reef loss over 240 years. *Science Advances* 3(9): e1603155.
Altmetric 450 (picked up by 33 news outlets, tweeted by 224)

Jarrold, MD, Humphrey, C, McCormick, MI, and Munday, P (2017). Diel CO_2 cycles reduce severity of behavioural abnormalities in coral reef fish under ocean acidification. *Scientific Reports* 7: 10153.
Altmetric 397 (mentioned by 45 news outlets, tweeted by 37)

Torda G, Donelson J, Aranda M, Barshis D, Bay L, Berumen M, Bourne D, Cantin N, Forêt S, Matz M, Miller D, Moya A, Putnam H, Ravasi T, van Oppen M, Vega Thurber R, Vidal-Dupiol J, Voolstra C, Watson S, Whitelaw E, Willis B and Munday P (2017). Rapid adaptive responses to climate change in corals. *Nature Climate Change* 7(9): 627-636.
Altmetric 268 (picked up by 18 news outlets, tweeted by 279)

PHOTO KATIE SIEVERS

BOOK CHAPTER (8)

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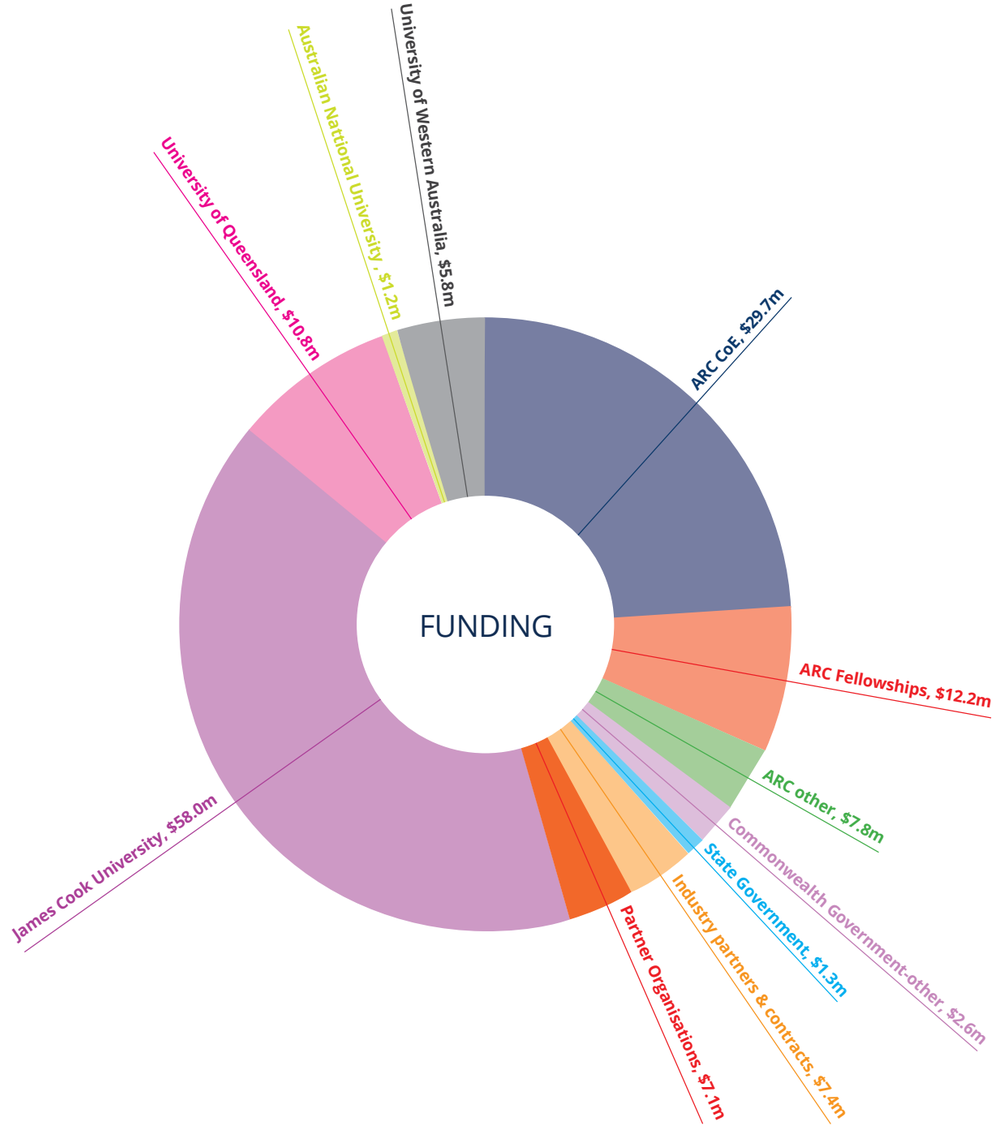
FINANCIAL STATEMENT

ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES
STATEMENT OF OPERATING INCOME AND EXPENDITURE FOR YEAR ENDED 31 DECEMBER 2017

	2016	2017	2018 FORECAST
INCOME	**$**	**$**	**$**
ARC Centre Grant	$4,265,997	$4,329,987	$4,394,936
ARC Fellowships	1,187,662	1,315,029	647,021
ARC Other		130,290	93,773
Host Institutions cash support	3,664,501	3,777,803	3,778,493
State Government	65,500	150,800	200,000
Commonwealth Government other grants	493,731	618,053	650,760
International and other contracts	1,367,409	1,268,373	1,371,603
TOTAL INCOME	**$11,044,801**	**$11,590,335**	**$11,136,586**
EXPENDITURE			
Salaries	$7,281,253	$7,503,235	$7,700,000
Equipment	443,055	468,195	500,000
Travel	1,541,483	1,317,242	1,350,000
Research maintenance and consumables	1,394,134	1,224,455	1,200,000
Scholarships and prizes	223,260	178,581	235,000
Public outreach and administration	136,719	133,515	90,000
TOTAL EXPENDITURE	**$11,019,904**	**$10,825,222**	**$11,075,000**
SURPLUS (DEFICIT)	**$24,897**	**$765,113**	**$61,586**

FINANCIAL OUTLOOK

As at December 2017, the total cash and in-kind financial outlook for the ARC Centre of Excellence for Coral Reef Studies for 1 January 2014 to 31 December 2020 totals $143.9m, 18% higher than when the Centre was established in 2014. The ARC Centre of Excellence grant represents 21% of the total funding pool.



2018 ACTIVITY PLAN

1. RESEARCH

a. Submit an Expression of Interest for a new ARC Centre of Excellence, led by Professor Graeme Cumming.

b. Consolidate the Centre's research activity in interdisciplinary research through supporting increased collaborations with researchers with expertise in economics and social networks.

c. Extend the Centre's interdisciplinary research capacity by recruiting four research fellows: two in *Social-Ecological Systems* and two in the Centre's research themes of *People and Ecosystems* and *Responding to a Changing World*.

d. Develop and implement a data management plan to support Centre members' adherence to the *Australian Code for Responsible Conduct of Research*.

e. Develop a portal on the Centre's website providing access to the Centre's datasets.

2. RESEARCH TRAINING AND PROFESSIONAL DEVELOPMENT

a. Review the Centre's professional development program for students and Early Career Researchers.

b. Deliver programs for the National Student Mentoring Day, Student and Early Career Researcher Retreats, and attendance at the Centre's annual symposium (Student and Postdoc Committees).

c. Deliver professional development workshops on statistics, coral identification, engaging with the media, communicating research to industry and the general public, publishing strategies and skills, and grant, award and fellowship writing.

d. Initiate a multiple stranded leadership development program for women in STEM for PhD students through to Research Fellows.

e. Extend further multi-institutional and/or multi-disciplinary supervisory arrangements.

3. NATIONAL AND INTERNATIONAL LINKAGES

a. Strengthen the Centre's research with WorldFish through the newly funded CGIAR Research Program on the Small-scale Fisheries Flagship project (FISH CRP), including the recruitment of two research fellows.

b. Continue to increase Research Fellow exchanges, working group meetings and co-tutelle PhD student arrangements with KAUST, Saudi Arabia, and University of Exeter, UK.

c. Recruit a research fellow to a jointly funded position with AIMS to study reef responses to climate change.

d. Host and fund six international research working group meetings.

e. Improve videoconferencing infrastructure for seminars and workshops.

4. IMPACTS AND END USER ENGAGEMENT

a. Contribute research findings to the 2019 *Outlook Report* of the Great Barrier Marine Park Authority.

b. Lead the *Coral Reef Health in the Coral Sea Marine Park* assessment project for the Australian Government Director of National Parks.

c. Continue to engage with government and stakeholders to implement the *Reef 2050 Plan*.

d. Plan and deliver the Centre's Annual Symposium and Public Forum on the *Future of Coral Reefs* in Brisbane on 19th and 20th July.

e. Expand the Centre's social media outreach through developing videos with Centre research content and establishing a creative commons image library.

5. GOVERNANCE

a. Review membership of the Centre's Advisory Board to assist strategic planning for a future ARC Centre of Excellence.

b. Continue developing a Centre culture that values gender equity and family friendly practices.

c. Review funding to the Centre's Research Programs in view of expanded leadership.

d. Modify the Centre's KPI data collection and reporting system in view of changed reporting requirements.

KEY PERFORMANCE INDICATORS

RESEARCH FINDINGS

MEASURE	TARGET 2017	OUTCOME 2017
No. of research outputs (p68)	315	**376**
Publications in journals with an Impact Factor > 4	85	**160**
Mean Impact Factor for journals published	4.0	**5.1**
Faculty of 1000 commentaries	8	**8**
No. of citations (p68)	21,000	**39,813**
No. of Centre researchers with >500 citations	18	**24**
No. of invited talks/papers/keynotes at international meetings	25	**43**
No. and nature of commentaries about the Centre's achievements (p58)		
• Articles	2,600	**9,399**
• Media releases	26	**26**
Awards, prizes or recognition (p8)	26	**42**

RESEARCH TRAINING AND PROFESSIONAL EDUCATION (p38)

MEASURE	TARGET 2017	OUTCOME 2017
No. of professional training courses for staff and postgraduate students attended	25	**62**
No. of Centre attendees at all professional training/ development courses offered by the Centre	95	**1,640**
No. of students mentored	180	**189**
No. of student attendances at the Centre's professional development events	75	**1,499**
No. of early career researchers participating in annual performance reviews, attending seminars, visiting other Centre nodes, attending ECR committee events	25	**34**
Stakeholder participation in Centre Working Group meetings, workshops and planning meetings	10	**254**
No. of new postgraduates enrolled	150 over life of Centre	**2017: 41 (171 to date)**
No. of postgraduate completions and completions times:		
• No. of completions	175 over life of Centre	**2017: 42 (176 to date)**
• No. submitting within 4 years of commencement	18	**16**
No. of new Honours students	80 over life of Centre	**2017: 7 (36 to date)**
No. of new postdoctoral researchers	40 over life of Centre	**2017: 12 (41 to date)**
No. of Early Career Researchers	16	**34**

INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

MEASURE	TARGET 2017	OUTCOME 2017
No. of international visitors (p55)	65	**76**
No. of national and international Working Groups held/ organised by the Centre	10	**23**
No. of visits to overseas laboratories and research facilities	105	**123**
Metrics of interdisciplinary research supported by the Centre:		
• No. of journal titles in which Centre outputs are published	95	**123**
• No. of four digit Field of Research disciplines in which the Centre research publications are classified	18	**51**
• No. of students with multidisciplinary supervisory arrangements	45	**52**

END-USER LINKS

MEASURE	TARGET 2017	OUTCOME 2017
No. of government, industry and business briefings (p58)	80	**121**
No. of public awareness programs	36	**89**
No. of talks open to the public	50	**58**
Website hits	6.5m	**14.1m**

ORGANISATIONAL SUPPORT

MEASURE	TARGET 2017	OUTCOME 2017
Annual cash contributions from Administering and Collaborating Organisations:		
• JCU	$1.00m	**$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	$5.80m	**$6.40m**
• ANU	$0.098m	**$0.12m**
• UQ	$1.19m	**$1.52m**
• UWA	$0.63m	**$0.63m**
Annual cash contributions from Partner Organisations:		
• AIMS	$122k	**$113k**
• CNRS	$7k	**$5K**
• GBRMPA	$0k	**$177k**
• Stanford	$4k	**$4k**
• WorldFish	$56k	**$194K**
Annual inkind contributions from Partner Organisations:		
• AIMS	$386k	**$386k**
• GBRMPA	$25k	**$25k**
• CNRS	$54k	**$54k**
• Stanford	$167k	**$167k**
• WorldFish	$100k	**$100k**
Other research income secured by Centre staff:		
• ARC Grants	$3.10m	**$3.11m**
• Other Australian competitive	$0.48m	**$0.40m**
• Public sector	$0.42m	**$0.22m**
• Industry and other research income	$0.40m	**$1.83m**
No. of new organisations collaborating with, or involved in the Centre	100 over life of Centre	**2017: 95 (174 to date)**
Level and quality of infrastructure provided to the Centre	$1.49m	**$1.76m**

GOVERNANCE

MEASURE	TARGET 2017	OUTCOME 2017
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 togethe to form an interactive and effective research team:		
• Participation in research program planning meetings	20	**20**
• Attendance at annual symposium	85	**152**
• No. of multi-institutional supervisory arrangements	46	**51**
• No. of cross-nodal publications	36	**40**

Capacity building of the Centre through scale and outcomes:		
• No. of countries where the Centre:		
• Undertakes fieldwork	23	**28**
• Advises governments and NGOs	11	**16**
• No. of international co-authors	36	**828**
• No. of overseas graduate student completions	100 over life of Centre	**2017: 32 (141 to date)**

NATIONAL BENEFIT

MEASURE	TARGET 2017	OUTCOME 2017
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	**20%**
• Interactions with industry, business and government	80 briefings	**123**
• Cross-institutional publications	150	**315**
Contribution to national research priorities	1 case study highlighted in the annual report	**See page 34**
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 2017	OUTCOME 2017
Prestige publications	100 publications over life of Centre	**2017: 31 (96 to date)**
Publications with cross-institutional co-authorships	180	**315**
New Centre graduate students attracted to Australia from overseas	100 over life of Centre	**2017: 33 (142 to date)**
Centre graduate students with cross-nodal supervision	120 over life of Centre	**2017: 6 (67 to date)**
Gender equity in research fellow appointments	50:50	**50:50 6 females: 6 males**

ACKNOWLEDGEMENTS

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

- Australian Academy of Science
- Australian Centre for Field Robotics, University of Sydney
- Australian Centre for International Agricultural Research (ACIAR)
- 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 National Centre for Ocean Resources and Security (ANCORS)
- Australian Society for Fish Biology
- Bigelow Laboratory for Ocean Sciences, USA
- 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
- Charles Darwin University, Australia
- Company of Biologists, UK
- Comunidad y Biodiversidad, Mexico
- Conservation International
- Deutsche Forschungsgemeinschaft, Germany
- Deutsche Forschungsgemeinschaft Excellence Cluster 'Future Ocean', University of Kiel, Germany
- Fisheries Research and Development Corporation, Canberra
- Georgia Institute of Technology, USA
- Great Barrier Reef Foundation, Australia
- Great Barrier Reef Marine Park Authority, Australia
- Harvey Mudd College, USA
- Holsworth Wildlife Research Endowment, Equity Trustees Charitable Foundation
- Ian Potter 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
- Mahonia Na Dari and Walindi Plantation Resort, Papua New Guinea
- Marine Parks Authority, Lord Howe Island Marine Park, Australia
- Morris Family Foundation, 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
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- Palau International Coral Reef Center
- Palawan State University, Philippines
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- Pew Charitable Trusts, USA
- Queensland Department of Environment and Heritage Protection
- Queensland Department of Natural Resources, Mines and Energy
- Queensland Department of Science, Information, Technology and Innovation
- Queensland Museum
- RARE Conservation, Philippines
- Reef Rescue, Australia
- Sea World Research and Rescue Foundation, Australia
- Secretariat for the Pacific Community, Noumea
- Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Japan
- Smithsonian Marine Network, USA
- Society for Experimental Biology
- Stockholm Resilience Centre, Sweden
- The Nature Conservancy, International
- Torres Strait Regional Authority
- University of California, Los Angeles (UCLA), USA
- 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 Indian Ocean Marine Science Association (WIOMSA), Zanzibar
- Wildlife Conservation Society, USA
- WorldFish, Malaysia
- World Wildlife Fund
- Yale Peabody Museum, USA

“The Great Barrier Reef has an economic, social and icon asset value of $56 billion. It supports 64,000 jobs and contributes $6.4 billion to the Australian economy.”

Executive Summary, Deloitte Access Economics, At what price? The economic, social and iconic value of the Great Barrier Reef

https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-great-barrier-reef-230617.pdf

PHOTO DAVID WILLIAMSON

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