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ANNUAL  
REPORT  
2019

# ANNUAL REPORT 2019

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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.

COVER PHOTO DAVID WILLIAMSON  
THIS PHOTO VICTOR HUERTAS

## VISION

Providing scientific knowledge that fosters sustainable use, adaptive governance and effective management of the world's coral reefs to enhance human well-being.

## MISSION

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

## AIMS

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

### RESEARCH

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

### RESEARCH TRAINING AND PROFESSIONAL EDUCATION

Build human capacity and expertise in coral reef science worldwide.

### NATIONAL AND INTERNATIONAL LINKAGES

Create a global hub for integrated coral reef research collaborations.

### IMPACTS AND END-USER ENGAGEMENT

Exchange and transfer knowledge, technologies and research outcomes with end-users and partners.

### GOVERNANCE

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

## OVERVIEW

The ARC Centre of Excellence for Coral Reef Studies commenced operations in 2014 following an award of \$28 million from the Australian Research Council to fund the Centre for seven years. Headquartered at James Cook University (JCU), the 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 2019, the Centre had collaborative links and co-authorships with 445 institutions in 69 countries.

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



PHOTO CHRISTOPHER BRUNNER



## DIRECTOR'S REPORT

Welcome to the 2019 annual report of the Australian Research Council (ARC) Centre of Excellence for Coral Reef Studies.

In 2019, the Centre's membership comprised 69 Chief Investigators, Research Fellows and Associates; 30 Partner Investigators, resident international scholars and adjunct researchers; and 170 research students (p69). Nine of the Centre's researchers this year were ARC Fellows (Australian Laureate, Future and DECRA) and one was an Advance Queensland Fellow. We welcomed ten new Research Fellows and Associates in 2019, and 26 new graduate students from 14 countries.

At the time of writing, in early March 2020, we are responding to a new severe incident of coral bleaching on the Great Barrier Reef, for the third time in the past 5 years. The ARC Centre will once more be undertaking rigorous aerial and underwater surveys to monitor the impact and address a range of research questions. Two of our 2019 journal articles on coral bleaching, published in *Nature* and *Nature Climate Change*, were listed in the *Altmetric Top 100* as articles that 'most captured the public's imagination' during the year (p73).

In 2019, Centre researchers provided 108 briefings across both the public and private sectors (p62). Our research findings continued to guide the agencies and governments responsible for reef management, and the industries that depend on coral reefs. For example, in an article published in *Nature* (p38), researchers from the ARC Centre recommended a new, holistic approach to safeguarding coral reefs – by focussing on the formal and informal governance of land as well as the ocean. Also in 2019, Centre researchers implemented the Climate Vulnerability Index (CVI) to rapidly assess climate change risk to World Heritage sites in Australia, Azerbaijan, France, the United Kingdom, and elsewhere.

The Centre's three research Program summaries on pp10-37 provide an overview of our activities

throughout 2019. In addition to our partnership with the Australian Institute of Marine Science and the Great Barrier Reef Marine Park Authority, the ARC Centre has formal international partnership agreements with the Center for Ocean Solutions at Stanford University, France's Centre National de la Recherche Scientifique (CNRS), and WorldFish in Malaysia. Our co-authors in 2019 came from 445 institutions in 69 countries, reflecting the Centre's continuously expanding international network of collaborators (p56).

In 2019, the Centre's research outputs were published in a total of 187 journal titles that span many fields of research, reflecting the multidisciplinary breadth of our activities. We produced 411 publications this year, including 363 peer-reviewed journal articles. Since 2014, our publications have increased by >30%, now exceeding one each day. Thirty-nine articles appeared this year in prestige journals such as *Nature*, *Science* and *PNAS*. ARC Centre researchers published 313 journal articles with cross-institutional co-authorship (p73).

I'd like to express my sincere gratitude to our many friends around the world for their contributions to an outstanding year, and to the Centre's Advisory Board, our research partners and end-users from many institutions in Australia and overseas. I am especially grateful to Brian Walker and Mandy Thomas for their long-standing, wise council on our Advisory Board (p66).

Finally, in 2020 we all face the uncertainty caused by the COVID-19 pandemic. ARC Centre researchers are already working from home, and we are responding quickly to manage the disruptions, care for each other, and remain as productive as possible over coming months.

Thank you very much for your support.

**Terry Hughes**  
Director

## RESEARCH IMPACT AND ENGAGEMENT

### ASSESSING CLIMATE IMPACTS

Jon Day and Scott Heron led a workshop to apply their Climate Vulnerability Index (CVI) to the 'Heart of Neolithic Orkney' UNESCO World Heritage Area. The CVI is a new methodology, developed by the ARC Centre, for rapidly assessing World Heritage properties (natural, cultural or mixed).

### INFORMING GENDER INTEGRATION

Danika Kleiber (p16) and Pip Cohen (WorldFish), co-led a three-day gender training workshop for researchers from the Solomon Islands, Vanuatu, Kiribati and Timor L'Este. The workshop increased the knowledge and skills of in-country fisheries officers on gender integration, with the goal of changing how fisheries officers collect data, and interact with communities.

### OUTREACH ON CLIMATE CHANGE AND CORAL BLEACHING

Terry Hughes delivered 19 talks and briefings on the Centre's coral reef research at the Scripps Institution of Oceanography, UCLA, UCSB, UCSC, Stanford University, U. Oregon, U. Washington, Friday Harbor Laboratories, Columbia University, U. Boston, U. Maine, U. Miami, Florida State University, Nova University and the National Science Foundation.

### DESIGNING MARINE RESERVE NETWORKS

Jorge Alvarez-Romero, in collaboration with the Mexican civil society organisation COBI, developed technical briefings about the proposed marine reserves for the Midriff Islands Region. His advice was provided to people and organisations working in the region (e.g. fishers, government agencies, conservation NGOs) to support their decision-making.

### BUILDING CAPACITY IN GENDER EDUCATION

Danika Kleiber's 2018 *Coral Reef Futures Symposium* talk was used by Danya Glabau, Anthropologist of Medicine and Technology, in her *Science and Feminism Syllabus* at New York University Tandon School of Engineering.

### COMMONWEALTH'S OUTLOOK REPORT

Terry Hughes was appointed to review the Great Barrier Reef Marine Park Authority's 2019 *Outlook Report*. Published every five years, the *Outlook Report* is a comprehensive assessment of the Great Barrier Reef's health, pressures, and likely future and is central to the development of government policy.

### LEADING REEF PLANNING AND MANAGEMENT

Ove Hoegh-Guldberg and Terry Hughes are members of the *Reef 2050 Plan Independent Expert Panel*, which provides scientific and expert advice related to the Great Barrier Reef, including support for the implementation and review of the *Reef 2050 Plan*, and the *Reef 2050 Water Quality Improvement Plan*. The Panel also advises the Australian Government Minister for the Environment and Energy on funding priorities for the *Reef Trust*.

### INFORMING THE REEF 2050 PLAN

Robert Mason, Yves-Marie Bozec (p24), Karlo Hock and Peter Mumby, analysed benefits of local management interventions under climate trajectories for the Queensland Government's Office of the Great Barrier Reef. The analysis was motivated by the need to better understand the impacts of reef interventions to inform the revision of the *Reef 2050 Plan*.

### NETWORKING GBR RESEARCH AND MANAGEMENT

David Wachenfeld (GBRMPA) and Alana Grech led 40 managers, researchers and PhD students in a speed networking event with the goal of facilitating introductions, conversations and partnerships between GBRMPA and the ARC Centre.

### PROTECTING THE ENVIRONMENT

Alana Grech, Jon Brodie and Terry Hughes provided a report to the Innovation, Tourism Development and Environment Committee of the Queensland Parliament – on the *Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Bill 2019*. Alana and Jon were invited witnesses at the Committee meeting in Townsville on 10<sup>th</sup> April 2019, to advise the parliamentary inquiry into the Bill.

### IMPROVING WATER QUALITY

Jon Brodie prepared material included in the Australian Coral Reef Society submission to the Senate Rural and Regional Affairs and Transport References Committee – regarding the identification of leading farm practices for improving water quality outcomes on the Great Barrier Reef.

### MONITORING AND MARINE RESERVE PERFORMANCE

Garry Russ and PhD students Eva McClure and Katie Sievers advised GBRMPA on no-take marine reserve performance under varying environmental and anthropogenic influences. David Williamson, Garry Russ, Geoff Jones and Hugo Harrison also gave a presentation to GBRMPA on progress on long-term monitoring of GBR inshore reefs.

### CONTROLLING CROWN-OF-THORNS STARFISH

Peter Mumby, George Roff, Karlo Hock and Yves-Marie Bozec (p24) created a dataset which GBRMPA is using for management and planning, including crown-of-thorns starfish control.

### MANAGING FISHERIES

PhD student Kyle Hillcoat and Garry Russ collaborated with colleagues from the Queensland Department of Agriculture and Fisheries (Northern Fisheries Centre) to improve assessments of harvested coral reef fish.

### REACHING OUT TO THE PUBLIC

Sue-Ann Watson's research on biodiversity and global climate change was showcased in the Natural Curiosity exhibition at the Museum of Tropical Queensland from April to November 2019.

### PLANNING MARINE PROTECTED AREAS

Peter Mumby briefed chief technical advisors to the Global Environment Facility project in South-East Asia, on new tools for planning marine protected areas.

### DEVELOPING FISHING POLICY

Michele Barnes provided scientific advice to scientists, fisheries managers, government officials, and community stakeholder groups at Kenya's *Annual Fishers Forum* on community-based management and policy development in small-scale fisheries.

### BUILDING CAPACITY

Ryan Lowe leads ongoing strong research partnerships with Indian Ocean island nations (especially Mauritius), supported by the Mauritius government and Australia's Department of Foreign Affairs and Trade. In 2019, these partnerships delivered international professional short courses on the management of coral reef coastlines, attended by government officials, coastal engineers, academics and NGOs.

### SUPPORTING INDIGENOUS WELLBEING

Jorge Álvarez-Romero, in collaboration with CSIRO and 50 Traditional Owners from 12 Indigenous groups, developed and tested interactive mapping tools to help inform and guide spatial planning in the Fitzroy River catchment. The tools, supported by spatial data created by the Centre, are contributing to assessing impacts of future developments on the wellbeing of Indigenous peoples.

### PLANNING NATIONAL PARK ZONING

Michele Barnes is a contributing member of the scientific reference group for the Great Sandy Marine Park. The group provides scientific advice to assist Queensland Parks and Wildlife and the Queensland Department of Environment and Science in reviewing the Great Sandy Marine Park Zoning Plan.

### INFLUENCING POLICY DEVELOPMENT

Sue-Ann Watson provided briefings on ocean acidification to policy makers in the Australian Government. Terry Hughes briefed parliament on the scientific evidence for climate change and its impacts so far on the Great Barrier Reef.

### REDUCING MARINE TURTLE AND CETACEAN BYCATCH

Alana Grech advised the Australian Government and authored a White Paper on current gaps in reporting of turtle and cetacean bycatch, including recommendations to Commonwealth and State governments for the improved reporting of bycatch.

### ERADICATING RATS

Andrew Hoey advised local (American Samoan) and National (US) agencies on the importance of pest eradication and native vegetation restoration for islands and the surrounding reef environment.

## RECOGNITION OF EXCELLENCE OF CENTRE RESEARCHERS

Highlights of 43 awards received by ARC Centre of Excellence researchers in 2019

Six ARC Centre researchers, **Ove Hoegh-Guldberg, Terry Hughes, Geoffrey Jones, Philip Munday, John Pandolfi** and **Morgan Pratchett**, were identified as 2019 *Highly Cited Researchers* by Clarivate Analytics, each ranking in the top 1% of researchers worldwide for their citations. Their research has demonstrated a significant impact through publication of multiple highly-cited papers during the past decade.

**Terry Hughes** was conferred an honorary Doctor in Science (*honoris causa*) from Trinity College, The University of Dublin, Ireland. Hughes also led the *National Coral Bleaching Taskforce* which was shortlisted for the Australian Museum's *Environment, Energy and Science Eureka prize*. The Taskforce's *Nature* paper 'Global warming impairs stock-recruitment dynamics of corals' was listed on *Carbon Brief's Top 10 climate papers most featured in the media in 2019*. This paper and their *Nature Climate Change* paper, 'Ecological memory modifies the cumulative impact of recurrent climate extremes', were listed in the *2019 Altmetric Top 100* as articles that 'most captured the public's imagination' in 2019, securing 14th and 22nd positions.

**David Bellwood** was awarded an ARC *Australian Laureate Fellowship* (p9). David was also named as James Cook University's *Primary Advisor of the Year*, for excellence in supervision of research degree candidates.

**Jodie Rummer** was named as the *2019 Queensland Young Tall Poppy Scientist of the Year*. **Andrew Hoey** also received a *Young Tall Poppy Award*. These prestigious awards recognise up-and-coming scientists who combine world-class research with a passionate commitment to science communication.

**Joshua Cinner** and **Ove Hoegh-Guldberg** (p34) were listed on The Australian newspaper's *Top 40 Stars of Research* Lifetime Achievement Leaderboard in the categories of 'Biodiversity and Conservation Biology' and 'Marine Sciences and Fisheries', respectively.

**Ove Hoegh-Guldberg** was named on Apolitical's list of *The world's 100 most influential people in climate policy*. Ove was also appointed as judge for the 2019 Queensland Premiers Award for Excellence to Protect the Great Barrier Reef.

**Sue-Ann Watson** won the inaugural Australian Marine Sciences Association *North Queensland Communication Award* for contribution to science communication, and was the runner-up in the International Society for Experimental Biology 2020 *President's Medal for Animal Biology*. She also won a *Women in Leadership Australia Scholarship* for the mid-career leadership Executive Ready Programme 2019–2020.

**Rene Abesamis** was a recipient of a 2019 *Australian Alumni Excellence Award* for his contributions to Philippine and global marine science. Australian Embassy awards celebrate the exceptional achievements of Australian-educated Filipinos.

**Graeme Cumming** was appointed joint head of the Faculty of the F1000 Ecosystem Ecology section. He was also appointed to the Scientific Advisory Panel of the Geneva Global Institute, and accepted an invitation to be a member of the scientific committee of Programme on Ecosystem Change and Society (PECS). PECS is part of Future Earth, a global sustainability research platform.

**Alana Grech** was awarded the 2019 James Cook University's *Award for Excellence in Graduate Research Leadership*.

**Danika Klieber** (p16) received a merit award from the Asian Fisheries Society, for organising the Gender Aquaculture and Fisheries Society meeting in 2019.

**David Miller** was awarded a *Bridge Fellowship* by the Japan Society for the Promotion of Science, to undertake research with colleagues at the Okinawa Institute of Science and Technology, Japan.

**Centre students** also received wide recognition in 2019 (p44).

## 2019 AUSTRALIAN RESEARCH COUNCIL FELLOWSHIPS

The Centre's commitment to world-best science is constantly reflected in the calibre of its researchers. In 2019, three of the Centre's most outstanding researchers were awarded prestigious ARC Fellowships: **Professor David Bellwood** was awarded an Australian Laureate Fellowship, **Dr Jennifer Donelson** a Future Fellowship, and **Dr Michele Barnes** received a Discovery Early Career Researcher Award (DECRA).

ARC Fellowships are highly competitive. We congratulate our newly minted Fellows, noting the range of career stages and research focuses they represent.



**Professor David Bellwood** *FAA ARC Australian Laureate Fellow*

Only the highest-quality researchers of international repute are considered for *Australian Laureate Fellowships*, with up to 17 five-year Fellowships awarded each year. The Fellows are chosen for their leadership of significant, ground-breaking research projects in Australia.

David's work focuses on identifying the key ecosystem functions needed to sustain coral reefs. He looks at threats to these reefs alongside the crucial ecosystem functions that support not only the reefs, but the people dependent on them.

David says coral reefs across the globe are changing fast. This pace challenges the traditional scientific, management and governance approaches to coral reefs.

His project will address these challenges by implementing a new, functional approach to coral reefs that exploits a unique combination of evolutionary and ecological methodologies. The project will provide a global overview of ecosystem function and an in-depth understanding of how ecosystems change over time, leading to specific, and practical, management objectives.



**Dr Jennifer Donelson** *ARC Future Fellow*

*Future Fellows* are recognised as excellent mid-career researchers undertaking high quality research in areas of national and international benefit.

Jenni's work investigates the effects of environmental change on coral reef fish. In particular, she examines fish that are able to adjust to warming waters by passing on heat-tolerant genes to their offspring.

Her research will generate new knowledge on the interplay between adaptation and plasticity, both from within and across generations, using novel experimental designs. Exposing fish to higher water temperatures appears to switch genes on, or off. This alteration in gene expression is transferred to the offspring, and this 'acclimation' acts as a buffer against increasingly warming waters.

The improved knowledge of fish acclimation and adaptation to environmental change developed by this project will inform the management of cumulative impacts on reef fish and fisheries. Jenni's research will provide significant benefits to all communities that rely on fish for nutrition, for their local economy and for the social values of well-managed reef fisheries.



**Dr Michele Barnes** *ARC DECRA Fellow*

The Discovery Early Career Researcher Award (*DECRA*) is a prestigious three-year fellowship for early career researchers. It is highly competitive, with only one in seven applicants being successful.

Michele examines how social networks and the distribution and sharing of power can affect adaptive action in response to climate change.

Her project is the first longitudinal study that tracks individuals – as well as governance institutions – before and after a global coral bleaching event. This approach will explicitly examine key factors that facilitate, or inhibit, adaptive action at multiple scales.

Michele aims to significantly improve the understanding of how the adaptive capacity of individuals and sectors of society can translate into action. Her research will explicitly examine the role of social networks and power in shaping these responses.

Her project will contribute practical guidance on how to build the adaptive capacity of both individuals and of key governance institutions.



## RESEARCH PROGRAM 1: PEOPLE AND ECOSYSTEMS

PHOTO JACQUELINE LAU



### Professor Terry Hughes *FAA*

Professor Terry Hughes is the Director of the ARC Centre and co-leader of Research Program 1. He received his PhD in 1984 from Johns Hopkins University and was a National Science Foundation Postdoctoral Fellow at the University of California, Santa Barbara, before moving to 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'. From 2008-2010, he was a member of the ARC Advisory Council. Terry has been awarded three Federation/Australian Laureate Fellowships by the ARC, from 2002-2017. He has received many additional prizes, including the prestigious quadrennial *Darwin Medal* of the International Society for Reef Studies (2008), an *Einstein Professorship* from the Chinese Academy of Science (2015), the *Sir John Maddox Prize* (2018), and the *Climate Change Award* from the Prince Albert II of Monaco Foundation (2018). In December 2019, he received an honorary doctorate from Trinity College, Dublin. Terry is a Clarivate *Highly Cited Researcher*.



### Professor Tiffany Morrison

Professor Tiffany Morrison is a political geographer and co-leader of Research Program 1. Tiffany's research combines human geography, political science and ecology to tackle increasing complexity in environmental governance. Tiffany received her PhD in 2004 from The University of Queensland, supported by a visiting fellowship at the University of Wisconsin-Madison, USA. From 2004-2008 she taught in the Master of Public Administration program in the School of Political and International Studies at Flinders University. During that time, she was awarded a visiting Fellowship at the University of Kyoto Disaster Prevention Institute, Japan. In 2008, Tiffany joined the School of Geography, Planning and Environmental Management at The University of Queensland where she co-lead an interdisciplinary team of ecologists, geographers, planners, economists and lawyers working on an ARC Super Science funded program of research on sea level rise. Since joining the ARC Centre in 2015, she has developed and led a major new research program on the governance of climate adaptation and on conflict in large-scale reef systems. Tiffany serves on the Editorial Board of *Earth System Governance*. Her recent studies of the complex governance of tropical ecosystems have been published in *Nature*, *PNAS*, *Nature Climate Change* and *Global Environmental Change*.



### 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 on the socio-economic aspects of 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 *Australian Ecology Research Award* from the Ecological Society of Australia in 2008. 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 WWF Australia's Eminent Scientists Group.

### RESEARCHERS

Jorge Álvarez-Romero, Michele Barnes, David Bellwood, Brock Bergseth, Jon Brodie, Iain Caldwell, Joshua Cinner, Pip Cohen, Graeme Cumming, Alana Grech, Georgina Gurney, Danika Kleiber, Jacqueline Lau, Laurence McCook, David Mills, John Pandolfi, Cristian Rojas, Garry Russ and Andrew Song.

## PROGRAM 1 REPORT

Research in Program 1 focusses on understanding the linkages between coral reef ecosystems, the goods and services they provide to people, and the governance of those systems. The overarching objective is to improve the stewardship of coral reefs and the wellbeing of reef-dependent populations worldwide, while simultaneously providing lessons and insights for other ecosystems. Key research questions include how economic development, social networks, local history and political drivers influence resource use and governance. Program 1 places a high value on engagement with 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 2019, the geographic, social and ecological scope of Program 1's research was very diverse, with major projects in Australia, 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 continues to develop a productive relationship with researchers at WorldFish (p58), headquartered in Malaysia. In 2019, Pip Cohen from WorldFish led a major paper in *Frontiers in Marine Science* on securing a just space for small-scale fisheries in the blue economy, with Centre co-authors Joshua Cinner, Terry Hughes and PhD student Emmanuel Mbaru (p51). Small-scale fisheries expert and recent

Centre PhD graduate Jacqueline Lau joined the Centre as the fourth post-doctoral fellow recruited to build our ongoing WorldFish collaboration. Iain Caldwell and Brock Bergseth also moved to the Centre in 2019. Iain joins us with a PhD from the University of British Columbia, Canada, following a postdoctoral fellowship at the University of California, Santa Barbara and Stanford University. Brock has moved to the Centre's Townsville node as a new postdoctoral fellow, following research appointments with CSIRO in Tasmania and the Munderoo Foundation in Western Australia.

Program 1 produced a record number of major publications in 2019, including many high-profile papers in *Nature*, *Science*, *Proceedings of the National Academy of Sciences (PNAS)*, *Nature Communications*, *Nature Sustainability*, *Nature Ecology and Evolution*, and *Global Environmental Change*.

Graeme Cumming led a special feature in *Biological Conservation* with Centre co-editors Morgan Pratchett and Georgina Gurney. The special feature was an outcome of a workshop held on Magnetic Island in 2018 on future directions for coral reef studies with over 20 Centre researchers. A [key paper](#) in the special feature analyses spatial mismatches and functional prioritisation, led by David Bellwood, with over a dozen Centre co-authors. Another [major paper](#) by Graeme Cumming and colleagues from the Great Barrier Reef Marine Park Authority, addresses spatial heterogeneity and scale in managing large marine protected areas.

Tiffany Morrison led a multi-disciplinary paper on navigating the politics of polycentric environmental governance, drawing together cases from the Great Barrier Reef, the Reducing Emissions from Deforestation and Degradation scheme (REDD+) and



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PHOTO MEIRA MIZRAHI



PHOTO JACQUELINE LAU



PHOTO JACQUELINE LAU

the European Water Framework Directive. The paper, in *Global Environmental Change*, was co-authored with Terry Hughes and Andrew Song from the Centre, and with colleagues from the UK, the USA, the Netherlands, Malaysia and Australia. Tiffany also led a high-profile Commentary in *Nature's* Special Issue on Climate Change, designed to coincide with the 2019 UN Climate Summit in New York. The paper, entitled 'Save reefs to rescue all ecosystems', sets out the reef climate challenge and proposes several land-based, philanthropic and activist solutions from across the tropics.

Joshua Cinner was lead author of a paper in *PNAS* analysing 16 years of social and ecological data, co-authored with four Centre researchers and colleagues from Singapore, the UK, France, and Papua New Guinea. The paper outlines challenges and opportunities for adaptive management of the commons. Joshua and Michele Barnes also published a conceptual paper on the social dimensions of resilience in social-ecological systems, in *One Earth*. Michele was also lead author on a 2019 paper in *Nature Communications* on social-ecological alignment and ecological conditions in coral reefs.

Program 1 researchers led over a dozen workshops and mentoring activities during the year. For example, Graeme Cumming led two workshops in Annapolis, USA as part of a National Socio-Environmental Synthesis Center (SESYN) project on quantitative synthesis and modelling of social-ecological dynamics. Other participants included Tiffany Morrison, Georgina Gurney and colleagues from the US, Germany, Sweden, South Africa, UK and Spain. Georgina Gurney co-lead a workshop with Emily Darling (Wildlife Conservation Society), funded by the National Center for Ecological

Analysis and Synthesis (USA) with meetings during 2019 in Santa Barbara and Rome, co-hosted by the UN Food and Agricultural Organization (FAO). This research group will provide the IUCN, member nations of The Pacific Community (SPC), the FAO, and a consortium of international NGOs, with a decision-support tool to make informed choices about the implementation of marine protected areas and other conservation measures.

Program 1 researchers had a busy year engaging with many end-users around the world. Tiffany Morrison represented the Centre at the WorldFish annual scientific management committee meeting at WorldFish headquarters in Penang, Malaysia. Joshua Cinner gave a series of public and university-wide seminars in his role as 'distinguished international visiting scholar' at the University of Rhode Island, USA. Terry Hughes delivered 19 lectures and public talks in the USA, including a briefing to the National Science Foundation, in Washington. Terry was also appointed as a reviewer of the 2019 Great Barrier Reef *Outlook Report*, delivered by the Commonwealth to UNESCO in December.

Program 1 members also received numerous accolades in 2019. Joshua Cinner was part of a team awarded US\$2.6m to study reef futures. A raft of Centre researchers were shortlisted for the Australian Eureka Award. Two PhD students won best paper awards at the Global Conference on Gender in Aquaculture and Fisheries in Bangkok (Sarah Lawless) and at the MARE People and the Sea conference in Amsterdam (Jacqueline Lau). In December, Centre Director, Terry Hughes, received an honorary doctorate from Trinity College, Dublin, Ireland.



PHOTO JACQUELINE LAU



PHOTO SARAH SUTCLIFFE



PHOTO MARK PRIEST

# Call for co-operation as 'blue boats' rob Pacific reefs

A flotilla of Vietnamese fishing boats with crews suffering in harsh conditions is stripping Pacific coral reefs of seafood, as poaching escalates to become an international human rights and security issue.

Dr Andrew Song, joint ARC Centre of Excellence for Coral Reef Studies and WorldFish research fellow, has produced the first analysis of international attempts to manage Vietnam's 'blue boat' fleet – small fishing vessels, commonly painted blue, that travel thousands of kilometres to fish illegally in Pacific waters.

Dr Song said the reasons are allegedly economic, but also geopolitical, as the intensified Chinese presence/interference has squeezed them out of their traditional fishing grounds in the South China Sea.

"The boats are between 10–15 metres in length and carry up to 17

people. The crews reportedly have no contract of employment and no insurance and are frequently abandoned after accidents or arrests. They travel more than 7000km around the Pacific and stay up to three months at sea," Dr Song said.

He said their main targets are high-value species of sea cucumber and giant clam found on many Pacific Island coral reefs.

Dr Song estimates the cost of the boats to be around AU\$15,000–\$35,000 each, while processed tropical sea cucumber species can retail at AU\$150–\$300 per kilogram in Hong Kong and Chinese markets. He said there is suspicion that the blue boats were meeting large 'mother-ships' in the open ocean to offload their catch and take on supplies. This is yet to be confirmed.

"The collection of sea cucumber in foreign waters is apparently easier

and less dangerous, since sea cucumber is still found six to seven metres deep on Pacific island reefs, whereas people have to dive 60 metres, even 80 metres in waters near Vietnam," Dr Song said.

"The poaching also directly endangers the livelihood security of coastal communities and the national export revenue in the Pacific. Sea cucumber fisheries are considered to be the second-most valuable export fishery for Pacific Island countries," he said.

Dr Song said Pacific Island countries face limitations in securing the resources to patrol such a vast area, and the wooden boats are difficult to find, even with radar, and harder to trace administratively than a large ship. He said the problem is intensifying.

"In Australian waters, the latest reported figures show the number of foreign fishing boats caught operating illegally has increased from six in 2014 up to 20 in 2016 with most originating from Vietnam and Indonesia," he said.

Dr Song said the poachers can be seen as a new kind of security threat—endangering the lives of Vietnamese fishers, endangering food security for Pacific Island nations, and putting Pacific Island economies, coastal communities and the workers on the boats at risk.

"By their dispersed and random nature, blue boats are bolstering the need for closer cooperation not only among governments and agencies, but also among coastal communities and individual fishers."

Song, A, Hoang, V, Cohen, P, Aqorau, T and Morrison, T. (2019). 'Blue boats' and 'reef robbers': a new maritime security threat for the Asia Pacific? *Asia Pacific Viewpoint* 60(3): 310-324.



PHOTO TANE SINCLAIR-TAYLOR

# Micronutrients 'slipping through the hands' of malnourished people

Millions of people across the globe are suffering from malnutrition, despite some of the most nutritious fish species in the world being caught near their homes, according to new research published in *Nature* today.

Scientists from the ARC Centre of Excellence for Coral Reef Studies (Coral CoE) are part of an international team that found children in many tropical coastal areas could see significant health improvements if just a fraction of the fish caught nearby was diverted into their diets.

Co-author Dr David Mills, based at Coral CoE, is a senior scientist with WorldFish. He says

populations, who are often those most in need.

"If these catches were more accessible locally, they could have a huge impact on global food security and combat malnutrition-related disease in millions of people."

The team of 11 researchers recorded the concentration of seven nutrients in more than 350 species of marine fish, and they developed a statistical model based on diet, sea water temperature, and energy expenditure to predict how much nutrition any given species of fish contains.

The predictive modelling allowed researchers to calculate the likely

Researchers say that a complex picture of international and illegal fishing and trade in seafood is standing between malnourished people and the more-than-adequate fish nutrients caught on their doorstep.

"Currently, many of the world's fisheries are managed to get the most revenue, often by directing efforts towards catching the highest-priced species and shovelling fish landings towards the mouths of the rich in cities, or feeding pets and livestock in wealthier countries," co-author Dr Philippa Cohen, a WorldFish partner investigator at Coral CoE, stated.



PHOTO TANE SINCLAIR-TAYLOR

PHOTO NICK GRAHAM

fish is an important source of protein, omega-3 fatty acids, and micronutrients. "Yet, more than two billion people worldwide suffer from micro-nutrient deficiencies," he said.

Lead author Prof Christina Hicks, Lancaster University, started the project when she was a research fellow at Coral CoE at JCU. The study suggests enough nutrients are already being fished from the oceans to substantially reduce malnutrition – but in some countries they are not reaching local

nutrient composition of thousands of fish species that were never nutritionally analysed before.

They used this model to quantify the global distribution of nutrients available from existing marine fisheries, and compared that with the prevalence of nutrient deficiencies around the world. Parts of Africa, Asia, the Pacific and the Caribbean were some of the regions with high malnutrition, despite sufficient fish nutrients in the national catches.

Dr Mills said this highlights the need for fisheries policies focused on improving nutrition, rather than simply increasing volumes of fish harvested or produced, or the revenues generated from fish exports.

Hicks, C, Cohen, P, Graham, N, Nash, K, Allison, E, D'Lima, C, Mills, D, Roscher, M, Thilsted, S, Thorne-Lyman, A, and MacNeil, A (2019). *Harnessing global fisheries to tackle micronutrient deficiencies. Nature* 574(7776): 95-98.

## RESEARCHER PROFILE: DANIKA KLEIBER

Danika Kleiber likes to describe herself as a feminist fisheries researcher. While many people interpret this as the practice of studying female fish, Danika is more interested in humans, and in particular, the intersection of gender and small-scale fisheries. She is a joint ARC Centre and WorldFish Research Fellow in the People and Ecosystems Research Program (Program 1), based at James Cook University.

Danika's uncommon research niche is the result of a lifelong interest in behavioural ecology and gender equity, coupled with a stubborn insistence on doing both. This is reflected in her undergraduate and graduate studies. Danika began with an undergraduate double major in biology and women's studies from Tufts University, USA (2002), after which she went on to chase western bluebirds (*Sialia mexicana*) as a field assistant at UC Berkeley in California, then song sparrows (*Melospiza melodia*) for her Master's thesis at the University of British Columbia, Canada. During her Masters, Danika took a course on the human dimension of conservation and resource management, and found her research home. She undertook a PhD at the University of British Columbia, where her doctoral research thesis, 'Gender and fisheries in the Central Philippines' focused on the intricacies of collecting sex-disaggregated data in small-scale fisheries contexts, and on women's and men's perceptions of, and participation in, community-based marine management.



Following her PhD, Danika went on to do postdoctoral research with the *Too Big To Ignore* project, based at Memorial University in Newfoundland, where she focused on transdisciplinary approaches to small-scale fisheries management. She also collaborated with several other gender and fisheries scholars and practitioners to analyse the implications of gender aspects of the 'Small-Scale Fisheries Guidelines'. The Guidelines were designed to influence small-scale fisheries policy and were the first

international fisheries policies to explicitly include gender equity and equality as a guiding principle for sustainable fisheries management. Shifting her focus back to the Pacific, Danika moved to Honolulu, where she worked for NOAA as a social scientist, exploring the cultural dimension of fisheries.

In 2018, Danika started her Research Fellowship with the ARC Centre of Excellence and WorldFish, headquartered in Penang, Malaysia. The project, which melds perfectly with her research interest and skill set, is focused on designing and implementing social science research on gender equity and fisheries in the Pacific Islands. It provides capacity building for gender integration to fisheries officers and development workers in the Solomon Islands, Vanuatu, Kiribati and East Timor. Danika also co-leads the *Illuminating Hidden Harvest* gender theme, which aims to give global estimates for the impact and importance of small-scale fisheries. This is a notoriously tricky prospect, because small-scale fisheries are frequently described as 'data-poor', and the available data are rarely sex disaggregated. When faced with a glaring lack of sex-disaggregated fisheries data, Danika helped to coordinate a team of over 35 gender and fisheries researchers and practitioners from around the world. Together they will ensure that women's contributions are included in the global story of small-scale fisheries.

## The Cure to the Tragedy of the Commons? Cooperation

### WHEN FISHERS COMMUNICATE OPENLY, CORAL REEFS WIN

by Steve Murray



PHOTO JACQUELINE LAU

Groups whose members cooperate almost always outperform those that don't. **New research** shows that these benefits can extend beyond the group to the environment around it. Specifically, the research demonstrates that cooperation among Kenyan fishing communities leads to larger fish stocks and healthier reefs.

A team led by Michele Barnes, a social scientist at James Cook University in Australia, interviewed almost 650 fishers across five coral reef fishing communities to document how they cooperated and established rules. They also looked at the gear the fishers used, the species they caught, and evaluated local reef conditions.

"Kenya is very dependent on reef fishing," says Barnes. "And, like many places across the globe, they're facing serious issues about the state of their reefs."

The researchers found significantly more fish and higher biodiversity in the hunting grounds near three of the five communities. These were sites where competing fishers communicated more openly about where and how they fish. These fishers also tended to discuss their operating rules and worked to resolve conflicts. "They had less variation in their vision of the resource and had developed stronger commitments toward managing it," says Barnes. The team was careful to rule out other environmental and social factors that might have accounted for the differences seen on the reefs.

"When people are engaged both with each other and with a common resource, they tend to form cooperative relationships," says Barnes. Not all community engagement is the same, however. The study found that only cooperation among fishers who are competing for the same species results in higher reef biomass.

The study results may offer a helpful guide for conservationists. "It gives us a pretty strong road map," says Jack Kittinger, a researcher with the nonprofit Conservation International's Center for Oceans and a study coauthor. "The hardest thing in conservation is getting a bunch of disparate people to cooperate to ensure the perpetuation of a resource that they all depend on. When that happens, lo and behold, you've got better ecological success," he says.

Malin Pinsky, an ecologist at Rutgers University in New Jersey who was not involved in the study, thinks that this research approach can be scaled to larger and more complex networks involving people and the environment. "It plays out in communities in Kenya," says Pinsky, "and it plays out between countries on a global stage." It may also become more relevant as the effects of climate change become starker for coastal communities. "Cooperation is getting much more difficult now that species are on the move, especially as they cross political boundaries," he adds.



## RESEARCH PROGRAM 2: ECOSYSTEM DYNAMICS, PAST, PRESENT AND FUTURE

PHOTO BURNETT HARTOG



### 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. He received his doctorate in 1999 from Stanford University in California, USA, for research on the ecology of rocky shores. In 1999-2000, Sean was a 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 12 publications in *Science* or *Nature*, and has supervised 42 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 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. Sean moved to Panama at the end of 2019, to take up a new position at the Smithsonian Tropical Research Institute.



### Dr Alana Grech

Dr Alana Grech, from James Cook University, is co-leader of Research Program 2 and Assistant Director of the ARC Centre of Excellence for Coral Reef Studies. She is an expert in conservation biogeography of coastal ecosystems, cumulative impact assessment (CIA), and environmental decision-making. Alana was previously employed as a Senior Lecturer in Spatial Information Science at Macquarie University, and as a Postdoctoral Research Fellow at the ARC Centre, James Cook University. She has authored more than 70 publications in leading international journals, including *Science*, *Global Change Biology*, *Conservation Letters* and *Frontiers in Ecology and the Environment*, and is Associate Editor of the journal *Diversity and Distributions*. Her research on coastal ecosystems of the Great Barrier Reef and Torres Strait has been instrumental to a range of Australian government policy and reports, with Alana regularly invited to provide technical and policy advice. In 2018, Alana received the *Queensland Young Tall Poppy Scientist of the Year Award* for her leadership in science and communication. Her contributions to research education at James Cook University were recognised in 2019 with an *Award for Excellence in Graduate Research Leadership*.



### Professor John Pandolfi

Professor John Pandolfi, from the School of Biological Sciences and Centre for Marine Science, at The 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 an emphasis on the effects of anthropogenic impacts and climate change on the recent history of modern coral reefs. His research on coral reef ecosystems asks fundamental ecological questions that are best answered by acquiring and using long-term data. John has published more than 190 papers, including 24 contributions to the journals of *Science* and *Nature*. He has served as President of the Australian Coral Reef Society, Co-Chief Editor of *Paleobiology*, and is Associate Editor for *Proceedings of the Royal Society B* and *Global Ecology and Biogeography*. He has supervised 22 PhD students. John has provided frequent briefings on coral reef management and policy (e.g. to the US Congress and Australian Senate) and has been invited to serve on numerous international working groups. In 2001, John received the *Discovery Magazine Science Story of the Year Award*. In 2013, he was awarded a prestigious *Discovery Outstanding Researcher Award* from the ARC (2013-2016). He was recently elected as a Fellow of both the International Coral Reef Society (2015) and The Paleontological Society (2016).

### RESEARCHERS

Kristen Anderson, Andrew Baird, David Bellwood, Yves-Marie Bozec, Tom Bridge, Jon Brodie, Jamie Caldwell, Severine Choukroun, Peter Cowman, Kay Critchell, Tom DeCarlo, Graeme Cumming, April Hall, Vanessa Haller, Hugo Harrison, Karlo Hock, Andrew Hoey, Terry Hughes, Geoff Jones, Sun Kim, Michael Kingsford, Nils Krück, Ryan Lowe, Robert Mason, Laurence McCook, Mark McCormick, Michael McWilliam, Vanessa Messmer, Peter Mumby, Philip Munday, Stephen Palumbi, Serge Planes, Morgan Pratchett, George Roff, Garry Russ, Eugenia Sampayo, Tim Staples, Greg Torda, Sue-Ann Watson, Sharon Wismer and Kennedy Wolfe.

## PROGRAM 2 REPORT

Research in Program 2 aims to understand the multi-scale dynamics of coral reefs, through the innovative integration of ecology, evolution, genetics, oceanography and palaeontology. Program 2 researchers focus primarily on four key research areas. Firstly, they 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. Secondly, they 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. Thirdly, Program 2 examines how populations of organisms living on different reefs are connected to each other through the dispersal of their offspring, promoting understanding of how reefs can recover from disturbances, such as bleaching events. Finally, they 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.

The ongoing effects of the devastating 2015–17 global coral bleaching event on reefs in Australia and elsewhere continued to be at the forefront of Program 2 research in 2019. The series of papers led by Terry Hughes continued in 2019, with new research published in *Nature* and *Nature Climate Change*. This research showed that the impact of climate change on coral reefs extends to the impairment of ‘stock-recruitment dynamics’ – the fewer coral colonies remaining alive, the lower the capacity of those

survivors to produce enough offspring to replenish the population – which has profound implications for the rest of the reef ecosystem (p26). Moreover, ecological memory of prior bleaching events can modify the cumulative impact of recurrent thermal stress. The Centre’s further work on this global bleaching event on the Great Barrier Reef and eastern Australian subtropical reefs shows the potential for refugia at depth (Andrew Baird in *Marine Ecology Progress Series*) and at high latitudes (Sun Kim and John Pandolfi in *Global Change Biology*).

Program 2 researchers made other important contributions to our understanding of the effects of climate change on coral reefs. In *Nature Communications*, Verena Schoepf and Malcolm McCulloch showed that corals resistant to thermal stress may still not be able to acclimatise to ocean warming. Jenni Donelson, Philip Munday and John Pandolfi worked with an international team of ecologists to publish a review in *Philosophical Transactions of the Royal Society B* on interactions between plasticity, adaptation and range shifts in response to marine environmental change.

In addition to their work on effects of climate change, Program 2 researchers made other important contributions to the fundamental understanding of the ecology and evolution of reef systems. For example, a *Science* paper from David Bellwood and colleagues showed the importance of small marine vertebrates (e.g. small cryptobenthic fish, like blennies) in maintaining ecological functions of coral reefs. John Pandolfi published a paper in *Nature Ecology & Evolution* with an international team on the global impacts of marine exotic species. In *Nature Communications*, Peter Mumby and colleagues showed how the supply of coral



larval and inter-reef connectivity is enhanced when the annual spawning event occurs over multiple lunar cycles. Jessica Hopf, Geoff Jones and Sean Connolly reported in *Ecological Applications* that both fisheries yields and metapopulation biomass are stabilised in the presence of no-take reserves, relative to without them.

Contributions to management and policy also formed an important component of Program 2 research in 2019, including a paper in *Nature Sustainability* by Graeme Cumming on how the concept of resilience can be applied in decision making for conservation. Peter Mumby and colleagues showed in *Nature Climate Change* that evolutionary responses of organisms during shifting environmental conditions can fundamentally change recommendations managers make for conservation actions. John Pandolfi published a paper in *Nature Ecology & Evolution* with an international team that highlighted the importance of a number of social-environmental drivers in the strategic management of coral. Finally, the 2nd Edition of *The Great Barrier Reef: Biology, Environment & Management* was published in 2019, co-edited by Michael Kingsford and Ove Hoegh-Guldberg along with Pat Hutchings from the Australian Museum.

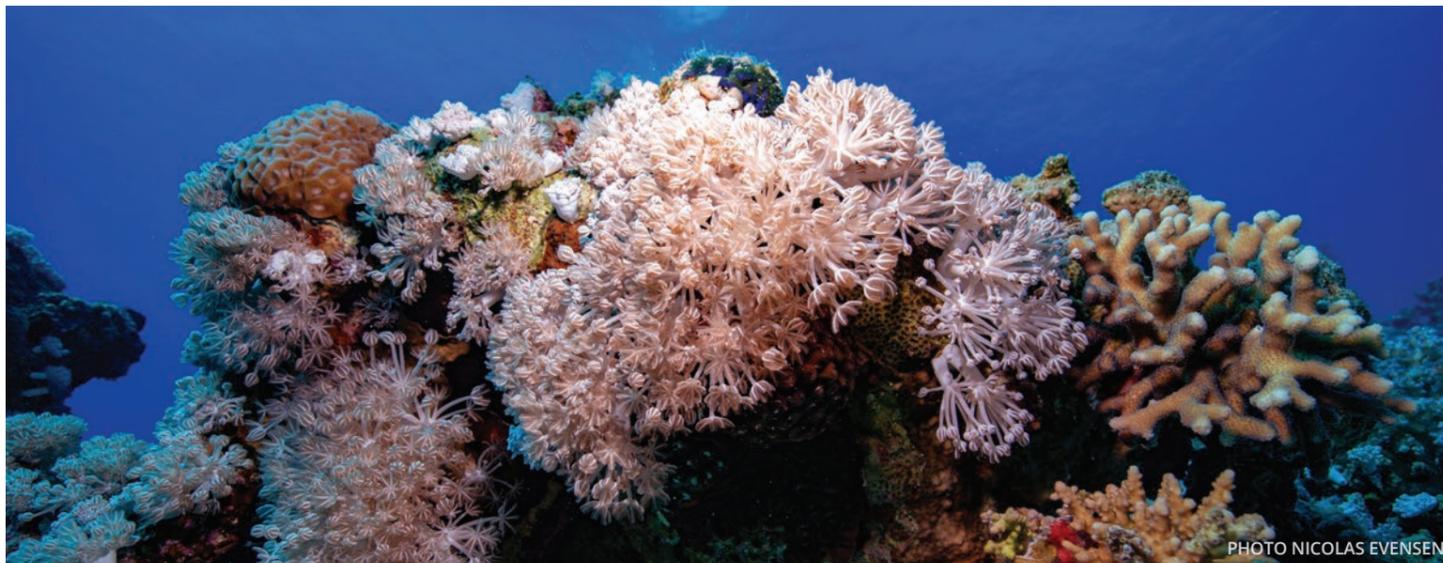
Program 2 researchers received strong recognition for their work in 2019. For example, David Bellwood was awarded a highly prestigious ARC Australian Laureate Fellowship, and Jenni Donelson was awarded an ARC Future Fellowship (p9).

At the end of 2019, the Centre farewelled long-term Program leader Sean Connolly who, in 2020, will move to the Smithsonian Tropical Research Institute in Panama. Program 2 thanks Sean for his enduring contributions to the Centre. We look forward to future

collaborations with him and to strengthening our links with the Smithsonian Institute. Similarly, Program 2 congratulates Program Leader Verena Schoepf who has been appointed as the MacGillavry Fellow, a tenure track position for talented female researchers, at the University of Amsterdam, strengthening the Centre’s extensive international alumni. Alana Grech was appointed as a new Program 2 leader in 2019. Graeme Cumming will take up a Program 2 leadership role in 2020.

Program 2 researchers also played key roles organising and participating in international workshops. Peter Mumby was an invited advisor at the Coral Triangle Initiative Workshop in Manado, Indonesia, to redesign the Regional Plan of Action. Morgan Pratchett led a workshop in the USA on ‘Coral demography in the Anthropocene’, bringing together coral biologists and demographic modellers to explore the consequences of increasing disturbances on the size and fate of reef-building corals.

Finally, Centre researchers continued to make important contributions to policy and management at a variety of domestic and international levels. These included multiple briefings to, and interactions with, the Great Barrier Reef Marine Park Authority to assist their publication of the *Great Barrier Reef Outlook Report 2019*. Alana Grech, Terry Hughes and Jon Brodie also prepared the ARC Centre’s submission to the *Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Bill 2019*, and presented their submission to the Queensland parliamentary hearings on this Bill. Finally, the UN Food and Agricultural Organisation has included Peter Mumby’s team as part of a regional proposal to improve fisheries management in the Gulf of Thailand.



# Waterways of Queensland and the Great Barrier Reef are suffering from pesticide management failure

Scientists say a failure of national management means excessive amounts of harmful chemicals — many now banned in other countries such as the European Union, USA and Canada — are damaging the nation's waterways and the Great Barrier Reef.

The new study was led by Professor Jon Brodie from the ARC Centre of Excellence for Coral Reef Studies.

Professor Brodie says pesticides found at concentrations exceeding the nation's own water quality guidelines have the potential to seriously damage aquatic plants and animals. Insecticides affect prawns in freshwater streams, and herbicides affect marine species such as seagrass.

Authority (APVMA), have serious deficiencies and in many cases are seriously flawed," he said.

However, Prof Brodie notes that the Queensland Government is taking action to reduce pesticide pollution through research, monitoring, risk assessments and application of better pesticide application methods.

Yet, only so much can be done at a local level.

"The APVMA are very slow to act on the copious evidence surrounding, for example, the continued use of a pesticide like imidacloprid."

The highest concentrations of pesticides, often found



PHOTO THOMAS BRIDGE

"The notorious insecticide imidacloprid — now banned for its effects on bees across Europe, the USA and soon to be banned in Canada — is found in many freshwater streams and estuaries in the Great Barrier Reef and also Queensland more broadly," Prof Brodie said.

"This can have a serious effect on aquatic life."

The regulation and management of pesticides in Australia is a joint responsibility of the Australian and State governments.

"There is no evidence at the moment that imidacloprid may be banned or regulated more closely in Australia," Prof Brodie said.

"The processes of the Australian Government regulator, the Australian Pesticide and Veterinary Medicine

above Australian guidelines, are found in freshwater bodies adjacent to, and downstream of, areas of intensive cropping. This is mainly sugarcane cultivation and horticulture.

Prof Brodie says Australia has the expertise and knowledge of pesticide management to take action and regulate.

"Though pesticide regulation and management in the Great Barrier Reef region has been unsuccessful, there is some hope that pesticide levels and risks to species and ecosystems can be reduced," he said.

Brodie, J, and Landos, M (2019). Pesticides in Queensland and Great Barrier Reef waterways – potential impacts on aquatic ecosystems and the failure of national management. *Estuarine, Coastal and Shelf Science* 230 (106447): 1-17.

# Cardinalfish caught sneaking a bit on the side

Scientists have revealed the torrid, adulterous love lives of the mouth-brooding cardinalfish, with cuckoldry going hand-in-hand with cannibalism of the young.

"This is a small and unassuming coral reef fish," said Dr Theresa Rueger, who led the study while she was a student at the ARC Centre of Excellence for Coral Reef Studies (Coral CoE).

On the surface, everything seemed to be as expected, with the pairs of fish apparently monogamous and forming larger social groups.

"Looking at the babies they produced, we saw that most of them do exclusively breed with their own partner," Dr Rueger said.

But on closer examination the researchers discovered some sneaky behaviour!

"When presented the chance, both males and females take the opportunity to mate with other individuals from outside the group."

After observing and analysing cardinalfish populations in Papua New Guinea for two years, the researchers found that of 105 broods analysed from 64 males, 30% were mothered by a female that was not the partner, about 11% of broods included eggs from two females, and more than 7% of broods were fertilised by two males.

As with most apparently monogamous species who invest time and energy rearing their young, these fish make sacrifices to ensure their babies survive. Paternal care, especially when the male carries the eggs in his mouth, is associated with a high degree of confidence in paternity.

"Staying faithful and caring for your offspring can be a winning evolutionary strategy," added co-author Dr Hugo Harrison, also from Coral CoE.

"By caring for the brood, males increase the survival of their offspring but also allow their partner to allocate more energy into producing the next clutch," Dr Harrison said.

"However, it seems that having a bit on the side might not hurt your evolutionary fitness."



PHOTO C HAMILTON

"This means the females are in an advantageous position, because they can produce eggs quicker than the male can brood them—so they can go and give eggs to another male," explained Dr Rueger.

"But the males can offset that advantage by eating some, or all, of the eggs. They can then accept eggs from another female."

Dr Rueger said in some cases, males even fertilise the eggs that another male is brooding. This saves them the energy they would need to brood the eggs themselves.

"What this study shows is a complicated mating system, which is something we didn't expect and could only find out by spending lots of time observing the fish and using genetic analysis to identify parentage," Dr Rueger said.

"Clearly, social interactions don't tell the whole story," added Dr Harrison. "But our parentage tests reveal the complex nature of social groups in fishes and how promiscuity could upturn theories for how monogamy arose."

Rueger, T, Harrison, H, Gardiner, N, Berumen, M, and Jones, G, (2019). Extra-pair mating in a socially monogamous and paternal mouthbrooding cardinalfish. *Molecular Ecology* 28(10): 2625-2635.

## RESEARCHER PROFILE: YVES-MARIE BOZEC

Yves-Marie Bozec is a Research Fellow in the Ecosystems Dynamics Program (Program 2) based at the University of Queensland node of the Centre. Growing up in France, Yves-Marie spent his childhood in the wetlands on the Atlantic coast, surrounded by salt marshes, mudflats and oyster farms. He vividly remembers exploring the intertidal zone with a shovel, hand net or crab hook. This is where his passion for marine life first began.

Yves-Marie completed an undergraduate degree in population biology and a MSc in oceanography and marine ecology at the University of Pierre et Marie Curie in France. A holiday in Egypt led Yves-Marie to his first snorkelling experience on a coral reef. This inspired a move to New Caledonia to complete his thesis project studying fish-habitat relationships on coral reefs. His PhD continued this coral reef theme, focusing on the response of coral reef fish to human-driven disturbances. During this research he developed a deep understanding of ecological statistics and modelling which later proved to be pivotal for his research career. In 2007, Yves-Marie moved to Mexico to study the impact of coastal development on corals, macroalgae and herbivorous fish on Yucatan reefs. This provided him with a sound knowledge of Caribbean reef ecology, and triggered his interest in coral-algal phase

shifts. Back in France, he focussed on artificial intelligence applied to fisheries management, and developing indicators of fishing effort along the French Mediterranean coast. While these were enriching experiences, they were a long way from his passion for coral reefs. Yves-Marie realised that his skills in community ecology, modelling and bioinformatics could make an original contribution to coral reef science. His chance came in 2010, when Yves-Marie took up a postdoctoral fellowship at the University of Queensland – to develop simulation models of reef resilience in the Caribbean. This research led to explicit recommendations for an ecosystem-based management of Caribbean reefs (*Proceedings of the National Academy of Sciences*, 2016).

Yves-Marie joined the ARC Centre in 2015, to investigate the mechanisms of reef resilience in the Indo-Pacific (Palau, French Polynesia, and the Great Barrier Reef). In 2017, he started an ambitious

project aimed at modelling coral populations along the length of the Great Barrier Reef (GBR), integrating the dynamics of larval connectivity, water quality, cyclones, marine heatwaves and crown-of-thorns starfish outbreaks. A later model incorporated evolutionary genetics in order to evaluate the scope of corals to adapt to ocean warming. This is the first model that attempts to reconstruct the recent reef trajectories across the GBR from the simulation of coral reproduction, growth and mortality from multiple stressors. It forms the basis of a suite of resilience tools enabling researchers and managers to explore strategic management options across the GBR, including improvement of water quality, starfish culling, protection from fishing, and coral population dynamics under climate change.



Centre led articles in The 2019 Altmetric Top 100 that 'most captured the public's imagination'

**14th**  
Global warming impairs stock-recruitment dynamics of corals  
*Nature*

**22nd**  
Ecological memory modifies the cumulative impact of recurrent climate extremes  
*Nature Climate Change*

# The Great Barrier Reef Was Seen as 'Too Big to Fail'. A Study Suggests It Isn't.

by Livia Albeck-Ripka

A study found that mass bleaching events had not only caused adult corals to die off, but also led to a decline in new corals settling on the reef.



PHOTO ED ROBERTS

MELBOURNE, Australia — For millenniums, ecosystems have withstood fires, floods, heat waves, drought and even disease by adapting and rebuilding their biodiverse communities.

But according to new research, there is a limit to what even the largest and most resilient places can stand, and climate change is testing that limit by repeatedly disturbing one of the earth's most precious habitats: the Great Barrier Reef.

The study, released Wednesday in the journal *Nature* by researchers from the ARC Center of Excellence for Coral Reef Studies in Australia, monitored the death and birth of corals following ocean heat waves that caused mass bleaching of the Great Barrier Reef in 2016 and 2017.

Not only did many of the adult corals die off, but for the first time, researchers observed a significant decline in new corals settling on the reef, compromising its capacity to recover.

"There are so many corals, and it's been disturbed many times in the past," said Andrew Baird, Chief Investigator at the research center and one of the paper's lead authors.

"We never thought we'd see this happen," he said.

The study is the first to show the collapse of fundamental ecosystem processes in a marine environment, Professor Baird said.

"We thought the Barrier Reef was too big to fail," he said, "but it's not."

The Great Barrier Reef, off Australia's east coast, covers 133,000 square miles and can be seen from outer space. It pumps 6.4 billion Australian dollars, or \$4.5 billion, into the Australian economy per year and supports tens of thousands of jobs, according to 2017 figures from Deloitte.

But in recent years, research has shown that the time left to save it is growing short.

Since 1998, the Great Barrier Reef has suffered four mass bleaching events, two of them back to back in 2016 and 2017. While coral populations can recover from a bleaching event — which stresses individual corals and strips them of their vibrant color — they need up to a decade to do so. And if carbon emissions continue at the high-emissions scenario, bleaching will occur twice

every decade starting in 2035, and annually after 2044, according to climate models from UNESCO.

"It's not too late to act, but time is running out," Professor Baird said, adding that without drastic climate action, reefs will be "fundamentally changed, as will everything."

Coral reefs were among the first ecosystems to respond to the rise in global temperatures, he said, "but it's only a matter of time before these changes are happening in our back gardens."

According to the researchers' findings, the settlement of baby corals on the reef declined 89 percent last year. The coral that experienced the most significant decline in new organisms, at 93 percent, was a type called *Acropora*, which provides most of the reef habitat that supports thousands of other species, including coral trout, clown fish and triggerfish.

Adult corals that were further south escaped bleaching, but they were too far from the bleached northern reefs to help them replenish, the scientists found. They also explored the impact of back-to-back cyclones in 2014 and 2015 on the reef's north at Lizard Island, which, despite killing off 80 percent of the adult corals, did not cause a decline in new corals settling.

"Cyclones are fairly patchy," Professor Baird said, whereas heat and bleaching "just kills everything."

The corals that do manage to survive such trauma, however, were found to be more resistant to periods of extreme warmth in a separate study conducted by Professor Baird and his colleagues last year. Scientists have been trying to breed the most resilient forms of coral in the hope that they can use these to repopulate the reef.

While crucial, such projects are limited, said Mark Eakin, the coordinator of the National Oceanic and Atmospheric Administration's Coral Reef Watch program, who was not involved in the study but has previously worked with the Australian researchers.

"Those are at the scale of a large family garden," he said of the restoration efforts, whereas the collapse of the Great Barrier Reef would mean "the loss of an entire seascape," akin, he said, to the fall of the Roman Empire.

"This is just further evidence of how much damage climate change is having," Dr. Eakin said.

Russ Babcock, a senior research scientist at an Australian government agency called the Commonwealth Scientific and Industrial Research Organization, said the study, which he was also not involved in, had confirmed many scientists' worst fears.

"All ecosystems have some things in common, and one of them is the ability to recover," he said. "There's going to be no lucky escape."

PHOTO GERGELY TORDA



PHOTO ED ROBERTS



PHOTO CHRISTOPHER BRUNNER



The New York Times

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## RESEARCH PROGRAM 3: RESPONDING TO A CHANGING WORLD

### Associate Professor Maja Adamska

Associate Professor Maja Adamska, from The Australian National University, is co-leader of Research Program 3. Her graduate and first postdoctoral projects addressed interactions between signalling pathways and transcription factors during vertebrate development. To pursue her interests in the evolutionary origin of animal developmental regulatory genes, Maja moved to The University of Queensland to study them in the first sponge to have its genome sequenced, *Amphimedon queenslandica*. From 2007 to 2015, Maja was a group leader at the Sars International Centre for Marine Molecular Biology in Bergen, Norway, and in 2015 she established a laboratory at the Research School of Biology at The Australian National University. Maja was awarded an ARC Future Fellow in 2017, and she continues to investigate the evolutionary origin of key developmental processes, such as cell type specification, segregation of germ layers and axial patterning of embryos and adults. Recent major research themes in her laboratory include regeneration of sponges and corals, in particular the mechanisms regulating gene expression, as well as sponge-bacterial symbiosis. Maja is also deeply interested in the emergence of complex multicellularity and its genomic background.

### RESEARCHERS

Kristen Anderson, Natalia Andrade Rodriguez, Andrew Baird, Tom Bridge, Sean Connolly, Peter Cowman, Thomas DeCarlo, Juan Pablo D'Olivo Cordero, Jennifer Donelson, Sophie Dove, Gal Eyal, Rebecca Green, Hugo Harrison, Ove Hoegh-Guldberg, Björn Illing, Michael Kingsford, Janice Lough, Ryan Lowe, Oliver Mead, David Miller, Aurélie Moya, Philip Munday, Stephen Palumbi, Morgan Pratchett, Veronica Radice, Jodie Rummer, Aleksey Sadekov, Eugenia Sampayo, Verena Schoepf, Greg Torda, Erin Vaughn and Sue-Ann Watson.



### 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 JCU. From 2008–2011, Mia was a Research Fellow at the Centre Scientifique de Monaco, and later at the University of Glasgow. Mia has broad research interests in physiology and ecology, and her research establishes mechanistic links between environmental change, physiology, and population and community dynamics. Her ecotoxicology research informs strategies for managing the impacts of environmental contaminants on coastal marine ecosystems. Mia's research is multi-disciplinary and collaborative. Over the last 10 years, she has published a diverse range of papers with >150 authors in 15 countries. Mia has published more than 60 papers in leading international journals: including, *Trends in Ecology and Evolution*, *Nature*, *Science* and *Current Biology*. She also actively participates in educational outreach programs that provide exciting marine biology field and laboratory experiences for secondary school students.

### Professor Ryan Lowe

Professor Ryan Lowe, from the UWA Oceans Institute at The University of Western Australia (UWA), is co-leader of Research Program 3. Ryan's research examines 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: improving predictions of coastal flooding and erosion risk along reef coastlines, identifying how ocean dynamics drive environmental variability within coral reefs, and multidisciplinary research into how oceanographic processes shape reef ecosystems. Ryan received his PhD in Civil and Environmental Engineering in 2005 from Stanford University, USA and has been based at UWA since 2007. He has authored more than 100 papers in leading international journals, as well as numerous technical reports for government and industry. Ryan is the Editor of the *Journal of Geophysical Research – Oceans*, he serves on the Expert Group in Physical Oceanography for the Australian Meteorological and Oceanography Society and on Australia's Surface Waves Working Group. In 2012, Ryan was awarded a four-year ARC Future Fellowship, and in 2014 he was the recipient of the UWA Vice Chancellor's Mid-Career Researcher Award.

## PROGRAM 3 REPORT

Research in Program 3 aims to understand and predict the responses of coral reef organisms and ecosystems to environmental change, particularly due to climate change and declining water quality. Biological responses of reefs to changing conditions are investigated from three tightly interlinked perspectives: the dynamics of the complex associations between corals and their symbiotic dinoflagellates and microbes; the physiological plasticity and capacity for adaptation of organisms, populations and species; and the stability of the carbonate frameworks that are synthesised and maintained by corals and other reef organisms.

In 2019, Program 3 researchers contributed major advances in understanding how coral reef organisms can acclimatise and/or adapt to stressors in the environment. In January, Jenni Donelson was the lead editor of a special issue in *Philosophical Transactions of the Royal Society B* on the role of plasticity in phenotypic adaptation to rapid environmental change. In a major review paper published in *Reviews in Fish and Fisheries*, PhD student Ian Bouyoucos and Jodie Rummer evaluated the use of oxygen uptake (respirometry) techniques for measuring stress in sharks and rays. Student-led research, published in *Frontiers in Ecology and Environment* by PhD student Hannah Epstein and co-author Greg Torda, explored the utility of microbiome engineering as a mechanism to enhance climate resilience of reef corals.

A central theme of research conducted in Program 3 during 2019 was understanding the responses of organisms to increasing ocean temperature. The importance of this research was emphasised by Ove Hoegh-Guldberg (p34) and collaborators in *Science*, where they highlighted the imperative to stabilise

global temperature at no more than 1.5°C above the pre-industrial level (p33). Experiments conducted by Verena Schoepf showed that the bleaching thresholds of stress resistant corals from the Kimberley region were unchanged after acclimatisation to both cooler and warmer temperatures (*Nature Communications*). Similarly, research by PhD student Saskia Jurriaans and Mia Hoogenboom in *Philosophical Transactions of the Royal Society B*, found a mismatch between the thermal performance of corals and the water temperatures at three locations on the Great Barrier Reef, indicating limited acclimatisation to local conditions. However, using skeletal cores of long-lived *Porites* corals, Tom DeCarlo and Hugo Harrison, in *PeerJ*, demonstrated a marked decline in the proportion of corals showing a chemical signature of heat stress over periods of years to decades. This latter study indicated that at least some corals can acclimatise to environmental change fast enough to keep pace with global warming.

Field-based studies conducted by Program 3 researchers revealed some of the environmental drivers of coral growth, abundance and diversity. Sophie Dove and Ove Hoegh-Guldberg showed a major shift in intertidal communities over a 91-year study of the Low Isles on the northern Great Barrier Reef (*Nature Communications*). During 2019, PhD student Camille Grimaldi and Ryan Lowe expanded the ARC Centre's research into the remote atolls off north-western Australia, as part of a joint research program with the Australian Institute of Marine Science (AIMS), to investigate oceanic drivers of reef connectivity. This new research builds on several research outputs in 2019 that reveal how oceanographic processes shape the ecology of the Scott Reef system of atolls. Complementing these field studies, results of combined field and mesocosm experiments

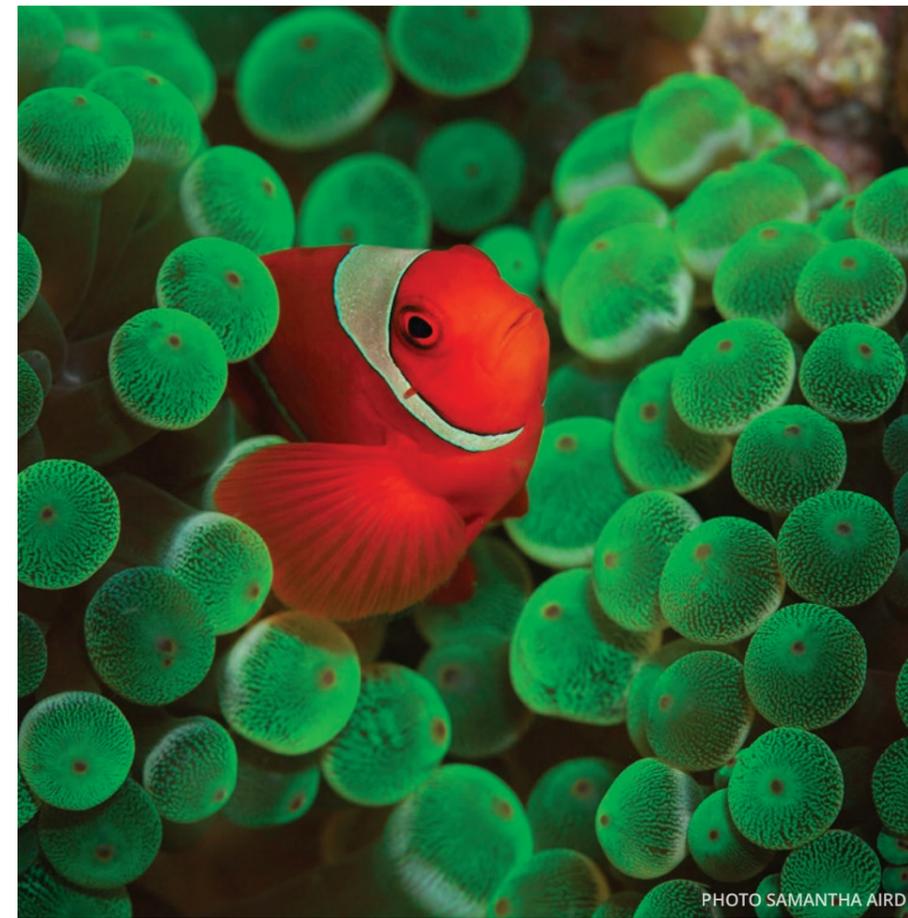


PHOTO SAMANTHA AIRD



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PHOTO SAMANTHA AIRD

conducted in Western Australia were also published in 2019. These new studies in *Nature Climate Change*, conducted by Steeve Comeau, Chris Cornwall and Tom DeCarlo, showed that water flow can have significant physiological effects on the calcifying fluid within coral tissues, as determined using novel geochemical and spectroscopic proxies (p32).

New studies by researchers in Program 3 this year highlighted the effects of various pollutants on coral reef organisms. Research by Mia Hoogenboom and collaborators in *Environmental Pollution*, revealed species-specific effects of microplastics on reef corals, and quantified levels of plastic debris in a river system that flows into the Great Barrier Reef catchment. Experimental studies conducted by Philip Munday and colleagues evaluated the effects of oil exposure on the sensory systems of coral reef fish (*Environmental Science & Technology*), and work by Mark McCormick showed the effects of exposure to boat noise on reef fish behaviour (*Scientific Reports*). Janice Lough developed and implemented new tools, based on the chemical composition of coral skeletons, to understand past and present concentrations of sediment and nutrients in coral reef waters (*Coral Reefs*).

In 2019, Program 3 researchers contributed to new understanding of the interactions between marine invertebrates and their single-cell symbionts. Building on the Australian Academy of Science Boden Workshop

hosted by the ARC Centre in 2018, David Miller and Maja Adamska worked with a global network of experts to publish two major outlook papers on symbiosis in the journal *Zoology*. Miller and the late Sylvain Forêt also co-authored a series of high-profile papers, addressing the interactions between reef-building corals and their bacterial and *Symbiodinium* partners. Miller, Adamska, and collaborators made major contributions to understanding the evolution of animal complexity, by developing and implementing novel genomic approaches. Several landmark papers in this area were published in 2019, including the whole genome sequence of *Acropora millepora* (*Genome Biology and Evolution*) and a study of the evolution of genome methylation mechanisms (*Nature Ecology and Evolution*).

In 2019, Program 3 researchers continued their ongoing commitment to public engagement. Maja Adamska contributed to an article about the evolution of animal cell types in the popular science magazine *Quanta*, and an opinion piece in *Nature Ecology and Evolution*. Adamska also co-organised an international workshop on Host-Microbiome Interactions. Jodie Rummer gave a Planet Talk at WOMADelaide, about the effects of oil drilling and pollution on marine life, and presented 'Let's talk: Sharks' at the World Science Festival in Brisbane. Program 3 congratulates Jodie, who was recognised as the 2019 Queensland Young Tall Poppy Scientist of the Year (p8).



PHOTO SAMANTHA AIRD



PHOTO VÍCTOR HUERTAS

## Coral reefs can't return from acid trip



PHOTO CHRISTOPHER CORNWALL

A new study published today in *Nature Climate Change* finds coral reefs are under threat from ocean acidification.

The study was led by researchers from the ARC Centre of Excellence for Coral Reef Studies (Coral CoE). Their results suggest that some corals and coralline algae – the ‘glue’ that holds reefs together – cannot survive the expected acidification of oceans caused by climate change.

“The results validate previous research on ocean acidification threats to coral reefs,” said lead author Dr Steeve Comeau, who is now based at the Sorbonne Université CNRS Laboratoire d’Océanographie de Villefranche sur Mer in France.

Co-author Prof Malcolm McCulloch, from Coral CoE at the University of Western Australia, said the researchers examined the calcifying fluid of four species of coral and two types of coralline algae, under a year-long simulation.

“The effects on the calcifying fluid were rapid and persisted for the whole year,” Prof McCulloch said.

Co-author Dr Chris Cornwall explained coralline algae cements reefs together by acting as a foundation species

and breeding ground for many species, from the poles to the tropics.

“Declines in coralline algae could lead to the loss of important marine species that use the algae as a nursery,” he explained.

“The results also confirm that ocean acidification could have repercussions on the competition between species. This can affect the ecological function of reefs,” Dr Comeau added.

He said the team did find two coral species were resistant to ocean acidification. However, these are corals that were resistant from the start.

“This result indicates they already had an in-built mechanism that made them resistant,” he explained, “whereas sensitive corals were affected from the start and were not actually able to acclimatise.”

The study suggests the composition and function of future reefs — if they can survive climate change — will be very different to what we see today.

Comeau, S, Cornwall, C, DeCarlo, T, Doo, S, Carpenter, R, and McCulloch M (2019). Resistance to ocean acidification in coral reef taxa is not gained by acclimatization. *Nature Climate Change* 9(6): 477-483.

## Investigating in climate change is good business

According to a new study published today in *Science*, reducing the magnitude of climate change is a good investment.

Acting over the next few decades to reduce the rate of change is expected to cost much less than the damage otherwise inflicted – on people, infrastructure and ecosystems – by not taking action.

Climate change impacts are now occurring faster and are more extensive than previously projected. Lead author Prof Ove Hoegh-Guldberg, Deputy Director of the ARC Centre for Excellence for Coral Reef Studies, explained the mismatch. “First, we underestimated the sensitivity of natural and human systems to climate change and the speed at which these changes are happening,” he said.

“Second, we underappreciated the synergistic nature of climate threats, with the outcomes tending to be worse than the sum of the parts. This results in rapid and comprehensive climate impacts, with growing damage to people, ecosystems, and livelihoods.”

For example, sea-level rise can lead to higher water levels during storm events and exacerbate the resulting damage. In already deprived areas this may intensify poverty, creating further disadvantage.

Prof Daniela Jacob, co-author and Director of Climate Services Centre (GERICS) in Germany, is concerned about these rapid changes – especially in regard to unprecedented weather extremes.

“We are already in new territory,” Prof Jacob said.

Since the Paris Agreement, there has been a race to quantify the benefits of limiting warming to 1.5°C to best inform policy to meet this target. “If such policy is not implemented, we will continue on the current upward trajectory of burning fossil fuels and continuing deforestation, which will expand the already large-scale degradation of ecosystems,” Prof Warren from the Tyndall Centre in the UK said.

A recent report from the United Nations projected that as many as a million species may be at risk of extinction over the coming decades and centuries. Climate change is not the only factor—but is one of the most important ones.

“The developing African countries are amongst those most affected in terms of projected impacts on economic growth, in the absence of strong climate change mitigation,” stated Prof Engelbrecht co-author from the Global Change Institute of the University of the Witwatersrand in South Africa.

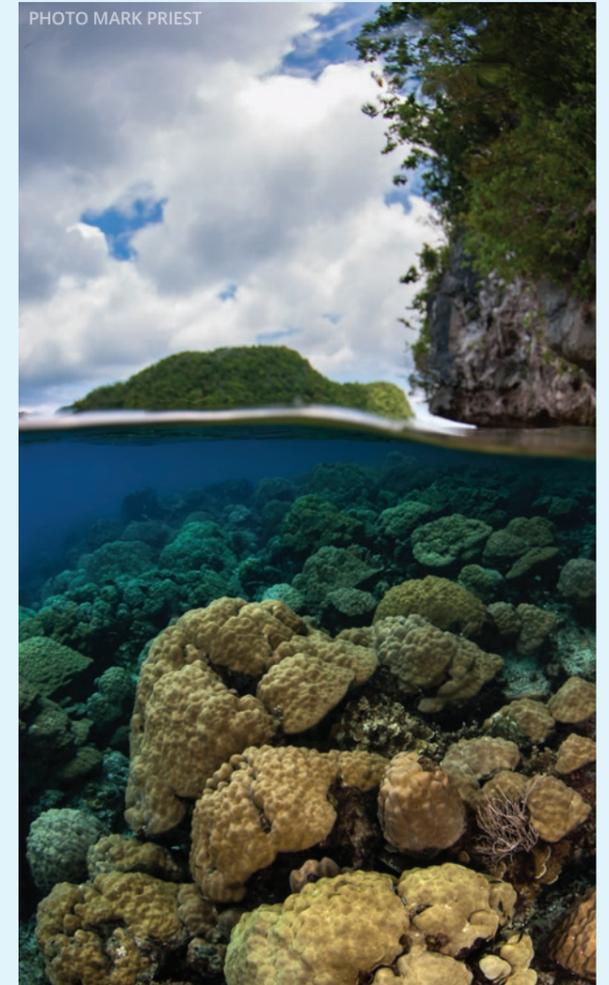


PHOTO MARK PRIEST

“Current emission reduction commitments are inadequate and risk throwing many nations into chaos and harm, with a particular vulnerability for poor peoples,” Prof Hoegh-Guldberg said.

“To avoid this, we must accelerate action and tighten emission reduction targets so that they fall in line with the Paris Agreement,” he said.

“This is much less expensive than suffering the impacts of 2°C or more of climate change.”

Hoegh-Guldberg, O, Jacob, D, Taylor, M, Guillén Bolaños, T, Bindi, M, Brown, S, Camilloni, I, Diedhiou, A, Djalante, R, Ebi, K, Engelbrecht, F, Guiot, J, Hijioka, Y, Mehrotra, S, Hope, C, Payne, A, Pörtner, H, Seneviratne, S, Thomas, A, Warren, R, and Zhou, G (2019). The human imperative of stabilizing global climate change at 1.5°C. *Science* 365(6459).

## RESEARCHER PROFILE: OVE HOEGH-GULDBERG

Ove Hoegh-Guldberg is Deputy Director of the ARC Centre and in the Responding to a Changing Program (Program 3), based at The University of Queensland. Growing up in Sydney, Ove spent his youth exploring and diving in Sydney Harbour. His interest in coral reefs was heightened when he had the opportunity to be an undergraduate field assistant for Professor Peter Sale on One Tree Island. After seeing some of the world's most spectacular reefs, Ove's fate was sealed.

Ove's PhD studies at the University of California, Los Angeles, were on the symbiosis of dinoflagellates with cnidarian hosts. Fieldwork in Israel and at Lizard Island led him to research that identified elevated temperatures as the most likely trigger for coral bleaching events that were commencing on the Great Barrier Reef in the mid-1980s. Following his PhD, Ove completed a postdoctoral fellowship at the University of Southern California (which involved ice diving in Antarctica!), before he returned to Australia to take up a lectureship at the University of Sydney.



Continuing his interest in climate change and coral reefs, Ove and his team identified the collapse of PSII/ RuBisCo under heat stress as the most likely mechanism explaining the sudden disintegration of coral-algal symbioses during heat stress. In 1999, Ove integrated these observations with the output of a number of climate models, projecting for the first time that tropical oceans would get too warm for coral reefs by mid-century if we didn't rapidly curb emissions of greenhouse gases. Two decades later, these projections have been sadly supported by the catastrophic loss of 50% of shallow water corals on the Great Barrier Reef and other sites globally.

As evidence has accumulated about the huge threat that ocean warming and acidification poses for coral reefs, Ove and colleagues have increasingly built research programs for understanding the problems and solutions for coral

reefs globally. For example, the XL-Catlin Seaview Survey measured the benthic structure over 1000 km of coral reefs across 25 countries. Ove also plays a significant role in the United Nations Intergovernmental Panel on Climate Change (IPCC), such as Coordinating Lead Author of the 'Ocean' chapter for the *Fifth Assessment Report*, and the 'Impacts' Chapter in the IPCC Special Report on the implications of global warming of 1.5°C.

Ove has authored over 350 peer-reviewed publications (>35 in *Science*, *Nature* or *PNAS*) and has been cited nearly 60,000 times. He has been awarded a *Eureka Prize* for his research, as well as a *Queensland Premier's Fellowship*, and an *ARC Australian Laureate Fellowship*. He was elected to the Australian Academy of Science in 2013, received the *Prince Albert II Award for Climate Change* in 2014, and the *International Award* from the Banksia Foundation in 2016. Ove is a *Highly Cited Researcher* (top 1% of his field) and, in 2019, was listed by *Apolitical* as one of the 100 most influential people in Climate Policy in the world.



PHD student Robert Streit captures an image of a large jellyfish harbouring a school of small fish in the Lizard Island lagoon during a research trip in January 2019

PHOTO ROBERT STREIT

# 'Bright white skeletons': some Western Australian reefs have the lowest coral cover on record

by James Paton Gilmour and Rebecca Green



Corals at Scott Reef in 2012, and at the same site during the 2016 mass bleaching. James Gilmour/AIMS

Diving on the remote coral reefs in the north of Western Australia during the world's worst bleaching event in 2016, the first thing I noticed was the heat. It was like diving into a warm bath, with surface temperatures of 34°C.

Then I noticed the expanse of bleached colonies. Their bright white skeletons were visible through the translucent tissue following the loss of the algae with which they share a biological relationship. The coral skeletons had not yet eroded and collapsed, a grim reminder of what it looked like just a few months before.

I spent the past 15 years documenting the recovery of these reefs following the first global coral bleaching event in 1998, only to see them devastated again in the third global bleaching event in 2016.

The WA coral reefs may not be as well known as the Great Barrier Reef, but they're just as large and diverse. And they too have been affected by cyclones and coral bleaching. Our recent study found many WA reefs now have the lowest coral cover on record.

When my colleague, Rebecca Green, witnessed that mass bleaching for the first time, she asked me how long it would take the reefs to recover.

"Probably not in my lifetime" was my reply – an abrupt but accurate reply considering the previous rate of recovery, future increases in ocean temperatures ... and my age.

## The worst mass bleaching on record

A similar scene is playing out around the world as researchers document the decline of ecosystems they have spent a lifetime studying.

Our study, published in the journal *Coral Reefs*, is the first to establish a long-term history of changes in coral cover across eight reef systems, and to document the effects of the 2016 mass bleaching event at 401 sites across WA.

Given the vast expanse of WA coral reefs, our assessment included data from several monitoring programs and researchers from 19 institutions.

These reefs exist in some of the most remote and inaccessible parts of the world, so our study also relied on important observations of coral bleaching from regional managers, tourist operators and Bardi Jawi Indigenous Rangers in the Kimberley.

Our aim was to establish the effects of climate change on coral reefs along Western Australia's vast coastline and their current condition.

The heat stress in 2016 was the worst on record, causing mass bleaching and large reductions in coral cover at Christmas Island, Ashmore Reef and Scott Reef. This was also the first time mass bleaching was recorded in the southern parts of the inshore Kimberley region, including in the long oral history of Indigenous Australians who have managed this Sea-Country for thousands of years.

The mass bleaching events we documented were triggered by a global increase in temperature of 1°C above pre-industrial levels, whereas temperatures are predicted to rise by 1.5°C between 2030 and 2052.

In that scenario, the reefs that have bleached badly will unlikely have the capacity to fully recover, and mass bleaching will occur at the reefs that have so far escaped the worst impacts.

The future of WA's coral reefs is uncertain, but until carbon emissions can be reduced, coral bleaching will continue to increase.

## Surviving coral reef refuges must be protected

The extreme El Niño conditions in 2016 severely affected the northern reefs, and a similar pattern was seen in the long-term records.

The more southern reefs were affected by extreme La Niña conditions – most significantly by a heatwave in 2011 that caused coral bleaching, impacted fisheries and devastated other marine and terrestrial ecosystems.

Since 2010, all of WA's reefs systems have bleached at least once.

have been affected equally.

In 2016 there was little (around 10%) bleaching recorded at the northern inshore Kimberley Reefs, at the Cocos Keeling Islands, and at the Rowley Shoals. Coral cover and diversity at these reefs remain high.

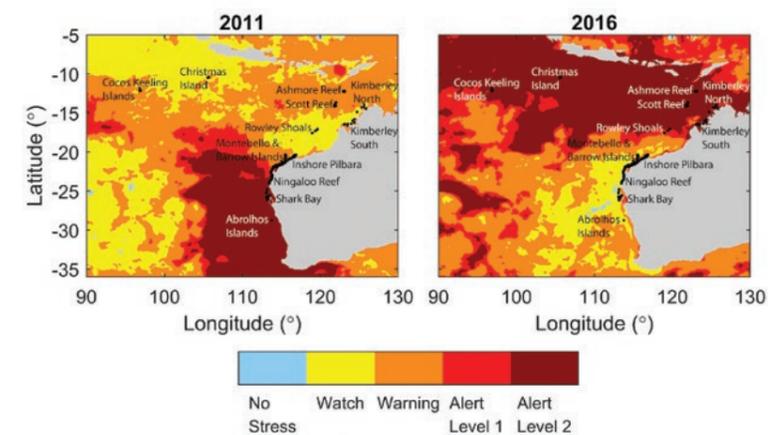
And during mass bleaching there were patches of reef that were less affected by heat stress.

These patches of reef will hopefully escape the worst impacts and retain moderate coral cover and diversity as the world warms, acting as refuges. There are also corals that have adapted to survive in parts of the reef where temperatures are naturally hotter.

Some reefs across WA will persist, thanks to these refuges from heat stress, their ability to adapt and to expand their range. These refuges must be protected from any additional stress, such as poor water quality and overfishing.

In any case, the longer it takes to curb carbon emissions and other pressures to coral reefs, the greater the loss will be.

Coral reefs support critical food stocks for fisheries around the world and provide a significant contribution



NOAA Coral Reef Watch Annual maximum bleaching alert levels for WA in 2011 and 2016. Black marks show bleaching observations or coral monitoring sites. No stress = no bleaching; warning = possible bleaching; alert level 1 = bleaching likely; alert level 2 = mortality likely. NOAA, Author provided (No reuse)

Frequent bleaching and cyclone damage have stalled the recovery of reefs at Shark Bay, Ningaloo and at the Montebello and Barrow Islands. And coral cover at Scott Reef, Ashmore Reef and at Christmas Island is low following the 2016 mass bleaching.

In fact, average coral cover at most (75%) reef systems is at or near the lowest on record. But not all WA reefs

to Australia's Blue Economy, worth an estimated A\$68.1 billion.

We are handing environmental uncertainty to the next generation of scientists, and we must better articulate to everyone that their dependence on nature is the most fundamental of all the scientific concepts we explore.

THE CONVERSATION <https://theconversation.com/bright-white-skeletons-some-western-australian-reefs-have-the-lowest-coral-cover-on-record-116423>

## Great Barrier Reef Governance

The global dynamics of greenhouse gas emissions represents the single largest threat to the world's coral reefs. The Centre's research on climate change, including a series of high profile papers in *Science* and *Nature* in 2017-2019, has been highly influential in drawing attention to the governance challenges of anthropogenic climate change (GBRMPA 2019). Drawing on the Centre's research, the Intergovernmental Panel on Climate Change (IPCC) Special Report (2018) concluded that most coral reefs will struggle to cope with further increases of global average temperatures of 0.5°C to 1°C above current levels. The Special Report concluded that global carbon emissions need to be slashed to 45% of 2010 levels by 2030 to secure the future of coral reefs.

Governance – the ways in which sectors of society share power and make decisions – is an area of active multidisciplinary research in the ARC Centre of Excellence for Coral Reef Studies. Governance has two interacting elements, formal and informal. Formal governance of the Great Barrier Reef is primarily the responsibility of the Commonwealth and Queensland State governments and their agencies, with international oversight from UNESCO and the World Heritage Committee. The informal governance of the Great Barrier Reef is increasingly powerful and diverse, and has played an often-unrecognised role in stewardship of the Reef.

Governance of the Great Barrier Reef, broadly defined, has evolved substantially over time – from a local mix of fishing and tourism stakeholders, local conservation groups, scientists, and Traditional Owners to a much more complex governance regime today that now includes the fossil fuel and mining industries, ports, agricultural industries, the media, international tourists, and globally-active environmental NGOs. Increasingly, securing a future for the Great Barrier Reef under climate change is as much a political challenge as an ecological or social one (Morrison *et al.* 2019).

The establishment of the Great Barrier Reef Marine Park Authority (GBRMPA) in 1976 was a major innovation in governance. It established the world's largest marine protected area, which five years later, in 1981, became the first marine World Heritage Area. However, four decades later, the major drivers affecting the Property all originate outside

its boundary, especially climate change. The proximate drivers of fishing and pollution on the GBR are themselves driven by distant dynamics in national and transnational markets, consumption, wealth and human demography. The Centre's recent research has focussed on addressing this mismatch in scale and framing (Bellwood *et al.* 2019, Morrison *et al.* 2019).

Poorly-scaled governance has focused attention on symptoms (e.g. loss of corals, outbreaks of crown-of-thorns starfish), rather than the root causes of ecological decline. For example, the recent global coral bleaching events have further exposed the limitations of conventional place-based ecosystem governance. In some countries, the preferences of the fossil fuel industry continue to outweigh those of the local communities, tourism and fishing industries, scientists, conservationists and domestic and international visitors.

In an article published in *Nature* in 2019, researchers from the ARC Centre suggested a new, holistic approach to safeguarding coral reefs – by focussing on the formal and informal governance of land as well as the ocean.

“We must take a new, bolder approach to tackle the underlying causes of coral reef decline,” lead author Prof Morrison said. “This means fixing the causes on a global, as well as local, scale—both in the sea and on land.”

As an example, to protect the Great Barrier Reef, Prof Morrison suggested policymakers in Australia should replace coal-fired power with renewable energy sources, and restore or rehabilitate terrestrial vegetation and wetlands in the 425,000-square-



PHOTO DEBORAH BURN

kilometre catchment of the Great Barrier Reef.

“Done strategically, these actions can reduce global emissions, capture carbon, curb agricultural runoff onto coastal reefs while also enhancing people's livelihoods and food security,” she said.

The *Nature* article argues that current approaches to coral reef conservation are failing to protect local biodiversity on reefs, where trying to restore damaged corals or build resilience is the main focus. The authors concluded that reefs won't disappear if we tackle the root cause of their decline. They suggest that a bolder, scaled-up approach to the stewardship of land and sea—focused initially on coral reefs—could itself help society meet this goal. Coral reefs cover only 0.5% of the ocean floor, but they support almost 30% of the world's marine fish species. 400 million people depend on reefs for work, food and protection from waves, storms and floods.

“What we're suggesting is feasible and bold,” the authors said. “Countries, States and cities such as Costa Rica, California and Copenhagen have all taken up initiatives to curb greenhouse gas emissions and

provide alternative economic opportunities that set powerful examples for the rest of the world.”

The *Nature* article urges scientists, -policymakers, non-governmental organisations and philanthropists to develop similarly bold strategies to protect reefs, other ecosystems and people in a warming world.

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# The Great Barrier Reef outlook is 'very poor'. We have one last chance to save it.

by Terry Hughes



Tourists on the Great Barrier Reef, the outlook for which has been officially rated "very poor"

It's official. The outlook for the Great Barrier Reef has been downgraded from "poor" to "very poor" by the Australian government's own experts.

That's the conclusion of the latest five-yearly report from the Great Barrier Reef Marine Park Authority, released on Friday. The report assessed literally hundreds of scientific studies published on the reef's declining condition since the last report was published in 2014.

The past five years were a game-changer. Unprecedented back-to-back coral bleaching episodes in 2016 and 2017, triggered by record-breaking warm sea temperatures, severely damaged two-thirds of the reef. Recovery since then has been slow and patchy.

Looking to the future, the report said "the current rate of global warming will not allow the maintenance of a healthy reef for future generations [...] the window of opportunity to improve the reef's long-term future is now".

But that window of opportunity is being squandered so long as Australia's and the world's greenhouse gas emissions continue to rise.

## The evidence on the reef's condition is unequivocal

A logical national response to the Outlook Report would be a pledge to curb activity that contributes to global warming and damages the reef. Such action would include a ban on the new extraction of fossil fuels, phasing out coal-fired electricity generation, transitioning to electrified transport, controlling land clearing and reducing local stressors on the reef such as land-based runoff from agriculture.

But federal Environment Minister Sussan Ley's response to the outlook report suggested she saw no need to take dramatic action on emissions, when she declared: "it's the best managed reef in the world".

The federal government's lack of climate action was underscored by another dire report card on Friday. Official quarterly greenhouse gas figures showed Australia's greenhouse gas emissions have risen to the highest annual levels since the 2012-13 financial year.

But rather than meaningfully tackle Australia's contribution to climate change, the federal government has focused its efforts on fixing the damage wrought on the reef. For example as part of a A\$444 million

grant to the Great Barrier Reef Foundation, the government has allocated \$100 million for reef restoration and adaptation projects over the next five years or so.

Solutions being supported by the foundation include a sunscreen-like film to float on the water to prevent light penetration, and gathering and reseeded coral spawn. Separately, Commonwealth funds are also being spent on projects such as giant underwater fans to bring cooler water to the surface.

But the scale of the problem is much, much larger than these tiny interventions.

## Climate change is not the only threat to the reef

The second biggest impact on the Great Barrier Reef's health is poor water quality, due to nutrient and sediment runoff into coastal habitats. Effort to address that problem are also going badly.



Major coral bleaching events in 2016 and 2017 have devastated the reef.

PHOTO BETTE WILLIS

This was confirmed in a confronting annual report card on the reef's water quality, also released by the Commonwealth and Queensland governments on Friday.

It showed authorities have failed to reach water quality targets set under the Reef 2050 Plan – Australia's long-term plan for improving the condition of the reef.

For example the plan sets a target that by 2025, 90% of sugarcane land in reef catchments should have adopted improved farming practices. However the report showed the adoption had occurred on just 9.8% of land, earning the sugarcane sector a grade of "E".

## So yes, the reef is definitely in danger

The 2019 Outlook Report and other submissions from Australia will be assessed next year when the UNESCO World Heritage Committee meets to determine if the Great Barrier Reef should be listed as "in danger" – an outcome the federal government will fight hard to avoid.

An in-danger listing would signal to the world that the Reef was in peril, and put the federal government under greater pressure to urgently prevent further damage. Such a listing would be embarrassing for Australia, which presents itself as a world's-best manager of its natural assets.

The Outlook Report maintains that the attributes of the Great Barrier Reef that led to its inscription as a world heritage area in 1981 are still intact, despite the loss of close to half of the corals in 2016 and 2017.

But by any rational assessment, the Great Barrier Reef is in danger. Most of the pressures on the reef are ongoing, and some are escalating – notably anthropogenic heating, also known as human-induced climate change.

And current efforts to protect the reef are demonstrably failing. For example despite an ongoing "control" program, outbreaks of the damaging crown-of-thorns starfish – triggered by poor water quality – have spread throughout the reef.

The federal government has recently argued that climate change should not form the basis for an in-danger listing, because rising emissions are not the responsibility of individual countries. But as Australia's greenhouse gas emissions continue to rise, the continued downward trajectory of the Great Barrier Reef is inevitable.

THE CONVERSATION <https://theconversation.com/the-great-barrier-reef-outlook-is-very-poor-we-have-one-last-chance-to-save-it-122785>

A vertical underwater photograph showing a diver in a coral reef environment. The diver is wearing a black wetsuit, a white tank, and yellow fins. They are positioned in the center-left of the frame, looking towards the right. The water is clear and blue, with sunlight filtering through from the top. The reef is composed of various coral structures, including a prominent, dark, branching structure in the foreground. The overall scene is vibrant and detailed, capturing the beauty of the underwater world.

## GRADUATE AND EARLY CAREER TRAINING

The ARC Centre of Excellence's objective is to build human capacity and expertise in coral reef science worldwide. Our capacity-building has a global footprint: in 2019, the Centre provided training and mentoring to 124 international graduate students from 36 countries, representing 74% of our research student membership. Almost 70% of the Centre's Early Career Researchers (ECRs) come from overseas.

Students and ECRs are essential contributors to the Centre's activities, publication outputs and success. During 2019, the Centre provided supervision, research funding and support to 170 research students across the four nodes of the Centre, >80% of whom are PhD students and 60% are women. Twenty-seven students completed their PhDs in 2019, while we welcomed 39 new graduate students. The ARC Centre also supports 30 Early Career Researchers.

The Centre has created an exciting and multi-disciplinary intellectual environment, with 52 students having multi-disciplinary advisory panels, and 50 receiving cross-institutional supervision.

Key to the student experience in the Centre of Excellence is extensive mentoring and training opportunities, to build the next generation of coral reef research leaders. Quantitative and modeling skills continued to be a priority. For example, in March, 30 students and ECRs attended training courses in advanced statistics, using the R platform. Overwhelmingly positive feedback from participants reaffirmed the annual running of this course, presented by Murray Logan from our Centre-partner the Australian Institute of Marine Science. Weekly 'CodeR' group meetings, hosted by DECRA Fellow Peter Cowman, provided statistics support, short talks and workshops on R, Python and Bash programming languages.

Writing retreats are a new addition to the Centre's professional development program in 2019. Four retreats were hosted for students, in addition to weekly 'Shut-up and Write' sessions. The three-day retreats enable students to do extensive writing in a supportive environment, removed from everyday distractions. Survey responses from students revealed strong support for this activity, which encourages them to develop their thesis write-up in a collaborative environment.

Scientific writing skills continues to be a major focus of our training. Morgan Pratchett ran three workshops throughout the year, on efficient and effective scientific writing. In August, Joshua Cinner hosted a 'Getting Published' workshop for PhD students and ECRs. Topics

included how to structure manuscripts effectively, the peer-review process, and building a portfolio of publications. Joshua's workshop was also offered to all students attending the annual Australian Coral Reef Society Conference in 2019, as part of the ARC Centre's National Student Mentoring Day, a long-standing and popular event. Joshua also ran this popular workshop in Kenya and at the University of Rhode Island, USA.

Communications and outreach was also a recurring feature of student and ECR training during 2019. In March, Alana Grech and Sean Connolly presented a workshop on 'Preparing your ARC ROPE' for ECRs submitting Australian Research Council grant applications. Michele Barnes led a session on 'How to wow the crowd with an effective scientific presentation', focusing on both seminars and preparing for job interviews. Maria Nayfa, the Centre's new Digital Communications Officer, led multi-nodal workshops on 'Creating video content for social media' and 'Let's talk media'. Maria also ran workshops and one-to-one mentoring sessions for students, on developing concise oral presentations of their research. One participant, Alexandre Siqueira Correa, won both the judges and popular prize at JCU's 'My research in three minutes' competition before going on to represent JCU at the national competition.

The ARC Centre supports a cross-nodal Student Committee and a Postdoctoral Committee, each of which is allocated funds and administrative support to develop an annual program of professional development. Thanks go to the 2019 Student Committee co-chairs, Katie Sievers and Shannon McMahon, and committee members Deborah Burn, Amy Coppock, Mike Mihalitsis, Henry Bartelet, Grace Cole, Laura Puk, Karin Zweip and Netra Sagar from the JCU, UQ and UWA nodes of the Centre. Thanks also to Peter Cowman and Jenni Donelson who chaired the Postdoc Committee in 2019.

A major focus of both committees is the design and implementation of the annual research student and ECR retreats, convened in conjunction with the ARC Centre's Annual Symposium. The 2019 student retreat was held in association with the Sydney Institute of Marine Science on Sydney Harbour. Fifty-three Centre students benefitted from the opportunity to collaborate with SIMS researchers, through scientific talks, presentations on how to review manuscripts, and on creating an effective covering letter and CV for job applications. The ECR retreat featured a session on 'Tips and Tricks for ARC Success' as well as a series of scientific and career development presentations, and a distinguished panel discussion featuring Gretta Pecl

(University of Tasmania), Iain Suthers (UNSW), Martina Doblin (UTS), Joey Dibattista (Curtin University) and Matt England (UNSW). Both committees also organised multiple social events across the four nodes of the Centre, enhancing the Centre's inclusive and supportive culture.

ARC Centre of Excellence students received wide recognition for their research in 2019, for example:

- Jessica Cramp was appointed as an *AAAS IF/THEN Ambassador* by the American Association for the Advancement of Science and Lyda Hill Philanthropies.
- Justin Geldard received a prestigious *Keiran McNamara World Heritage Scholarship*, to represent Australia at the international *Our Ocean Youth Leadership Summit* in Norway.
- Camille Grimaldi won the *Australian Marine Sciences Association (AMSA) Diversity Prize* for her presentation at the 2019 conference. Camille and Mario Conde-Frias won *Robson and Robertson Awards* to support their research.
- Mila Grinblat was awarded the *Robert Logan Memorial Bursary*, to attend the workshop 'At the roots of bilaterian complexity: insights from early emerging metazoans' in Germany. Mila also won an *Australian Coral Reef Society (ACRS) Travel Award* to attend the Society's 2019 conference, and she received an *Orpheus Island Research Station Morris Family Trust Student Grant*.
- Victor Huertas Martin and Ramona Brunner won *ACRS Student Research Awards*.
- Kelly Hannan attracted a *Sea World Research and Rescue Foundation Grant* and was also awarded the *2019 Lizard Island Reef Research Foundation Fellowship*.
- Jacqueline Lau won the best paper award at the *MARE People and the Sea Conference*, in Amsterdam.
- Sarah Lawless won the best paper award at the *Global Conference on Gender in Aquaculture and Fisheries*, in Bangkok.
- Michael McWilliam's PhD thesis was awarded *Cum Laude* at JCU.
- Pauline Narvaez and Laura Velasquez were awarded travel grants to attend the Australian Society of Fish Biology Conference, and Christopher Hemingson won the *Best Graduate Student Presentation* at the conference. Laura Velasquez also won a *Company of Biologists Travel Grant*, to attend the Society of Experimental Biology conference in Spain.
- Carrie Sims and Pauline Narvaez were awarded *Holsworth Wildlife Research Endowments* by the Ecological Society of Australia.
- Patrick Smallhorn-West was selected as an Explorer in National Geographic's 2019 Early Career Leadership Program.

- Rachel Spinks won an *Australian Academy of Science Mobility Grant* to attend the Re:produce workshop, and a *Max Planck Institute for Evolutionary Biology Travel Grant* to attend their workshop 'Causes and Consequences of Inclusive Inheritance' in Europe.
- Sterling Tebbet's research was supported by an *International Coral Reef Society Graduate Fellowship* and an *Orpheus Island Research Station Morris Family Trust Student Grant*.
- Cassie Thompson won the *Ron Kenny Student Poster Prize* at the AMSA's annual conference.
- Carolyn Wheeler was awarded an *Australia Graduate Education Scholarship* from the American Australian Association, to support her PhD research.
- Jacqueline Lau received the 2019 *Glenn Almany Memorial Prize* for her research in Papua New-Guinea on understanding the importance of ecosystem services in developing coastal communities. This prize is awarded to a Centre graduate student whose research required them to work with people beyond traditional academic boundaries, to make a difference or which has the potential to influence policy, management or practice.

Lau, J, Hicks, C, Gurney, G and Cinner, J (2019). What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosystem Services* 35:219-230.

- The ARC Centre's *Virginia Chadwick Awards* recognise the most five most outstanding publications each year by ARC Centre of Excellence graduate students. In 2019, the recipients were Harry Clarke, Saskia Juriaans, Sun Kim, Renato Morais, and Ed Roberts, who are based at three nodes of the Centre of Excellence – James Cook University, The University of Queensland and The University of Western Australia:

Clarke, H, D'Olivo, JP, Conde, M, Evans, RD and McCulloch, M (2019). Coral records of variable stress impacts and possible acclimatization to recent marine heat wave events on the Northwest Shelf of Australia. *Paleoceanography and Paleoclimatology* 34(11): 1672-1688.

Jurriaans, S and Hoogenboom, MA (2019). Thermal performance of scleractinian corals along a latitudinal gradient on the Great Barrier Reef. *Philosophical Transactions of the Royal Society B: Biological Sciences* 374: 20180546.

Kim, SW, Sampayo, EM, Sommer, B, Sims, CA, Gómez-Cabrera, MDC, Dalton, SJ, Begger, M, Malcolm, HA, Ferrari, R, Fraser, N, Figueira, WF, Smith, SDA, Heron, SF, Baird, AH, Byrne, M, Eakin, CM, Edgar, R, Hughes, TP, Kyriacou, N, Liu, G, Matis, PA, Skirving, WJ and Pandolfi, JM (2019). Refugia under threat: mass bleaching of coral assemblages in high-latitude eastern Australia. *Global Change Biology* 25(11): 3918-3931.

Morais, RA, Connolly, SR and Bellwood, DR (2019). Human exploitation shapes productivity-biomass relationships on coral reefs. *Global Change Biology* doi.org/10.1111/gcb.14941.

Roberts, TE, Bridge, TCL, Caley, MJ, Madin, JS and Baird, AH (2019). Resolving the depth zonation paradox in reef-building corals. *Ecology* 100(8):e02761.

## 2019 PHD STUDENTS IN THE ARC CENTRE

Student Name	University	Country	Thesis Title	ARC Centre Advisers
Samantha Aird	JCU	Australia	Socio-ecological dynamics in archaeological shellfish fisheries: a case from the Keppel Islands, Great Barrier Reef, Australia.	A Hoey
Mariana Alvarez Noriega	JCU	Mexico	Competition and coexistence of reef-corals. (PhD awarded)	S Connolly, A Baird, M Hoogenboom
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.	R Pressey, S Connolly, T Bridge
Eoghan Aston	JCU	United Kingdom	Spatial dynamics of tropical shallow marine habitats and their related mobile marine faunal communities.	A Hoey
Kevin Bairos Novak	JCU	Canada	Metapopulation dynamics of coral polyp dispersal and juvenile fish recruitment after severe bleaching events.	S Connolly, M Hoogenboom
Henry Bartelet	JCU	Netherlands	The resilience of ecologically-dependent human communities to disturbances within volatile social-ecological systems.	G Cumming, S Connolly
Anne Bauer-Civiello	JCU	USA	From people to reef, marine debris and plastic pollution in north Queensland.	M Hoogenboom
Makeely Blandford	JCU	Australia	Interactions between fish and coral reefs: the influence of habitat degradation on fish communities.	M McCormick, A Hoey
Joshua Bonesso	UWA	Australia	Underpinning reef-island resilience to climate driven changes in metocean states in the Pilbara Archipelago, North West, Western Australia.	R Lowe
Chloë Boote	JCU	United Kingdom	The larval development, microbiome, and stress response of the mushroom coral <i>Heliofunga actiniformis</i> .	D Miller, A Moya
Ian Bouyoucos	JCU, CRIOBE	USA	A challenging environment in a changing world for juvenile sharks: ecological energetics of climate change with implications toward conservation.	J Rummer
Christopher Brunner	JCU, AIMS	Germany	Cumulative impacts of water quality and climate change (sea surface temperature warming and ocean acidification) on important reef species.	M Hoogenboom
Ramona Brunner	JCU	Germany	The function and ligands of G-protein coupled receptors (GPCRs) in coral larvae settlement.	D Miller, A Moya
Cüneyt Caglar	ANU	Germany	Sponge and coral regeneration: cellular and molecular characterisation of regeneration in reef-building invertebrates.	M Adamska
Paula Cartwright	UWA	Australia	Metocean processes and anthropogenic influences in the southern coastal Pilbara/Exmouth Gulf: what are the primary drivers of water quality and habitat distribution?	R Lowe
Leela Chakravarti	JCU, AIMS, U Melbourne	United Kingdom	Manipulation of coral photosymbionts for enhancing resilience to environmental change. (PhD awarded)	M Hoogenboom
Tory Chase	JCU	USA	Effects of coral-dwelling damselfishes abundance and diversity on host coral dynamics. (PhD awarded)	M Hoogenboom, M Pratchett
Sivee Chawla	JCU	India	Understanding ecosystem service choices made by individual actors and their implications for social-ecological interactions.	G Cumming, T Morrison
Carolina Chong-Montenegro	UQ, U.Exeter	Ecuador	Examining trajectories of decline of megafauna in our coastal seas.	J Pandolfi
Harry Clarke	UWA	Australia	Resolving the impacts of ocean warming and dredging in coral cores collected from the NW shelf of Australia.	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.	A Hoey, G Russ

Student Name	University	Country	Thesis Title	ARC Centre Advisers
Mario Conde-Frias	UWA	Colombia	Investigating the sediment dynamics within submerged canopies for unidirectional and oscillatory flows.	R Lowe
Amy Coppock	JCU	United Kingdom	Climate change and disturbance events: the role of settlement behaviour and larval connectivity in changes to coral reef fish communities.	G Jones, M McCormick
Jessica Cramp	JCU	USA	Evaluating the effectiveness of policy, fisheries management tools and large-scale marine protected areas on wide-ranging sharks.	R Pressey
Benjamin Cresswell	JCU	United Kingdom	The ecology of mesopredator fishes in reef networks: considerations for conservation and fisheries management.	G Jones, M McCormick, H Harrison
Augustine Crosbie	JCU, MTQ	Australia	Integrating physiological and environmental drivers of depth zonation patterns on coral reefs.	A Baird, T Bridge
Amber Datta	JCU, U.Montana	USA	Untapped capacity for adaptation and transformation in coral reef social-ecological systems: exploring governance and discourse in the Great Barrier Reef and Hawaiian Islands	M Barnes, T Morrison
Daniel Raj David	UWA	India	The interaction of WECs in an array and its influence on coastal processes.	R Lowe
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.	R Pressey, T Morrison
Stephanie Di Perna	JCU, AIMS	Canada	Coastal acidification in the benthic boundary layer on inshore reefs: implications on water chemistry and benthic communities.	M Hoogenboom
Beatriz Diaz-Guijarro	JCU	Spain	A comparison of the regeneration stages with developmental stages of corals including those in the family <i>Heliofungia</i> .	D Miller, A Moya
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?	T Hughes, S Connolly
Adam Downie	JCU	Canada	How do coral reef fish develop into athletes?	J Rummer, P Cowman
Ameer Ebrahim	UQ, USC	Seychelles	The role of rabbitfish in a marine environment, and their contribution towards the resilience of tropical coral reefs.	P Mumby
Estefania Erazo Mera	JCU	Ecuador	Assessing cumulative impacts of land use in the wet tropics catchments on the Great Barrier Reef: remote sensing and Bayesian modelling for a new conservation planning scheme.	B Pressey, A Grech
Nicolas Evensen	UQ, CSIRO	United Kingdom	Bottlenecks of coral recovery on degraded reefs. (PhD awarded)	P Mumby, YM Bozec
Legana Fingerhut	JCU	Netherlands	Genome wide detection and evolutionary analysis of antimicrobial peptide repertoires in corals.	D Miller
Fikri Firmansyah	UQ	Indonesia	Optimizing fisheries management tools implementation to sustain tropical reef fisheries.	P Mumby
Eric Fisher	JCU, AIMS	Australia	Spawning aggregation sites on tropical reefs.	M McCormick
Renan Fonseca da Silva	UWA	Brazil	Understanding and predicting the impact of submerged structures on coastal processes with application to wave energy converters.	R Lowe
Kerrie Fraser	UQ, JCU	Australia	Marine protected areas: evaluating policy efficacy and impact in conserving biodiversity. (PhD awarded)	J Pandolfi, R Pressey
Gemma Galbraith	JCU	United Kingdom	Submerged pinnacle coral reefs; reef fish ecology and functional connectivity.	G Jones, M McCormick
Justin Geldard	UWA	Australia	Impact of surface wave hydrodynamics on coral reef structures.	R Lowe

Student Name	University	Country	Thesis Title	ARC Centre Advisers
Bettina Glasl	JCU, AIMS	Austria	Microbial Indicators for environmental stress and ecosystem health assessment.	B Willis
Saul Gonzalez Murcia	JCU	El Salvador	The impact of parrotfishes on the coral new recruits.	G Jones, G Russ
Alexia Graba-Landry	JCU	Canada	The effect of temperature on seaweed-herbivore interactions on tropical coral reef systems.	A Hoey, M Pratchett
Shanna Grafeld	JCU	USA	Market structures, trade networks and governance of coral reef fisheries across a development gradient.	M Barnes, J Cinner, T Morrison
Ruby Grantham	JCU, WorldFish	United Kingdom	The temporal dynamics of reef fisheries as part of diversified coastal livelihoods.	G Cumming, D Mills
Camille Mathilde Grimaldi	UWA, AIMS	France	Oceanography drivers of coral reef connectivity of north western Australia.	R Lowe
Mila Grinblat	JCU	Russia	Sex change and gene expression in <i>Fungia fungites</i> coral.	D Miller, P Cowman
Rodrigo Gurdek	JCU, AIMS	Uruguay	Spatial and temporal connectivity dynamics on the Great Barrier Reef Marine Park using genomics and biophysical modelling.	H Harrison
Nataly Gutierrez Isaza	UQ	Colombia	Ecological stoichiometry of corals, symbionts and macroalgae along the latitudinal gradient in eastern Australia.	J Pandolfi
Nicholas Hammerman	UQ	USA	Historical response of Red Sea coral habitats to environmental change.	J Pandolfi
Kelly Hannan	JCU	USA	The mechanisms underpinning maintained or enhanced performance of coral reef fishes under elevated carbon dioxide conditions.	J Rummer, P Munday
Kynan Hartog -Burnett	JCU	Australia	Population ecology of common baitfish species in the Indo-Pacific.	M Kingsford
Margaux Hein	JCU, CSIRO, GBRMPA	Monaco	Characterising the effectiveness of coral restoration to build reef resilience: a socio-ecological perspective. (PhD awarded)	B Willis
Christopher Hemingson	JCU	USA	The evolution, biogeography and ecological significance of colour in coral reef fishes.	D Bellwood, P Cowman
Sybille Hess	JCU	Switzerland	The effects of suspended sediments on the physiology and behaviour of coral reef fishes. (PhD awarded)	J Rummer, A Hoey
Tessa Hill	JCU, MTQ	United Kingdom	Direct and indirect effects of ocean acidification on reef corals.	M Hoogenboom, S-A Watson
Kyle Hillcoat	JCU	Australia	Latitudinal variations in age-based demography of three large predatory reef fishes ( <i>Lutjanus sebae</i> , <i>Lutjanus malabaricus</i> and <i>Lutjanus erythropterus</i> ) in Queensland, Australia.	G Russ, G Jones
Lucy Holmes McHugh	JCU	Australia	Power and participation in seascape conservation in the Anthropocene: how are new governance models turning the tide?	T Morrison, A Song, P Cohen
Jeremy Horowitz	JCU, MTQ	USA	Predicting 'the unknown unknowns' in the global oceans: increasing certainty of species distributions to inform conservation in marine ecosystems.	T Bridge, B Pressey, P Cowman
Victor Huertas Martin	JCU, CNRS	Spain	Feeding ecology of corallivorous reef fishes.	D Bellwood, S Connolly
Michael Jarrold	JCU	United Kingdom	The effects of natural variation in CO <sub>2</sub> and rising CO <sub>2</sub> on coral reef fish. (PhD awarded)	P Munday, M McCormick
Dharini Jha	JCU, AIMS	India	Investigation into artificial intelligence methods for hyperspectral image analysis in coral reef science applications.	M Hoogenboom
Saskia Jurriaans	JCU, Centre Scientifique de Monaco	Netherlands	Thermal performance of scleractinian corals. (PhD awarded)	M Hoogenboom, S Connolly

Student Name	University	Country	Thesis Title	ARC Centre Advisers
Tania Kenyon	UQ	Australia	Physical and biological dynamics of post-disturbance coral reef rubble fields.	P Mumby, S Dove
Catherine Kim	UQ	USA	Determining drivers of benthic composition, marine biodiversity, and coral health in Timor-Leste. (PhD awarded)	O Hoegh-Guldberg, S Dove
Sun Kim	UQ	South Korea	Evolution and ecology of coral range dynamics. (PhD awarded)	J Pandolfi
Felicity Kuek	JCU, AIMS	Malaysia	Dimethylsulfoniopropionate (DMSP) metabolism within the coral holobiont.	D Miller, A Moya
Bethan Lang	JCU	United Kingdom	The effect of ocean warming on the behaviour and fitness of post-settlement crown-of-thorns starfish ( <i>Acanthaster cf. solaris</i> ).	M Pratchett, A Hoey
Marie Lapointe	JCU	Canada	Understanding ecosystem service preferences and wellbeing benefits along a rural-urban gradient.	G Cumming, G Gurney
Jacqueline Lau	JCU, U.Lancaster	Australia	'The Reef is our Garden': expanding analysis of ecosystem services in coastal communities. (PhD awarded)	J Cinner, G Gurney
Taryn Laubenstein	JCU	USA	Relationships between behavioural and physiological performance under elevated CO <sub>2</sub> in marine fishes. (PhD awarded)	P Munday, J Rummer
Sarah Lawless	JCU, WorldFish	Australia	The diffusion of meta-norms in natural resource governance.	T Morrison, P Cohen, A Song
Zoe Loffler	JCU	Australia	The persistence of <i>Sargassum</i> communities on coral reefs: resilience and herbivory. (PhD awarded)	A Hoey, M Pratchett
Jake Lowe	JCU	Australia	Effects of no-take marine reserve protection on abundance and demography of tropical wrasses.	G Russ
Chancey MacDonald	JCU, MTQ	New Zealand	Depth as refuge: depth gradients in ecological pattern, process, and risk mitigation among coral reef fishes. (PhD awarded)	G Jones, T Bridge
Eva Maire	JCU, U.Montpellier	France	Socio-ecological drivers of fish biomass on coral reefs: The importance of accessibility, protection and key species. (PhD awarded)	J Cinner, A Hoey
Samuel Matthews	JCU, AIMS	Australia	Modelling tools for the management of crown-of-thorns starfish ( <i>Acanthaster cf. solaris</i> ) outbreaks on Australia's Great Barrier Reef. (PhD awarded)	M Pratchett, V Messmer
Emmanuel Mbaru (p51)	JCU, U.Lancaster	Kenya	Diffusion of a gear-based conservation innovation: adoption patterns and social-ecological outcomes. (PhD awarded)	J Cinner, T Morrison, M Barnes
Eva McClure	JCU	Australia	No-take marine reserve performance under varying environmental and anthropogenic influences. (PhD awarded)	G Russ, A Hoey
Shannon McMahon	JCU	Australia	Effects of rising water temperature and food availability on predatory reef fish.	J Donelson, P Munday
Jennifer McWhorter	UQ, U.Exeter	United Kingdom	Coral reef futures under climate change and ocean acidification.	P Mumby
Michael McWilliam	JCU	United Kingdom	The functional diversity and redundancy of corals. (PhD awarded <i>Cum laude</i> )	T Hughes, M Hoogenboom
Matheus Antonio Mello Athayde	UQ	Brazil	<i>Porites cylindrica</i> (Dana, 1846), a resilient coral found on the Great Barrier Reef: present and future coral physiology.	S Dove
Michalis Mihalitsis	JCU	Greece	Predator-prey interactions in coral reef fishes: ecology and function.	D Bellwood, S Connolly
Rebecca Millington	UQ, U.Exeter	United Kingdom	Modelling the role of biodiversity in ecosystem resilience to climate change.	P Mumby
Meira Mizrahi	JCU	Australia	Maximizing potential impact of marine protected area (MPA) placement: an integrated socio-economic perspective.	R Pressey

Student Name	University	Country	Thesis Title	ARC Centre Advisers
Jose Montalvo Proano	JCU, AIMS	Ecuador	Mechanisms involved in the potential acclimation of corals to future environmental conditions.	P Munday
Renato Morais Araujo	JCU	Brazil	Habitat effects on coral reef fish growth and biomass production.	D Bellwood, S Connolly
Katie Motson	JCU	United Kingdom	The impacts of coral reef health on fish-parasite interactions.	A Hoey
Pauline Narvaez	JCU	France	Food preferences of cleaner organisms and the impact of cleaning interactions on pathogen transmission.	M McCormick
Tiffany Nay	JCU	USA	Temperature preferences of tropical fishes and the influence of local abiotic and biotic factors.	A Hoey, M Pratchett
Sekondeko Ronnie Noga	JCU	Botswana	Territorial use rights in small-scale fisheries management and the role of collective governance for sustainable fisheries in Botswana.	T Morrison
Nery Contti Neto	UWA	Brazil	Field observations of sediment dynamics within coastal benthic ecosystems.	R Lowe
Samuel Payet	JCU	Australia	The role of hybridisation in the evolution of coral reef fishes.	H Harrison, G Jones, M Pratchett
Katie Peterson	JCU, QUT	USA	Ecological drivers of community stability in space and time.	T Hughes, S Connolly
Mark Priest	UQ, Palau ICRC	United Kingdom	A multi-disciplinary approach to predictive management of coral reef fisheries.	P Mumby
Abdi Priyanto	UQ, MMAF, Indonesia	Indonesia	Marine spatial planning in Indonesia: options for improved efficiency.	P Mumby
Laura Puk	UQ	Germany	Population dynamics of the brown <i>Macroalga lobophora</i> sp. and its control by herbivorous fish.	P Mumby
Veronica Radice	UQ	USA	Trophic ecology and microbial communities of shallow and deep reef-building corals of the Maldives, Indian Ocean. (PhD awarded)	O Hoegh-Guldberg, S Dove
Jeremy Raynal	JCU	USA	Assessing the potential for recreational fishing to contribute to conservation of coastal marine species and habitats.	R Pressey
Johan Risandi	UWA	Indonesia	Assessing the hydrodynamics and morphodynamics of a reef-fringed pocket beach.	R Lowe
Arnold van Rooijen	UWA, Deltares	Netherlands	Wave-driven hydromechanics in coastal canopies. (PhD awarded)	R Lowe
Cristina Ruano Chamorro	JCU	Spain	Equity in fisheries co-management: social-ecological determinants and trade-offs.	J Cinner, G Gurney
Alfonso Ruiz Moreno	JCU	Spain	Spatial and temporal dynamics of reef fish diversity: community ecology and phylogenetics.	S Connolly, D Bellwood
Edmond Sacre	JCU	Australia	Developing spatial prioritisation strategies to maximise conservation impact. (PhD awarded)	R Pressey
Netramani (Netra) Sagar	UWA	India	Reconstructing climate and anthropogenic signals on the Indian Ocean margins using geochemistry of marine calcifiers.	M McCulloch, A Sadekov
Ayse Defne Sahin	UWA	Turkey	Assessing the response of shallow water and deep-sea zooxanthellae corals to climate change using geochemical proxies.	M McCulloch, V Schoepf, R Lowe
Katie Sambrook	JCU, CNRS	United Kingdom	Beyond the reef: the influence of seascape structure on fish communities and ecological processes on reefs.	A Hoey, G Cumming
Jodie Schlaefer	JCU	Australia	Determining the population structures of cubozoan jellyfishes with biophysical modelling.	M Kingsford
Molly Scott	JCU, AIMS	Australia	Spatial and temporal variation in movement patterns and behaviour of a large, coral reef mesopredator, <i>Plectropomus leopardus</i> , on the Great Barrier Reef. (PhD awarded)	M Pratchett

Student Name	University	Country	Thesis Title	ARC Centre Advisers
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.	G Russ, G Jones
Tiffany Sih	JCU, AIMS	USA	Diving into the deep-end: investigating tropical deep-reef fish assemblages. (PhD awarded)	M Kingsford
Carrie Sims	UQ	Australia	Community ecology of corals and their symbionts.	J Pandolfi
Alexandre Siqueira Correa	JCU	Brazil	Regulators of coral reef diversity through space and time.	P Cowman, D Bellwood
Patrick Smallhorn-West	JCU, MTQ	Canada	Efficacy of community-based marine management in the Kingdom of Tonga.	G Jones, T Bridge, B Pressey, G Gurney
Blake Spady	JCU, MTQ	USA	Effects of diel CO <sub>2</sub> cycles on the early development and behaviour of coral reef fishes under ocean acidification. (PhD awarded)	S-A Watson, P Munday,
Jessica Spijkers	JCU, U.Stockholm	Sweden	The future for governing highly migratory straddling stocks: conflict or cooperation?	T Morrison, G Cumming
Rachel Spinks	JCU	Australia	Keeping up with climate change: the evolutionary potential of coral reef fishes to rising sea temperature.	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.	D Bellwood, G Cumming
Sarah Sutcliffe	JCU, WorldFish	Australia	Macro and micro level determinants of the contribution of fish to nutritional security.	J Cinner, M Barnes, A Song
Siham Afatta Kemal Taruc	UQ	Indonesia	An assessment of the sustainability and resilience of livelihoods within an Indonesian marine social-ecological system. (PhD awarded)	O Hoegh-Guldberg
Sterling Tebbett	JCU	Australia	The functioning of future coral reefs: fishes, sediments and productivity.	D Bellwood, S Connolly
Tullia Isotta Terraneo	JCU, KAUST	Italy	Species boundaries in the coral genus <i>Porites</i> : an integrated approach.	A Baird, D Miller
Jodi Thomas	JCU	New Zealand	The neurobiological mechanisms through which ocean acidification effects invertebrate behaviours.	P Munday, S-A Watson
Damian Thomson	JCU	Australia	Resilience of coral assemblages in NW Australia.	A Hoey, M Pratchett
Cheng-Han Tsai	JCU, AIMS	Taiwan	The structure and dynamics of reef fish communities.	S Connolly, D Bellwood
Laura Velasquez Jimenez	JCU	Colombia	Effects of boat noise on parental contributions to the dynamics of coral reef fishes.	M McCormick, G Jones
Casey Whalen	JCU	USA	Coral mediation of associated microbial community.	D Miller, A Moya
Carolyn Wheeler	JCU, U. Mass	USA	Quantifying life history energetics of an oviparous elasmobranch subject to future warming waters.	J Rummer
Adam Wilkinson	JCU	United Kingdom	The identification of potential links between fibropapillomatosis prevalence in green sea turtles ( <i>Chelonia mydas</i> ) and toxic metal contamination along the Great Barrier Reef, Australia.	J Brodie
Jennifer Wilmes	JCU	Belgium	Spatial variation in the density and demography of newly settled crown-of-thorns starfish ( <i>Acanthaster cf. solaris</i> ).	M Pratchett, A Hoey, V Messmer
Jessica Zamborain Mason	JCU	Spain	Towards the sustainability of coral reef fisheries: a functional approach.	S Connolly, J Cinner
Jia Zhang	JCU	China	Genome wide analysis of natural selection in thermally tolerant coral communities from North Western Australia.	D Miller
Kim Zoeller	JCU	South Africa	Understanding the production of cultural ecosystem services and benefits.	G Cumming, G Gurney
Karin Zwiep	UQ	Netherlands	Using DNA to reconstruct past coral reef ecosystems.	J Pandolfi

## GRADUATE PROFILE: EMMANUEL MBARU

Emmanuel Mbaru grew up in the coastal city of Mombasa, Kenya, where he spent his early life close to the ocean. It was natural therefore that his undergraduate studies were in Fisheries and Aquatic Sciences, at Moi University. As part of his undergraduate degree, he visited public and private institutions involved in research and management of water and fisheries resources in Kenya. It was because of these amazing field trips that he became passionate in pursuing a career in fisheries research.

After graduating, Mbaru was employed as a research associate in a World Bank-funded project to assess the sustainability of fisheries in the western Indian Ocean, and to build capacity among fisheries scientists in the region. Through this project, he received financial support for a MSc in Fisheries Science at Rhodes University, South Africa. Subsequently, he worked closely with local and international NGOs to develop local management of Kenya's nearshore fisheries. This research was prompted by the introduction of increased management restrictions in Kenya, and the need to develop alternative fishing methods to ensure the sustainability of fisheries. The connection between conservation and people's livelihoods became a growing interest in Mbaru's career, and one he wished to develop further.

Enrolment as a PhD student in the ARC Centre of Excellence for Coral Reef Studies changed Mbaru's future direction as a fisheries scientist. Importantly, his thesis project was based on his experience studying the coastal fisheries in Kenya, and it examined how conservation interventions affect both people and the environment. He explored these issues by examining the introduction of the escape slot trap in coastal Kenya, an initiative to reduce fisheries bycatch (incidental take). This intervention was introduced with the explicit aim of protecting biodiversity, by harvesting fish species at sizes that ensure sustainability of the local fishery. The research drew on social science theories and breakthroughs in functional ecology research. Mbaru's results affirmed the viability of the escape slot trap as a sound gear-based conservation innovation for coral reef fisheries.

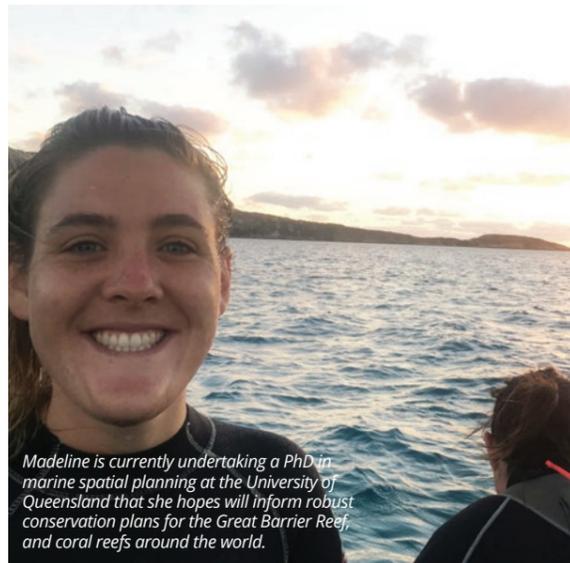
Shortly after his return to Kenya, and following the submission of his thesis in Australia, Mbaru moved to a new national Mariculture and Fisheries Research Centre. There he is working to develop fisheries monitoring programmes, and to assist in the development of fisheries innovations in Kenya. His unique knowledge on conservation and fisheries management will help practitioners and resource managers to implement innovations and further influence fisheries practices in Kenya. Mbaru is currently running three projects that advance the work he did during his PhD. His approach has significance and wide appeal in many areas, such as, community development studies, participatory research, community intervention, and behaviour change. He is very excited about this opportunity to contribute to the management of marine resources in his home country.



# “You easily feel helpless and overwhelmed”: What it’s like being a young person studying the Great Barrier Reef

by Angela Heathcote

It’s not unusual for a young PhD student studying the Great Barrier Reef to watch the coral they’d been observing for months bleach in just a single summer.



Madeline is currently undertaking a PhD in marine spatial planning at the University of Queensland that she hopes will inform robust conservation plans for the Great Barrier Reef, and coral reefs around the world.

IN 2016, ONE of Australia’s most respected coral biologists Terry Hughes tweeted a graph depicting the extreme coral bleaching event that occurred on the Great Barrier Reef in 2016.

Alongside the graph, Terry wrote, “I showed the results of aerial surveys of #bleaching on the #GreatBarrierReef to my students, and then we wept.”

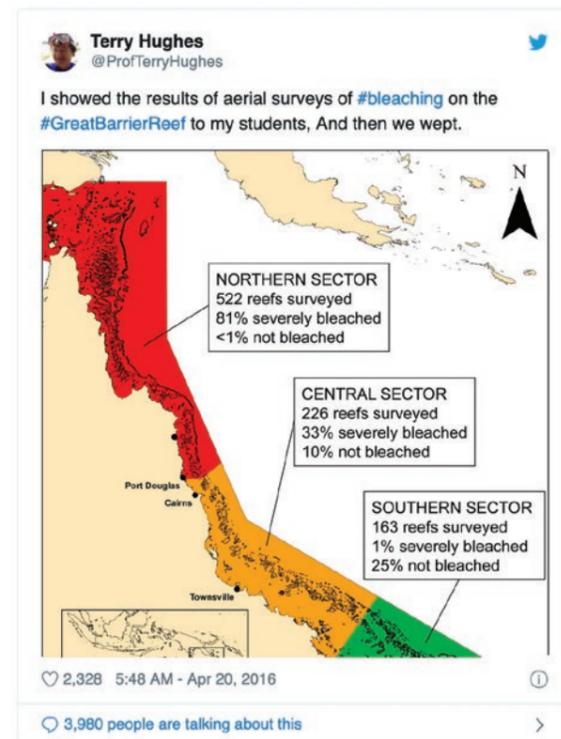
The northern parts of the Great Barrier Reef were the hardest hit, with 81 per cent considered “severely bleached”. The central third of the Great Barrier Reef suffered even more bleaching in 2017. This was the first ever recorded back-to-back bleaching event caused by global heating from CO<sub>2</sub> emissions.

In the November/December issue of *Australian Geographic* (on sale 7 November 2019), Terry further detailed the challenges faced by young coral reef scientists.

“We have to relearn how the system is now working,” he says. “It is a huge research challenge for the next generation of marine scientists.

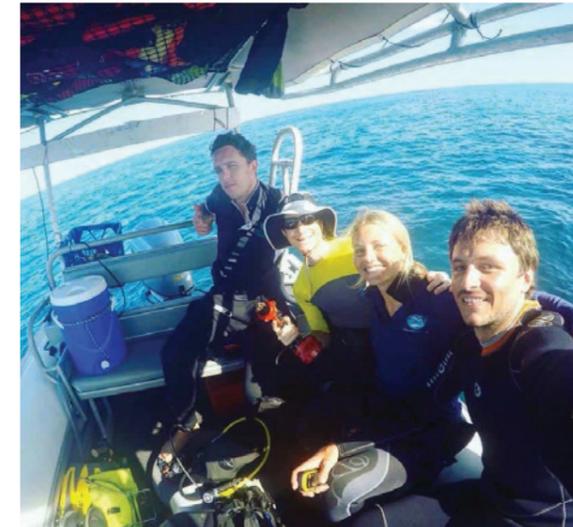
“Many of my students have had to redesign their projects because their corals died, but I tell them to hang in there because there has never been a greater need for coral reef researchers.”

Queensland is the unofficial home of marine science in Australia given its proximity to institutions such as the Australian Institute for Marine Science and the Great Barrier Reef Marine Park Authority, and the Reef itself.



The ARC Centre of Excellence for Coral Reef Studies, headquartered at James Cook University in Townsville, is particularly distinguished in the field of marine science. We sat down with three ARC students to ask them what it’s like studying the Great Barrier Reef in the midst of the climate crisis.

Andreas Dietzel



Andreas began his PhD on the Great Barrier Reef in 2015, and following the bleaching events of 2016–2017, adapted the focus of his research to explore the consequences of the unprecedented event.

Alongside Terry Hughes, Andreas helped map the 2016 bleaching event in the northern Great Barrier Reef (the data was included on the map tweeted by Terry).

“My colleagues and I were just on our way back from two physically and mentally challenging weeks surveying the most severely bleached reefs in the far north, when we heard the news that Donald Trump had just been elected president of the USA,” Andreas says.

“A feeling of shock and disbelief mixed with the sobering realisation that the chances of averting further climate breakdown, whose impact on even the most remote parts of the Reef we had just witnessed, was quickly dwindling.

“When mass bleaching returned in 2017, the fear that climate change was already here now and not a distant, slowly unfolding threat, became stronger and has stayed with me ever since.”

While Andreas didn’t expect his PhD to be easy, it’s come with added stress.

“Feeling overwhelmed is a natural part of any PhD but witnessing and documenting an ecosystem as marvellous as the Great Barrier Reef degrade so significantly over the course of your own PhD comes with its own challenges,” Andreas says.

“The question I have often asked myself is how to make a difference as a PhD student or early-career scientist and significantly add to a body of knowledge that has too often fallen on deaf ears with politicians.

“Building the emotional resilience to not let your professional life impact your private life too much is particularly challenging when you are not only trying to be part of the solution but your Western lifestyle also makes you part of the problem.”

The biggest challenge for young marine scientists, Andreas foresees, is factoring in the possibility of disturbances affecting their research projects, such as loss of coral.

“Having a back-up plan and being able to adjust your goals and methods quickly will be essential.

“As disturbances become more frequent and larger, reefs and reef dynamics will resemble their historic counterparts less and less.

“On one of my first trips to the GBR, we surveyed a breathtaking reef. Back at the surface I shared my excitement with my colleagues, who were quick to note that most reefs used to look like this or better.

“The baseline of what a pristine reef should look like has and will continue to shift as reefs continue to degrade.”



Alexia Graba-Landry

In total, Alexia has spent over 600 field-work days on the Great Barrier Reef for both her PhD research and related projects.

Alexia’s PhD investigates the influence of temperature on fish-algae interactions on coral reefs.

“This is important because by eating the algae, the fish keep the algae in a cropped state, and make space for corals to settle and grow,” Alexia explains.

“Understanding how this important process might change as oceans continue to heat up can give us an idea of what reefs might look like into the future.”

Alexia’s thorough knowledge of the Great Barrier Reef gave her the opportunity to work as a camera assistant

and dive supervisor for the BBC's Blue Planet 2 program.

But the long amount of time she's spent on the Reef has opened her eyes to the immense pressure its under.

"Studying climate change and the Great Barrier Reef can sometimes be overwhelming, particularly when the results of your studies confirm just how vulnerable coral reefs are to climate change.

"Coral reefs are one of the most threatened ecosystems, and during my short time researching the reef, I have witnessed the devastating effects of recurrent cyclones, and recurrent coral bleaching events, and widespread coral mortality."

Alexia was a part of surveys that quantified the coral loss of the northern parts of the Great Barrier Reef, where she'd already witnessed the impacts of cyclones Nathan and Ita years before.

"I think a big challenge for young people studying the Reef is that they will never get to see it as it was.

"I don't think any of us will ever get to fully comprehend what a pristine reef looks like, or that it was right in our backyards.

"Our reefs will be different to the generations before us: lower in biodiversity and complexity."

#### Madeline Davey

Madeline is currently undertaking a PhD in marine spatial planning at the University of Queensland that she hopes will inform robust conservation plans for the Great Barrier Reef, and coral reefs around the world.

For Madeline, the biggest challenges for young marine scientists is facing the reality that much of your research will be ignored, as well as reading media reports that misrepresent the current trajectory of the Great Barrier Reef.

The 2016–2017 bleaching event left Madeline feeling sad, but mostly defeated.



"With catastrophic events like this, it is incredibly hard to be optimistic about the future, but as a coral reef scientist, I think it's a part of my role to motivate citizens to stay informed and engaged," Madeline says

"It is really challenging to navigate the media reports and persistent questions about whether the reef is 'really' dead. It is incredibly hard to give decisive answers about an uncertain future when we don't know ourselves, and so much depends on whether or not people take action.

"It's also especially hard to keep studying and working in coral reef conservation when it often feels like all this hard work and research is ignored by those who have power to make the changes we need to see to ensure the Reef retains its wonder and global importance."

Madeline says, however, that she personally witnessed how the back-to-back bleaching event got Australians more concerned about the science of climate change.

"I've been a CoralWatch ambassador since 2017, which gave me good insight into the number of concerned citizens who wanted to know more about what coral bleaching is, and what they can do to help prevent further devastation to our reef."

The biggest challenge for young marine scientists, Madeline says, is centred on innovation, specifically the question, "how can we assist in rapid recovery of coral reef ecosystems?"

In 2019, the Centre provided training and mentoring to 170 graduate students, 124 of whom came from 36 overseas countries.

## NATIONAL AND INTERNATIONAL LINKAGES

The ARC Centre of Excellence is a global hub for multidisciplinary coral reef research. Collaborations associated with our research continue to grow. They are exemplified by the number of cross-institutional publications, the countries in which we undertake fieldwork, the workshops and working group meetings we convene, and the number of international visitors we host annually. The Centre's research profile and reputation has attracted 198 international graduate students since 2014 (p42), including 26 new graduate enrolments from 14 countries in 2019.

In 2019, ARC Centre researchers published 313 journal articles with cross-institutional co-authorship, involving collaborators from 445 institutions in 69 countries. Centre researchers convened 23 international working groups and workshops, involving >300 external researchers and stakeholders. Across the four nodes of the ARC Centre, we hosted 79 international visitors from 25 countries during the year.

Our fieldwork was conducted in 28 countries in 2019, and the resulting outputs, media uptake, public outreach and impact is global (p62). The ARC Centre's researchers are major contributors to intergovernmental organisations such as the Intergovernmental Panel on Climate Change (IPCC), the World Bank, UNESCO, Programme on Ecosystem Change and Society (PECS), and the International Council for Science (ICSU). Centre personnel are also appointed to many editorial boards of international journals. 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).

In addition to our partnership with the Australian Institute of Marine Science, and the Great Barrier Reef Marine Park, the ARC Centre has formal international partnership agreements with the Center for Ocean Solutions at Stanford University, France's Centre National de la Recherche Scientifique (CNRS), and WorldFish in Malaysia. Centre researchers also collaborate extensively with four major international non-government organisations (NGOs) – The Nature Conservancy (TNC), the Worldwide Fund for Nature (WWF), the Wildlife Conservation Society (WCS), and Conservation International (CI). These collaborations result in tangible outcomes and impacts, including the development of trans-disciplinary research projects, co-tutelle PhDs, visiting scholar exchanges, recruitment of co-funded postdoctoral fellows, and enhanced

engagement and uptake of our research by end-users around the world. These links are further strengthened by the ARC Centre's governance structure (p66).

### Australian Institute of Marine Science

The Australian Institute of Marine Science (AIMS) 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 and is responsible for the long-term monitoring of the Great Barrier Reef. AIMS 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. Dr Paul Hardisty, the AIMS Chief Executive Officer, is a member of the Centre's Advisory Board while AIMS' senior principal research scientist, Janice Lough is a very active Partner Investigator in the Centre. AIMS and the ARC Centre share valuable infrastructure, co-supervise graduate students (18 in 2019) and co-fund two postdoctoral fellows: Hugo Harrison who was appointed in 2019, and Kristen Anderson. AIMS and ARC Centre researchers co-authored 50 journal articles in 2019, focussing mainly on research on the Great Barrier Reef and on reefs in Western Australia.

### Centre National de la Recherche Scientifique (CNRS), France

The Centre National de la Recherche Scientifique (CNRS) is France's major research organisation. CNRS conducts a globally-significant program of coral reef research, centred on field laboratories and other research facilities in French Polynesia, New Caledonia, the Indian Ocean and the Caribbean. The ARC Centre's partnership with CNRS is led by Partner Investigator Professor Serge Planes. In 2019, CNRS collaborations with the ARC Centre generated 44 journal articles, with 95 French co-authorships. For example, Geoff Jones, Serge Planes and others generated significant and global media attention on an *Ecology Letters* publication which reported that the reproductive success of the clownfish depends almost entirely on having a high-quality anemone home. Joshua Cinner's collaboration with David Mouillot at the University of Montpellier has also generated a number of high profile publications, including in 2019, in *Nature Ecology and Evolution* and *Scientific Advances*. David is a frequent visitor to the JCU node of the Centre, and he identifies the Centre of Excellence as his secondary affiliation as a

Clarivate *Highly Cited Researcher*. Jodie Rummer also works closely with Serge Planes on a shark research program at the Centre de Recherche Insulaire et Observatoire de l'Environnement (CRIOBE), a research centre supported by the CNRS in French Polynesia. ARC Centre PhD students, Ian Bouyoucos, Victor Huertes Martin and Katie Sambrook are co-supervised by CNRS researchers. Ian and Victor have been undertaking studies to understand the capacity for newborn sharks in French Polynesia to acclimate and adapt to climate change conditions. In December, Jodie held a workshop at CRIOBE for 12 French and Polynesian Masters students, on the conservation and physiology of sharks.

### Great Barrier Reef Marine Park Authority

The 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. GBRMPA's role is to assess, inform, and implement government policies to maintain the environmental quality of the Great

Barrier Reef. The ARC Centre's 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 and advice. GBRMPA is embedded within the ARC Centre's governance structure (p66), to facilitate research planning and the exchange of information and data. In 2019, GBRMPA's newly appointed Chief Executive Officer, Josh Thomas joined the Centre's Advisory Board, and the Authority's Chief Scientist, Dr David Wachenfeld, is a member of the Centre's Scientific Management Committee. GBRMPA managers receive regular updates, advice and briefings on the Reef from ARC Centre researchers. For example, in 2019, Josh Thomas met repeatedly with Centre researchers to discuss our current research within the Great Barrier Reef Marine Park, and pathways for the uptake of research into management. In August, GBRMPA and the Centre co-hosted an inaugural 'speed-networking' event attended by 40 participants from the two organisations, to facilitate linkages, research updates and management priorities. Terry Hughes was appointed by the Commonwealth

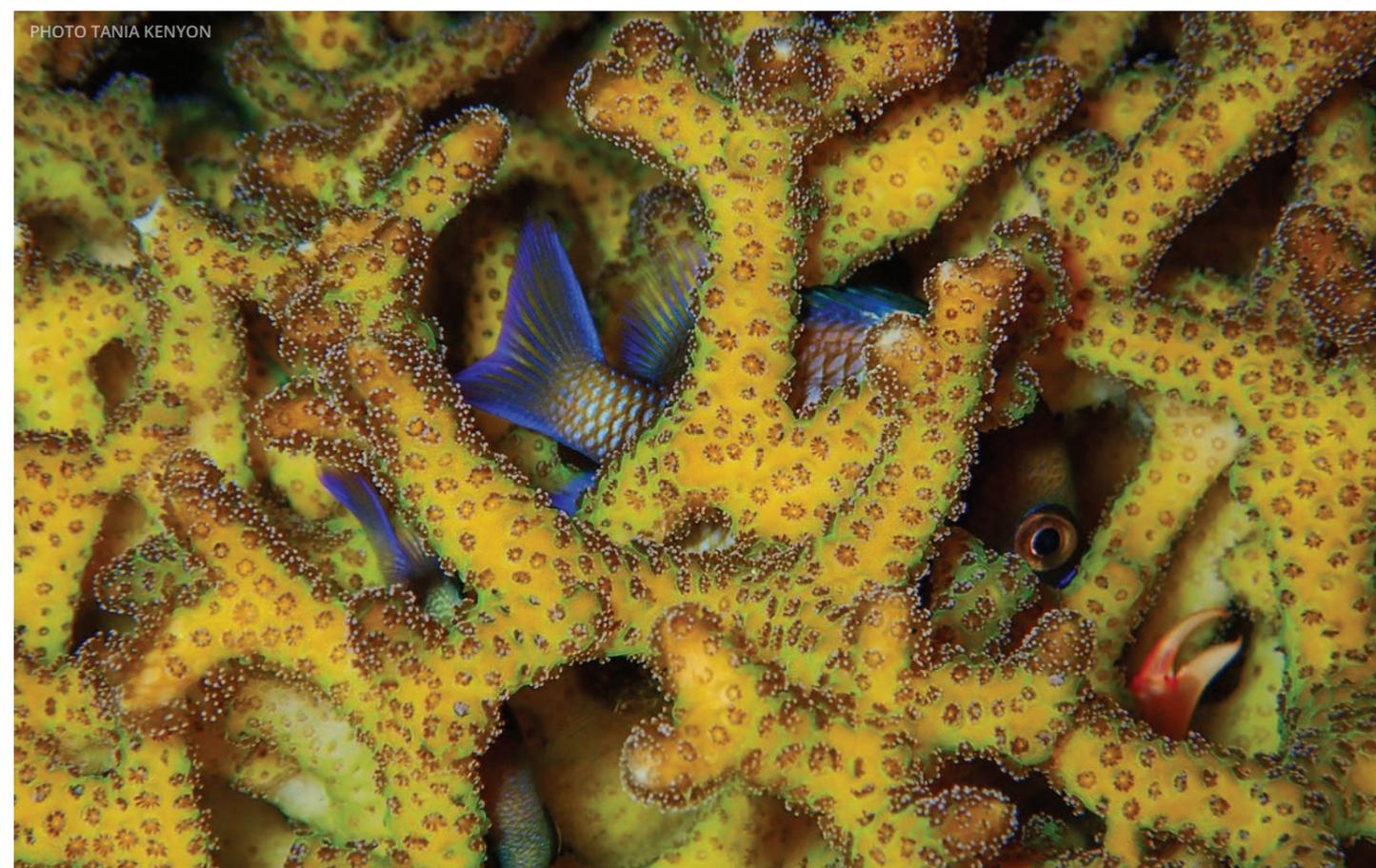


PHOTO TANIA KENYON

government to review the 2019 Great Barrier Reef (GBR) *Outlook Report*. Produced every five years, the *Outlook Report* is an assessment of the GBR and its future. It forms part of Australia's State Party reports to UNESCO on the status of World Heritage properties. Ove Hoegh-Guldberg and Terry Hughes are members of the Independent Expert Panel which provides expert advice to GBRMPA, and the Queensland and Federal governments on the Great Barrier Reef. In October Terry Hughes, David Wachenfeld and Ian Chubb provided a briefing to the Australian Government on the science of climate change for the Great Barrier Reef. An additional briefing on this topic was provided to the Honourable Sussan Ley, Minister for the Environment. Peter Mumby, Karlo Hock, George Roff and Yves-Marie Bozec (p24) are working with GBRMPA managers to develop a 'resilient reef dataset' to inform crown-of-thorns starfish control. During 2019, Centre researchers David Williamson, Garry Russ and Geoff Jones continued to deliver findings to GBRMPA on their assessment of the ecological effects of fishing on inshore reefs of the GBR. In November, Centre researchers Scott Heron, Janice Lough and others joined 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.

#### Queensland Museum

The Museum of Tropical Queensland, in Townsville, is one of five museums in the Queensland Museum Network. The Museum is internationally renowned for its marine biological collections, and it houses the world's largest and most significant collection of reef corals. The collection is an invaluable resource for understanding the diversity and evolutionary history of corals and coral reefs, as well as for quantifying the magnitude of changes to coral reef systems in the Anthropocene. Museums are increasingly recognised as holding a key role for both documenting and conserving biodiversity, and also in communicating to the broader public. The ARC Centre has strengthened its linkages to the Museum by co-appointments of two researchers: Tom Bridge and Sue-Ann Watson now occupy Senior Curator co-funded positions at the Queensland Museum as well as at the ARC Centre. In 2019, six PhD students were jointly supervised by the ARC Centre and Museum, Augustine Crosbie, Tessa Hill, Jeremy Horowitz, Chancey MacDonald, Patrick Smallhorn-West and Blake Spady.

Partnering with the ARC Centre has also provided the Museum with an increased capacity to participate in field work and make new collections of Australia's unique marine biodiversity. In 2019, five public outreach events were facilitated by the collaboration. In 2019, this new collaboration resulted in 13 co-authored publications.

#### WorldFish, Malaysia

WorldFish is an international non-profit scientific agency headquartered in Malaysia, undertaking research projects in Africa, Asia and the Pacific. It has a global staff of about 330, permanent offices in seven countries, and ongoing projects in 25 countries. Its objective is to improve food and nutrition security and to reduce poverty 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-associated fisheries. WorldFish and the ARC Centre have a strong ongoing and productive partnership, which in 2019 generated 22 co-authored publications – comprising 16 journal articles, 4 book chapters and 2 reports. Joshua Cinner led a high-profile paper in *PNAS* which presented a 16-year analysis of ecological outcomes and perceived livelihood impacts from coral reef management initiatives in Papua New Guinea. During 2019, the WorldFish collaboration was further strengthened by the appointment of small-scale fisheries expert Dr Jacqueline Lau. Jacqueline joins Danika Kleiber and Andrew Song as co-funded research fellows, and David Mills, a WorldFish senior scientist, based at the JCU node of the Centre. As part of the WorldFish collaboration, Jennifer Lappin and Tiffany Morrison attended the international FISH CRP management committee meetings in Myanmar and Penang, respectively. Jacqueline Lau presented her research at the 5th Global Science Conference on Climate-Smart Agriculture, in Bali. She also attended the 'Regional workshop for the development of an integrated livelihoods approach for Pacific Island small-scale fishing communities', co-hosted by the ARC Centre and WorldFish on Magnetic Island, in November. Also in November, joint Centre/WorldFish research fellow Danika Kleiber (p16) hosted the WorldFish Gender team meeting, at the ARC Centre at JCU. Danika also delivered the capacity building webinar *Gender Equity and Equality in the Small-Scale Fisheries Guidelines* in April 2019. PhD students Sarah Lawless, Sarah Sutcliffe and Ruby Grantham, who are jointly supervised by Centre and WorldFish researchers, benefited hugely from participation in these activities. In recognition of the strength of the Centre's relationship with WorldFish, Pip Cohen was appointed to the Centre's Advisory Board in 2019. Pip is Research Leader of the Global Program on Resilient Small-Scale Fisheries, at WorldFish. The Centre's ongoing collaboration with WorldFish creates strong links to end-users, including local communities, many inter-governmental organisations and NGOs, and to the governments of many developing countries, particularly in the Coral Triangle region.

#### International visitors to the Centre in 2019

In 2019, the ARC Centre of Excellence hosted 79 visitors from 25 countries at its four nodes

Name	Overseas institution	Country
Dr Dominic Andradi-Brown	World Wildlife Fund	United States
Chelsey Beese	Victoria University of Wellington	New Zealand
Dr Francesca Benzoni	King Abdullah University of Science and Technology	Saudi Arabia
Prof Debashish Bhattacharya	Rutgers University	United States
Dr Ben Bolker	McMaster University	Canada
Dr Jamie Caldwell	Stanford University	United States
Dr Afrina Choudhury	WorldFish	India
Dr Pip Cohen	WorldFish	Malaysia
Dr Amber Dance	Nature Magazine	United States
Dr Emily Darling	Wildlife Conservation Society	United States
Prof Rob DeSalle	American Museum of Natural History	United States
Dr Michelle Devlin	Centre for Environment Fisheries and Aquaculture Science	United Kingdom
Adele Dixon	University of Leeds	United Kingdom
Luiz Dos Santos Ribas	Universidade Federal de Goiás Goiânia	Brazil
Sarah Erickson	University of California Davis	United States
Prof Francini Filho	Universidade Federal da Paraíba	Brazil
Prof Maoz Fine	Interuniversity Institute for Marine Sciences	Israel
Prof Amatzia Genin	InterUniversity Institute for Marine Sciences	Israel
Justin Gilligan	National Geographic	United States
Dr Chelcia Gomeze	WorldFish	Malaysia
Dr Paul Halloran	University of Exeter	United Kingdom
Prof Ben Halpern	NCEAS and University of California, Santa Barbara	United States
Faridul Haque	WorldFish	India
Dr Saki Harii	University of Ryukyus	Japan
Zinat Hasiba	WorldFish	India
Prof Jim Haywood	University of Exeter	United Kingdom
Dr Tessa Hempson	Oceans without Borders	South Africa
Dr Missaka Hettiarachchi	WWF International	United States
Dr Jules Jaffe	University of California, San Diego	United States
Prof Michal Kowalewski	Florida Museum of Natural History and the University of Florida	United States
Philip Kuhel	Columbia University	United States
Liam Lachs	University of Leeds	United Kingdom
Dr Jonathan Lambrechts	University of Belgium	Belgium
Dr Sjannie Lefevre	University of Oslo	Norway
Bruce Lendon	Australian High Commissioner to the Caribbean	Trinidad and Tobago
Jonathan Levine	Princeton University	United States
Prof Don Levitan	Florida State University	United States
Prof Oren Levy	Bar-Ilan University	Israel
Timothy Lewis	Columbia University	United States

Name	Overseas institution	Country
Neil Maginnis	University of Denmark	Denmark
Dr Sangeeta Mangubhai	Wildlife Conservation Society	Fiji
Dr Laurence McCook	South China Sea Institute of Oceanology	China
Dr Cynthia McDougall	WorldFish	Malaysia
Julia McDowell	Université de Montpellier	France
Joshua Modeste	Columbia University	United States
Prof David Mouillot	Université de Montpellier	France
Prof Ryan Mulligan	Queen's University	Canada
Dr Julie Newton	WorldFish	Malaysia
Prof Goran Nilsson	University of Oslo	Norway
Dr Steven Palmer	University of Exeter	United Kingdom
Bruna Pereira Luz	Universidade Federal do Paraná	Brazil
Prof Serge Planes	Centre de Recherches Insulaire et Observatoire de l'Environnement (CNRS) University of Perpignan	France
Dr Surendran Rajaratnam	WorldFish	Malaysia
Prof Matt Reidenbach	University of Virginia	United States
Dr Alf Ring Kleiven	Institute of Marine Research	Norway
Giovanna Sabini-Leite	Smith College	United States
Antoine Saint Amand	Université Catholique de Louvain	Belgium
Diego Salgueiro Otera	University of Barcelona	Spain
Julie Schlieger	University of Paris	France
Dr Molly Scott	University of Hawaii	United States
Lydia Sheyda	School for International Training	United States
Prof Brian Silliman	Duke University	United States
Gideon Singer	Purdue University	United States
Dr Fred Sinniger	University of Ryukyus	Japan
Prof Simon Sprecher	University of Fribourg	Switzerland
Dr Yusuke Sudo	Okinawa Prefectural Fisheries and Ocean Research Center	Japan
Dr Ruth Thurstan	University of Exeter	United Kingdom
Dr Ap van Dongeren	Deltares	Netherlands
Clara Vie	University of Strasbourg	France
Prof Stephan von Cramon-Taubadel	University of Gottingen	Germany
Prof Christian Voolstra	University of Konstanz	Germany
Dr Arthur Webb	United Nations Development Program	Fiji
Prof Kerstin Wiegand	University of Gottingen	Germany
Dr Syafyudin Yusuf	Hasanuddin University	Indonesia
Dr Mikolaj Zapalski	University of Warsaw	Poland
Dr Fernando Zapata	Universidad del Valle	Colombia



Crab in a 'forest' of Black Sun Coral (*Tubastrea*) taken by PhD student Tania Kenyon on a night dive to the Rannimari wreck, Ihuru Island, Maldives, towards the end of a field trip.

PHOTO TANIA KENYON

## COMMUNICATIONS, MEDIA AND PUBLIC OUTREACH

The ARC Centre has a highly successful strategy for communicating research findings to a diverse audience. For example, the Centre's communications program actively promotes research outcomes through traditional and digital platforms. The Centre's comprehensive website recorded 11.8 million hits in 2019. The Centre's weekly multi-nodal seminar series, which is publicly accessible through the Centre's YouTube channel, hosted 31 online presentations during 2019. Other presentations include a Women in Science video of early career researcher Natalia Andrade Rodriguez, which was featured on the UNESCO website for World Oceans Day.

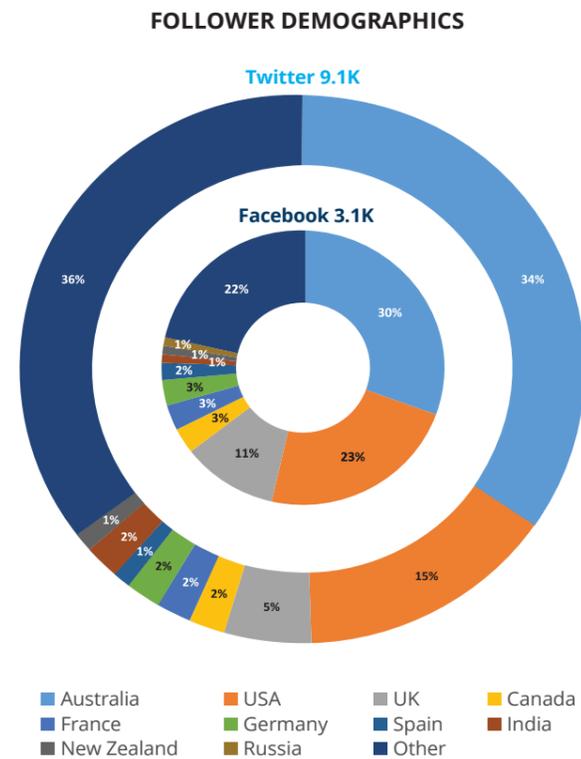
The ARC Centre's annual *Coral Reef Futures Symposium* and *Public Forum* were highly successful events, fostering collaborations and collegiality amongst internal and external stakeholders. The two-day symposium was held this year in Sydney, at the Australian National Maritime Museum. The sold-out Public Forum 'What Every Australian Should Know about Climate Change' was hosted by popular social media commentator, Tanya Ha, and featured a panel of four climate change experts: Joëlle Gergis (ANU), Lesley Hughes (Macquarie University), Simon Holmes à Court (Climate Energy Council) and the Centre's Director, Terry Hughes. The Centre crowd-sourced the most popular questions for the Public Forum's panel, from the audience and from participants watching the event as it livestreamed on [Facebook live](#).

### Social Media

During 2019, the Centre's digital engagement continued to expand rapidly. The number of followers of the Centre's Twitter account @CoralCoE grew to over 9,100. Followers from over ten countries registered more than 1 million impressions (including over 1,600 retweets and 3,600 likes) in Twitter feeds over the year. The Centre's Twitter account was named as one of the top social media accounts of ARC-funded research groups in 2019 by the Director of Innovation at *Digital Science*. The annual *Coral Reef Futures Symposium* and *Public Forum* featured a targeted Twitter campaign, resulting in the event hashtag #coral2019 trending in Australia throughout the entire event.

The ARC Centre's [Facebook](#) page, also grew in 2019 receiving over 3,200 total 'Page Likes'. Expanding the Centre's video library and online presence was a priority this year, resulting in our YouTube Channel garnering over 1,100 hours of total watch time. Centre researchers also actively participated in hundreds

of international documentaries, TV shows, as well as News and Radio interviews.



### Briefings

The Centre continues to provide timely and informative advice to key stakeholders, on relevant coral reef science issues. In 2019, researchers engaged in 108 briefings across both the public and private sectors.

Regular briefings were delivered to partners at the Great Barrier Reef Marine Park Authority (GBRMPA). For example, Terry Hughes, Tom Bridge, April Hall, Severine Choukroun, Iain Caldwell, Graeme Cumming, Alana Grech, Jodie Rummer, Jennifer Donelson, Michele Barnes, Sue-Ann Watson, Garry Russ, David Williamson, Geoff Jones, Hugo Harrison, Andrew Baird, Daniela Ceccarelli, Andrew Hoey, Kennedy Wolfe, Peter Mumby and eight PhD candidates all gave briefings to GBRMPA throughout the year – on topics such as bleaching response, climate change, reef management, and reef resilience. In August, GBRMPA and the ARC Centre co-hosted a 'speed networking event' attended by 40 people from both organisations, to facilitate the flow of information between the two organisations.

Sophie Dove, Andrew Baird, and Terry Hughes briefed the United States' National Oceanic and Atmospheric Administration (NOAA) on listing specific corals on the IUCN Red List, and on the status of the Great Barrier Reef, and coral bleaching. Morgan Pratchett contributed to the Northern Territory Ecological Risk Assessment, for the Northern Territory Aquarium Fishery. Rene Abesamis, Garry Russ, and Angel Alcalá conducted several government briefings in the Philippines, on the design and establishment of marine reserves and marine protected areas.

Jon Brodie provided expert input to the Australian Government, Queensland Government and local conservation groups on water quality and its effects on the Great Barrier Reef. Scott Heron and Jon Day developed the *Climate Vulnerability Index (CVI)*, a systematic tool to rapidly assess climate change risk to World Heritage sites, which has been widely adapted by sites in Australia, Azerbaijan, France, the United Kingdom, and elsewhere. In Australia, Jorge Álvarez-Romero gave 16 talks to industry, community, and government organisations, presenting development scenarios and initiatives for the Fitzroy River catchment, Kimberley, Western Australia.

### Public talks and school outreach

Public engagement and outreach were a major focus in 2019, resulting in 75 outreach events and public talks conducted by Centre researchers, in 11 countries.

For example, in April and November, Terry Hughes completed two lecture tours along the East and West Coast of the United States. In total, he gave 19 presentations at 14 universities, government agencies and organisations: including, the National Science Foundation, Columbia University, Stanford University, and the Scripps Institution of Oceanography. In June, Hughes also spoke at the *Climate Reality Leadership Corps Training* in Brisbane, with former U.S. Vice President Al Gore.

Jodie Rummer spoke at two sold-out events, at the World Science Festival in Brisbane, on 'Saving what we've got: Australia's wildlife under threat' and 'Let's talk: Sharks', reaching audiences exceeding 100,000. In October, Ove Hoegh-Guldberg joined a panel on ABC News to discuss 'Is it too late to save the Great Barrier Reef, or is there hope?'

In November, Andrew Hoey worked closely with Ocean School, a collaboration between the Ocean Frontier Institute, Dalhousie University, and the National Film

Board in Canada, to bring corals reefs, biodiversity and climate change to students in grades 6-9. Also this year, Verena Schoepf shared her research internationally through Skype a Scientist, where she spoke to students in Singapore and the UK.

### Plenary talks

In 2019, ARC Centre researchers delivered 43 keynote addresses in 18 countries across the globe. For example, Ove Hoegh-Guldberg was an invited plenary speaker at the *24th World Energy Congress* in Abu Dhabi, where he spoke about 'Stepping up on Climate Action'. Tiffany Morrison was an invited panellist in the United States, at both the *Ostrom Workshop (WOW6)* and the *International Studies Association Annual Convention*. Geoff Jones delivered an invited plenary lecture at the *Gordon Research Conference on Marine Molecular Ecology*, in Hong Kong. Rene Abesamis presented a plenary address at the Philippines National Academy of Sciences. Andrew Baird spoke at the *Fourth Workshop on Trait-based Approaches to Ocean Life*, in the UK.

In September, David Miller gave two keynote addresses in Germany on coral evolution and whole genome sequencing, at the *Biannual International Workshop on Cnidarian Molecular and Cell Biology*, as well as a plenary talk in China at the *ICG Ocean 2019* conference. Danika Kleiber delivered keynote talks at the *3rd World Small-Scale Fisheries Congress* in Thailand, and the *Seeds of Change: Gender Equality through Agricultural Research for Development* in Canberra, Australia. Graeme Cumming delivered two keynote addresses at the *Australasian Ornithological Conference* in Darwin, Australia and at the *29th International Congress for Conservation Biology* in Malaysia.

### The Conversation

The ARC Centre regularly publishes original research-based articles and commentaries in the popular online media resource, *The Conversation*. Throughout 2019, ten ARC Centre researchers published 12 articles. Examples include:

Aurélie Moya. *Curious Kids: how do shells get made?* 3 March 2019. <https://theconversation.com/curious-kids-how-do-shells-get-made-111072>

Rebecca Green and James Gilmour. *Bright white skeletons: some Western Australian reefs have the lowest coral cover on record.* 22 March 2019. <https://theconversation.com/bright-white-skeletons-some-western-australian-reefs-have-the-lowest-coral-cover-on-record-116423> (p36)

Morgan Pratchett. *Coral reproduction on the Great Barrier Reef falls 89% after repeated bleaching.* 4 April 2019. <https://theconversation.com/coral-reproduction-on-the-great-barrier-reef-falls-89-after-repeated-bleaching-114761>

Jon Day and Scott Heron. *The Great Barrier Reef is in trouble. There are a whopping 45 reasons why.* 12 September 2019. <https://theconversation.com/the-great-barrier-reef-is-in-trouble-there-are-a-whopping-45-reasons-why-122930>

Jon Brodie. *Climate change is the defining issue of our time – we're giving it the attention it deserves.* 16 September 2019. <https://theconversation.com/climate-change-is-the-defining-issue-of-our-time-were-giving-it-the-attention-it-deserves-123592>

George Roff and Christopher Brown. *Shark nets and culls don't necessarily make Australian beaches safer.* 27 September 2019. <https://theconversation.com/shark-nets-and-culls-dont-necessarily-make-australian-beaches-safer-124156>

## Media and Altmetrics

In 2019 the Centre developed and distributed 35 media releases, generating 5,500 news items and commentaries across the world. On average during 2019, Centre researchers and/or research were referenced in media articles 15 times per day. The Centre's research was featured across multiple platforms – digital, TV, radio, and print, and in many of the world's most prominent news outlets, such as *BBC*, *The New York Times*, *Financial Review*, *Le Monde*, and *National Geographic*.

Altmetric scores provide a metric of the attention paid to a research publication – by tracking the media, Twitter, Facebook, blogs, and other online sources. Two Centre publications were listed in *The 2019 Altmetric Top 100*, the most visible articles among 2.7 million research outputs during the year. In 14th place was the 10 December 2018 *Nature Climate Change* paper 'Ecological memory modifies the cumulative impact of recurrent climate extremes' which generated 20,200 tweets, reaching an audience of 9.5 million Twitter followers. In 22nd place was the April 2019 *Nature* paper 'Global warming impairs stock-recruitment dynamics of corals' which triggered 12,489 tweets, with an audience of 13.7 million Twitter followers. This article was also ranked in sixth place in the Top 10 Climate papers of 2019 reported by *Carbon Brief*. The Centre's paper 'Harnessing global fisheries to tackle micronutrient deficiencies' was highlighted in *Nature's* '2019: The year in science' collection.

Additional media highlights throughout 2019 include:

**Australian Financial Review** – Blockchain, Patagonia toothfish and saving the planet. What could go wrong?, J. Cinner, 23 January 2019. <https://www.afr.com/companies/blockchain-patagonian-toothfish-and-saving-the-planet-what-could-go-wrong-20190118-h1a7vo>

**Eco Magazine** – *The Conservation Planning Database*, J. Álvarez-Romero, 26 March 2019. <https://www.ecomagazine.com/in-depth/featured-stories/the-conservation-planning-database>

**National Geographic** – *The Great Barrier Reef's corals are struggling to recover fast enough*, T. Hughes, 3 April 2019. <https://www.nationalgeographic.com/environment/2019/04/great-barrier-reef-coral-not-recovering-climate-change/>

**USA Today** – 'Dead corals don't make babies': Great Barrier Reef can't heal after global warming damage, T. Hughes, A. Baird, 4 April 2019. <https://www.usatoday.com/story/news/nation/2019/04/03/coral-reefs-great-barrier-reef-cant-recover-global-warming-damage/3352764002/>

**BBC News** – *Great Barrier Reef: mass decline in 'coral babies', scientists say*, A. Baird and T. Hughes, 4 April 2019. <https://www.bbc.com/news/world-australia-47809500>

**CNN.com International** – *'Dead corals don't make babies': Great Barrier Reef losing its ability to recover from bleaching*, T. Hughes and M. Pratchett, 4 April 2019. <https://edition.cnn.com/2019/04/04/australia/great-barrier-reef-coral-bleaching-intl/index.html>

**CBC Radio, Quirks & Quarks** – *Collapsing coral reefs – can we rebuild them?*, T. Hughes, 13 April 2019. <https://www.cbc.ca/radio/quirks/april-13-2019-black-hole-imagined-a-new-tiny-human-rebuilding-coral-reefs-and-more-1.5093713/collapsing-coral-reefs-can-we-rebuild-them-1.5093734>

**Los Angeles Times** – *Meet the tiny fish that have a huge effect on coral reef ecosystems*, D. Bellwood, 29 May 2019. <https://www.latimes.com/science/la-sci-coral-reef-tiny-fish-20190529-story.html>

**The Week** – *Ocean acidification threatens the survival of coral reefs: Study*, M. McCulloch and S. Comeau, 30 May 2019. <https://www.theweek.in/news/sci-tech/2019/05/30/Ocean-acidification-threatens-the-survival-of-coral-reefs-Study.html>

**ABC Radio National** – *Sharks, devils, wombats: three homo sapiens saving what we've got*, J. Rummer, 7 June 2019. <https://www.abc.net.au/radionational/programs/sciencefriction/saving-what-weve-got/11189084>

**New Atlas** – *Climate change may cause an increase in squid populations*, B. Spady, 14 June 2019. <https://newatlas.com/squid-acidification-climate-change/60122/>

**Science Daily** – *Untangling the complicated relationships between people and nature for a brighter future*, M. Barnes, G. Cumming and T. Morrison, 24 June 2019. <https://www.sciencedaily.com/releases/2019/06/190624111456.htm>

**The Guardian** – *Saltwater Kimberley: is WA's marine wilderness safe?*, V. Schoepf, 3 July 2019. <https://www.theguardian.com/environment/2019/jul/03/saltwater-kimberley-is-was-marine-wilderness-safe>

**SBS News** – *From Shark Bay seagrass to Stone Age Scotland, we can now assess climate risks to World Heritage*, J. Day and S. Heron, 4 July 2019. <https://www.sbs.com.au/news/from-shark-bay-seagrass-to-stone-age-scotland-we-can-now-assess-climate-risks-to-world-heritage>

**Quanta Magazine** – *Scientists debate the origin of cell types in the first animals*, M. Adamska, 17 July 2019. <https://www.quantamagazine.org/scientists-debate-the-origin-of-cell-types-in-the-first-animals-20190717/>

**ScienceDaily** – *Fussy fish can have their coral, and eat it too*, C. MacDonald, 23 July 2019. <https://www.sciencedaily.com/releases/2019/07/190723104043.htm>

**The New York Times** – *A raft of floating rock stuns sailors. but can it save the Reef?*, T. Hughes, 27 August 2019. <https://www.nytimes.com/2019/08/27/world/australia/pumice-raft-coral.html>

**Phys.org** – *Tracking baby fish for better reef management*, H. Harrison, 2 August 2019. <https://phys.org/news/2019-08-tracking-baby-fish-reef.html>

**Fox10tv.com** – *Scientists studied 2,500 coral reefs to figure out how to save them*, G. Gurney, 13 August 2019. [https://www.fox10tv.com/news/us\\_world\\_news/scientists-studied-coral-reefs-to-figure-out-how-to-save/article\\_809a60bc-95a9-5d33-9610-f64044cda3b7.html](https://www.fox10tv.com/news/us_world_news/scientists-studied-coral-reefs-to-figure-out-how-to-save/article_809a60bc-95a9-5d33-9610-f64044cda3b7.html)

**Forbes** – *3 strategies for saving coral reefs in the Indian and Pacific Oceans*, G. Gurney, 20 August 2019. <https://www.forbes.com/sites/priyashukla/2019/08/20/3-strategies-for-saving-coral-reefs-in-the-indian-and-pacific-oceans/#48a4cbdc4de5>

**Il Globo** – *Coral reef expert from Brisbane speaks at symposium in Modena*, J. Pandolfi, 12 September 2019. <https://ilglobo.com/news/coral-reef-expert-from-brisbane-speaks-at-symposium-in-modena-45046/>

**The Tribune India** – *Shark pups fight to survive during climate crisis: Study*, J. Rummer, 18 September 2019. <https://www.tribuneindia.com/news/archive/science-technology/shark-pups-fight-to-survive-during-climate-crisis-study-834525>

**ScienceDaily** – *Longest coral reef survey to date reveals major changes in Australia's Great Barrier Reef*, O. Hoegh-Guldberg, 27 September 2019. <https://www.sciencedaily.com/releases/2019/09/190927074930.htm>

**QLD Government Podcast** – *Episode 8: Scientist Jon Brodie*, J. Brodie, 12 October 2019. <https://www.reefplan.qld.gov.au/working-together/podcasts/episode-08-jon-brodie>

**Smithsonian Magazine** – *Massive citizen science effort seeks to survey the entire Great Barrier Reef*, P. Mumby, 18 October 2019. <https://www.smithsonianmag.com/science-nature/massive-citizen-science-effort-seeks-survey-entire-great-barrier-reef-180973367/>

**Herald Sun** – *FNQ lifeguards preparing for busy summer as stinger stats revealed*, M. Kingsford, 18 October 2019. <https://www.heraldsun.com.au/news/national/fnq-lifeguards-preparing-for-busy-summer-as-stinger-stats-revealed/news-story/a79a931a88c5bba67d77cfd0540e0cf3?btr=30012e1b03d818ddac773e47208a5ea0>

**The Economist** – *Asia's corals face a deadly onslaught*, P. Mumby, 24 October 2019. <https://www.economist.com/asia/2019/10/24/asia-coral-faces-a-deadly-onslaught>

**ABC News Radio** – *Long term study reveals magnitude of human impact on Great Barrier Reef coral cover*, D. Ceccarelli, 25 October 2019. <https://www.abc.net.au/radio/newsradio/long-term-study-reveals-magnitude-of-human-impact/11638692>

**CGTN** – *Coral study challenges long-held scientific theory*, T. Roberts and T. Bridge, 3 November 2019. <https://news.cgtn.com/news/2019-11-02/Coral-study-challenges-long-held-scientific-theory-LhOMZyTPI4/index.html>

**The Good Men Project** – *Seabed carbon storage may help in climate crisis*, O. Hoegh-Guldberg, 3 November 2019. <https://goodmenproject.com/featured-content/seabed-carbon-storage-may-help-in-climate-crisis/>

**MSN** – *Irukandji threat at Queensland beaches can be better monitored, scientist says*, M. Kingsford, 10 November 2019. <https://www.msn.com/en-au/news/other/irukandji-threat-at-queensland-beaches-can-be-better-monitored-scientist-says/ar-BBWw6Z>

**AllAfrica.com** – *Seychelles: Save Our Seas study finds that Seychelles' St. Joseph is healthy place for blacktip reef sharks*, J. Rummer, 11 November 2019. <https://allafrica.com/stories/201911110182.html>

**London Daily Mirror** – *Losing Nemo*, G. Jones, 27 November 2019. <https://www.mirror.co.uk/news/world-news/finding-nemo-fish-facing-extinction-20975719>

**The Star Online** – *Experts: runaway warming could sink fishing and reef tourism*, O. Hoegh-Guldberg, 8 December 2019. <https://www.thestar.com.my/news/regional/2019/12/08/experts-runaway-warming-could-sink-fishing-and-reef-tourism#FiwYMIQ7qQdefcKp.99>

**Phys.org** – *Corals survive to tell the tale of Earth's newest island eruption*, P. Smallhorn-West and T. Bridge, 10 December 2019. <https://phys.org/news/2019-12-corals-survive-tale-earth-island.html>

**Dhaka Tribune** – *Extremes of global heat bring tipping points closer*, O. Hoegh-Guldberg, 11 December 2019. <https://www.dhakatribune.com/climate-change/2019/12/11/extremes-of-global-heat-bring-tipping-points-closer>

**ABC News: The Drum** – *Great Barrier Reef Special*, O. Hoegh-Guldberg, 23 December 2019. <https://view.abc.net.au/show/drum/series/0/video/NC1907H181500>



PHOTO PAULA CARTWRIGHT

## GOVERNANCE

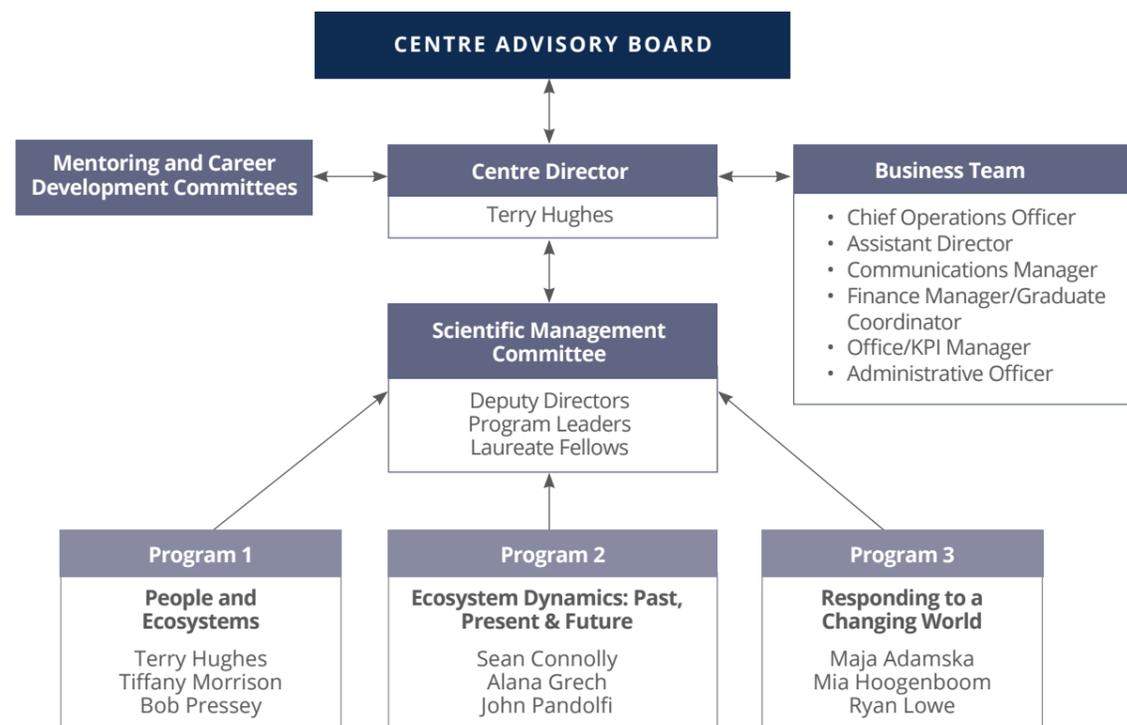
The ARC Centre of Excellence has a clearly defined and effective governance structure that engages key stakeholders in strategic planning, research program development, and knowledge exchange. A key objective is to foster sustainable use, adaptive governance and effective management of the world's coral reefs.

James Cook University is the Administering Organisation of the ARC Centre. Centre Director, Terry Hughes, reports directly to the JCU Provost, Professor Chris Cocklin. Operations are managed by the Chief Operations Officer, Jennifer Lappin, in consultation with the Centre Director and Assistant Director, Alana Grech, supported by an effective business team. Further support is provided by administrative staff at The Australian National University, The University of Queensland and The University of Western Australia.

The diagram below summarises the Centre's governance structure and relationships. 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, research fellows and students are located across three Divisions

of James Cook University, and at the Centre's other university nodes. Partner Investigators are based at the Australian Institute of Marine Science, the Great Barrier Reef Marine Park Authority and in leading international research institutions (p56). Adjunct researchers (p71) based in institutions in Australia and overseas make a significant contribution to the Centre's research.

The Centre's two principal governance committees are the Centre Advisory Board and the Scientific Management Committee. Eminent international researchers chair both committees, and the Chief Operations Officer, Jennifer Lappin, is Secretary. The Centre also supports two career development committees, run by Centre graduate students and early career researchers. These committees contribute to the development and mentoring of early career researchers, and are responsible for the organisation of annual retreats, training workshops and other career development activities (p42). An informal group, comprising all 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 to the Centre Director, and facilitates and advises on strengthening 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.

Membership of the Centre's Advisory Board reflects the Centre's strong multi-disciplinary research activities. Members include a distinguished international researcher as Chair, the Chief Executive Officer of the Great Barrier Reef Marine Park Authority, the Chief Executive Officer of the Australian Institute of Marine Science, a senior representative from WorldFish, and an independent senior University leader. In 2019, our long-standing Chair, Professor Brian Walker FAA, announced that he would retire at the end of the year. Brian's leadership was characterised by fair and wise counsel and the enormous experience and knowledge of interdisciplinary research he brought to the Board. Similarly, Professor Mandy Thomas advised that she too would be retiring from her position at the end of 2019. Mandy also brought a deep understanding of multi-disciplinary research to the Board with enormous knowledge and experience of social sciences, Australia's research funding processes and insightful analysis. We sincerely thank Brian and Mandy for their contribution to the leadership of the Centre over many years.

In 2019, the Centre welcomed two new Board members. Josh Thomas, the newly appointed Chief Executive Officer of the Great Barrier Reef Marine Park Authority joined in March. He brings with him a wealth of experience in senior roles in the public and private sectors, nationally and internationally. Dr Pip Cohen a senior program leader at WorldFish also joined the Centre's Advisory Board later in the year. An interdisciplinary fisheries and social scientist, Pip will provide connections and insights into international non-profit research in developing nations and strategies for poverty reduction in particularly in SE Asia and the western Pacific.

The Board met formally in Sydney on 22nd October 2019. A key focus for the Board during 2019 was providing advice on preparing the Centre for longer term business continuity in 2021-2023, and establishing ongoing governance arrangements.

### Membership of the Centre Advisory Board

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

**Dr Philippa Cohen**  
Research Program Leader  
Resilient Small-Scale Fisheries  
WorldFish, Malaysia

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

**Josh Thomas**  
Chief Executive Officer  
Great Barrier Reef Marine Park Authority

**Dr Britta Schaffelke**  
Research Program Leader, A Healthy and Sustainable Great Barrier Reef  
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 and stewardship of the ARC Centre's scientific research program are the responsibilities of the Scientific Management Committee (SMC). The Committee is chaired by distinguished social scientist and pioneer of interdisciplinary research, Professor Katrina Brown, from the University of Exeter, United Kingdom. Other members are the Centre's Director and Deputy Directors, leaders of each of the Centre's Research Programs, the Centre's current Australian Laureate Fellows, and the Chief Scientist of the Great Barrier Reef Marine Park Authority. Membership of the SMC is continuously evolving. In 2019, Alana Grech was appointed as a new Program 2 leader, replacing Verena Schoepf who took up a prestigious position at the University of Amsterdam. At the end of 2019, Terry Hughes stepped down as the leader of Program 1 to support strong transition planning, and Joshua Cinner will assume this position in 2020. Similarly, Graeme Cumming will begin a Program 2 leader

role early in 2020, following Sean Connolly's move to the Smithsonian Tropical Research Institution. We sincerely thank Verena and Sean for their strong and committed leadership, for building cross-institutional collaborations, and for providing effective mentoring for women and early career researchers.

The SMC met formally three times in 2019, twice in Townsville and once in Sydney. Continuing priorities in 2019 were: research planning, fostering outstanding transdisciplinary research across the Centre's research programs and nodes, producing high quality outputs, and mentoring postdoctoral fellows and postgraduate students. Members of the SMC continued to take a key role in providing advice to the Queensland and Australian Governments on the *Reef 2050 Long-Term Sustainability Plan*.

#### Membership of the Scientific Management Committee

**Professor Katrina Brown** (Chair)  
*Chair in Social Science*  
University of Exeter  
United Kingdom

**Distinguished Professor Terry Hughes** *FAA*  
*Centre Director and Leader, Research Program 1*  
James Cook University

**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

**Dr Alana Grech** (from May 2019)  
*Leader, Research Program 2*  
James Cook University

**Professor John Pandolfi**  
*Leader, Research Program 2*  
University of Queensland

**Dr Verena Schoepf** (to May 2019)  
*Leader, Research Program 2*  
University of Western Australia

**Associate Professor Maja Adamska**  
*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 Malcolm McCulloch** *FAA FRS*  
*Deputy Director*  
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

## MEMBERSHIP

In 2019, the ARC Centre's membership comprised: 69 Chief Investigators, Research Fellows and Associates; 30 Partner Investigators, resident international scholars and adjunct researchers; and 170 research students (p42). Nine of the Centre's Research Fellows were funded by ARC Fellowships (Australian Laureate, Future and DECRA) and one by an Advance Queensland Fellowship.

In 2019, the ARC Centre welcomed ten new Research Fellows and Associates: Brock Bergseth, Iain Caldwell, Jamie Caldwell, Gal Eyal, Vanessa Haller, Hugo Harrison, Sun Kim, Jacqueline Lau, Veronica Radice and Sharon Wismer. Five of these new recruits are women, and the Centre has achieved its target of 50:50 gender equity in research fellow recruitment.

We also said farewell to ten researchers in 2019 who have taken up new positions around the globe, further extending the ARC Centre's network of alumni collaborators: Kay Critchell, Thomas DeCarlo, Juan Pablo D'Olivo Cordero, Nils Krueck, Michael McWilliam, Oliver Mead, Aurélie Moya, Verena Schoepf, Andrew Song, and Erin Vaughn. We wish them well in their future research careers!

## CHIEF INVESTIGATORS AND RESEARCH FELLOWS

**Professor Terry Hughes**  
*Centre Director*, James Cook University

**Associate Professor Maja Adamska**  
*ARC Future Fellow*, Australian National University

**Dr Jorge Álvarez-Romero**  
*Research Fellow*, James Cook University

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

**Dr Natalia Andrade Rodriguez**  
*Research Associate*, James Cook University

**Professor Andrew Baird**  
*Chief Investigator*, James Cook University

**Dr Michele Barnes**  
*Discovery Early Career Researcher Award (DECRA)*, James Cook University

**Professor David Bellwood**  
*ARC Australian Laureate Fellow, Chief Investigator*, James Cook University

**Dr Brock Bergseth**  
*Research Fellow*, James Cook University

**Dr Yves-Marie Bozec**  
*Research Fellow*, University of Queensland

**Dr Tom Bridge**  
*Discovery Early Career Researcher Award (DECRA)*, James Cook University and Queensland Museum

**Professor Jon Brodie**  
*Research Fellow*, James Cook University

**Dr Iain Caldwell**  
*Research Fellow*, James Cook University

**Dr Severine Choukroun**  
*Research Associate*, James Cook University

**Professor Joshua Cinner**  
*ARC Future Fellow*, James Cook University

**Professor Sean Connolly**  
*Chief Investigator*, James Cook University

**Dr Peter Cowman**  
*Discovery Early Career Researcher Award (DECRA)*, James Cook University

**Dr Kay Critchell**  
*Research Associate*, University of Queensland

**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**  
*ARC Future Fellow*, James Cook University

**Associate Professor Sophie Dove**  
*Chief Investigator*, University of Queensland

**Dr Alana Grech**  
*Research Fellow*, James Cook University

**Dr Rebecca Green**  
*Research Associate*, University of Western Australia

**Dr Georgina Gurney**  
*Research Fellow*, James Cook University

**Dr April Hall**  
*Advance Queensland Research Fellow*, James Cook University



PHOTO DEBORAH BURN

**Dr Vanessa Haller**

Research Associate, University of Queensland

**Dr Hugo Harrison**

Discovery Early Career Researcher Award (DECRA), James Cook University and Australian Institute of Marine Science

**Associate Professor Scott Heron**

Research Associate, James Cook University

**Dr Karlo Hock**

Research Fellow, University of Queensland

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In 2019, researchers from the ARC Centre of Excellence produced 411 publications, comprising 363 journal articles, 4 books, 31 book chapters, 5 conference proceedings, and 8 reports. Since 2014, annual publications have increased by >30%, exceeding one each day.

Centre researchers published 166 articles in journals that have an Impact Factor greater than four, including 39 outputs this year in prestige journals – *Nature* and other *Nature* journals, *Science*, *Trends in Ecology and Evolution*, *Science Advances*, *Molecular Biology and Evolution*, *Proceedings of the National Academy of Sciences*, *Frontiers in Ecology and the Environment* and *Global Environmental Change*. The average Impact Factor for all 363 journal articles in 2019 was 5.7. The Centre's research outputs were published this year in a total of 187 journal titles that span many fields of research, reflecting the multidisciplinary breadth of the Centre's activities.

According to *Scopus*, Centre researchers were cited 41,036 times in 2019. Thirty-two researchers were cited more than 500 times each, and 22 had more than 1000 citations during the year.

Articles published in 2019 that received the highest Altmetric scores for ARC Centre publications were:

Hughes, TP, Kerry, JT, Baird, AH, Connolly, SR, Chase, TJ, Dietzel, A, Hill, T, Hoey, AS, Hoogenboom, MO, Jacobson, M, Kerswell, A, Madin, JS, Mieog, A, Paley, AS, Pratchett, MS, Torda, G and Woods, RM (2019). [Global warming impairs stock-recruitment dynamics of corals](#). *Nature* 568(7752): 387-390.

**Altmetric:** 4631 (referenced by 1 policy source, 47 news outlets, Tweeted by 6239, ranked #14 in the Altmetric Top 100 of 2019)

Hughes, TP, Kerry, JT, Connolly, SR, Baird, AH, Eakin, CM, Heron, SF, Hoey, AS, Hoogenboom, MO, Jacobson, M, Liu, G, Pratchett, MS, Skirving, W and Torda, G (2019). [Ecological memory modifies the cumulative impact of recurrent climate extremes](#). *Nature Climate Change* 9(1): 40-43.

**Altmetric:** 4098 (referenced by 1 policy source, 100 news outlets, Tweeted by 4773, ranked #22 in the Altmetric Top 100 of 2019)

Hoegh-Guldberg, O, Jacob, D, Taylor, M, Bolaños, TG, Bindi, M, Brown, S, Camilloni, I, Diedhiou, A, Djalante, R and Ebi, K (2019). [The human imperative of stabilizing global climate change at 1.5°C](#). *Science* 365(6459): 1-13. **Altmetric:** 780 (picked up by 29 news outlets, Tweeted by 774)

Hicks, CC, Cohen PJ, Graham, NA, Nash, KL, Allison, EH, D'Lima, C, Mills, DJ, Roscher, M, Thilsted, SH, and Thorne-Lyman, AL (2019). [Harnessing global fisheries to tackle micronutrient deficiencies](#). *Nature* 574:95-98. **Altmetric:** 656 (picked up by 25 news outlets, Tweeted by 654)

Leggat, WP, Camp, EF, Suggett, DJ, Heron, SF, Fordyce, AJ, Gardner, S, Deakin, L, Turner, M, Beeching, LJ, Kuzhiumparambil, U, Eakin, CM and Ainsworth, TD (2019). [Rapid coral decay is associated with marine heatwave mortality events on reefs](#). *Current Biology* 29(16): 2723-2730.

**Altmetric:** 624 (picked up by 50 news outlets, Tweeted by 223)

Darling, ES, McClanahan, TR, Maina, J, Gurney, GG, Graham, NAJ, Januchowski-Hartley, F, Cinner, JE, Mora, C, Hicks, CC, Maire, E, *et al* (2019). [Social-environmental drivers inform strategic management of coral reefs in the Anthropocene](#). *Nature Ecology and Evolution* 3:1341-1350.

**Altmetric:** 679 (19 news outlets, Tweeted by 681)

Brandl, SJ, Tornabene, L, Goatley, CHR, Casey, JM, Morais, RA, Côté, IM, Baldwin, CC, Parravicini, V, Schiethkatte, NMD and Bellwood, DR (2019). [Demographic dynamics of the smallest marine vertebrates fuel coral reef ecosystem functioning](#). *Science* 364:1189-1192.

**Altmetric:** 565 (34 news outlets, Tweeted by 435)

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- Loya, Y, Puglise, K and Bridge, TC (2019). Mesophotic coral ecosystems. Coral Reefs of the World (Vol. 12). Springer, Switzerland, 1-1003 pp.

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- Achlatis, M, Pernice, M, Green, K, de Goeij, JM, Guagliardo, P, Kilburn, MR, Hoegh-Guldberg, O and Dove, S (2019). Single-cell visualization indicates direct role of sponge host in uptake of dissolved organic matter. *Proceedings of the Royal Society B: Biological Sciences* 286(1916): 20192153.
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## 2020 ACTIVITY PLAN

Note added in press: This Activity Plan for 2020 was developed well in advance of the COVID-19 pandemic. It will be modified in response to the pandemic's effects on Centre personnel, and restrictions on travel and other activities.

### 1. RESEARCH

- a. Conduct world-leading, innovative research that consolidates the Centre's international profile.
- b. Implement strategic recruitment and workforce establishment to support research program directions.
- c. Grow the Centre's research project 'Coral Reefs in the Anthropocene', with an emphasis on an interdisciplinary approach to governance, resilience and adaptation.
- d. Assess coral bleaching outlook on the Great Barrier Reef and worldwide, and extend research in this area, targeting high profile journals, especially *Science* and *Nature*.
- e. Present 125 talks, and have a high-profile presence at the quadrennial *International Coral Reef Symposium* (ICRS2020) in Bremen, Germany in July 2020.

### 2. RESEARCH TRAINING AND PROFESSIONAL DEVELOPMENT

- a. Deliver professional development workshops on statistics, publishing skills and strategies, scientific writing, networking at conferences, effective scientific presentations and career pathways.
- b. Collaborate with the Student Committee of the International Coral Reef Society to develop professional development programs at the ICRS2020.
- c. Support and promote the research of ARC Centre students and Early Career Researchers presenting at ICRS2020.
- d. Continue to progress a leadership development program for women in STEM, for PhD students and Research Fellows.
- e. Deliver workshops to address unconscious bias and gender stereotypes.
- f. Provide mentoring and coaching to early career researchers, in development of research proposals and award applications.

### 3. NATIONAL AND INTERNATIONAL LINKAGES

- a. Grow strategic, value-adding, international collaborations and partnerships.
- b. Strengthen the Centre's research partnership with WorldFish on small-scale fisheries, including the recruitment of a fifth research fellow based at the ARC Centre.
- c. Increase visiting scholar programs, working group meetings and co-tutelle PhD student arrangements with international partners and collaborators.
- d. Extend multi-institutional and/or multi-disciplinary supervisory arrangements for Centre students.

### 4. IMPACTS AND END USER ENGAGEMENT

- a. Showcase the ARC Centre's achievement over two ARC funding cycles.
- b. Pursue additional contract research with Australian and State governments, helping to provide high quality research to inform policy and decision-making.
- c. Continue to engage with government and stakeholders to provide the science that underpins the *Reef 2050 Long-Term Sustainability Plan*.
- d. Promote the impact of the Centre's research at the quadrennial *International Coral Reef Symposium* in Bremen, Germany.
- e. Build the Centre's social media engagement strategies with an aim of exceeding 10,000 followers on Twitter.

### 5. GOVERNANCE

- a. Appoint a new Chair of the Centre's Advisory Board and expand membership to reflect the Centre's changing research directions, and to assist strategic planning.
- b. Renew research program leadership roles on the Scientific Management Committee, to facilitate succession planning.
- c. Review the Centre's Strategic Plan for business continuity post ARC Centre of Excellence funding to strengthen and diversify income sources.
- d. Mentor female researchers and mid-career researchers into leadership roles in the Centre.
- e. Continue developing a Centre culture that values diversity, gender equity and the family.
- f. Update the Centre's KPI targets in view of strong performance.



PHOTO ROBERT STREIT

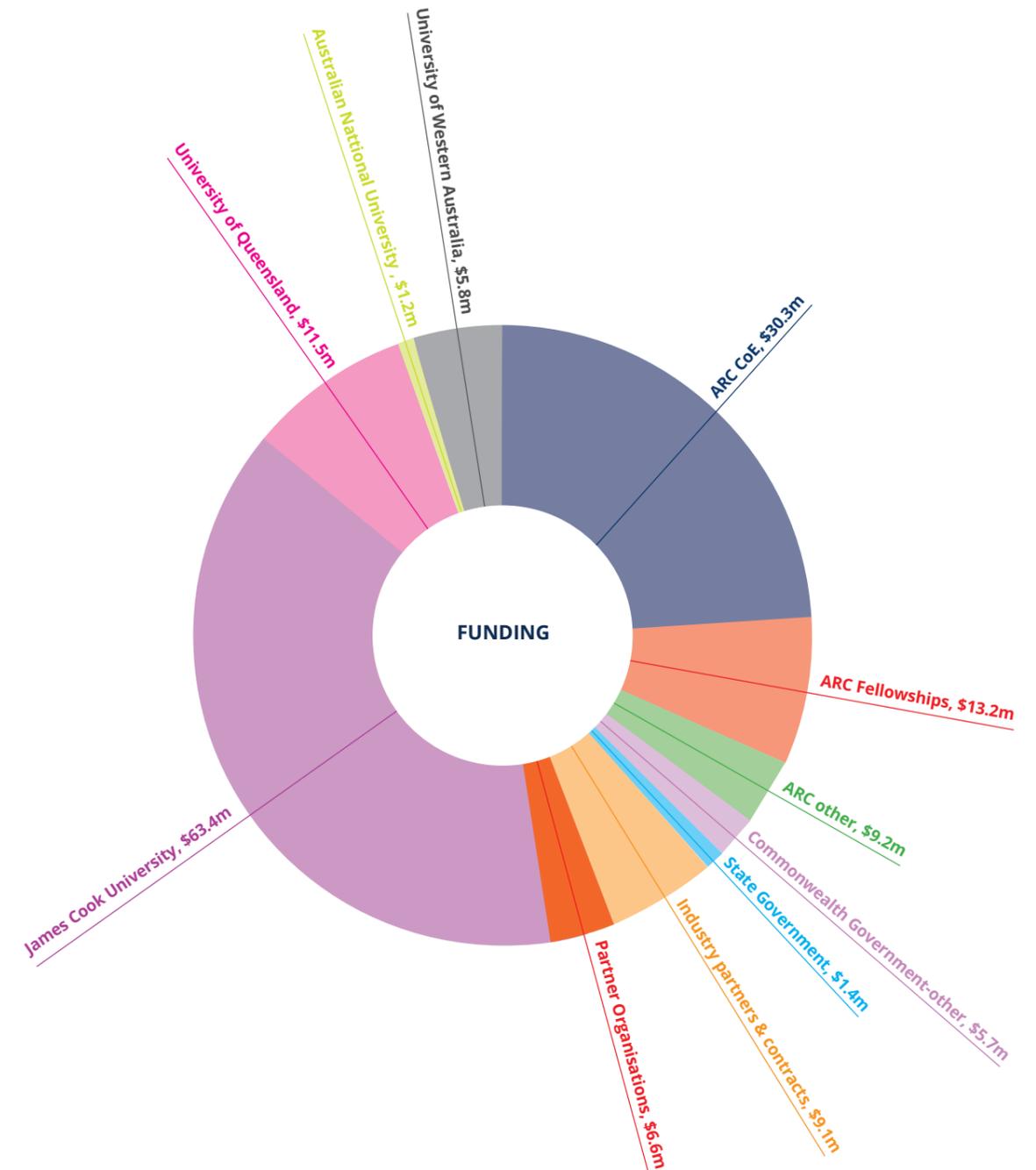
## FINANCIAL STATEMENT

### ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES STATEMENT OF OPERATING INCOME AND EXPENDITURE FOR YEAR ENDED 31 DECEMBER 2019

	2018	2019	2020 forecast
	\$	\$	\$
<b>Income</b>			
ARC Centre Grant	\$4,394,936	\$4,478,439	\$4,559,049
ARC Fellowships	660,724	735,407	721,732
ARC Other	123,773	135,812	
Host Institutions cash support	3,909,991	4,037,115	3,701,794
State Government		49,469	66,309
Commonwealth Government other grants	564,950	553,978	547,754
International and other contracts	1,173,993	938,311	713,376
<b>Total Income</b>	<b>\$10,828,367</b>	<b>\$10,928,532</b>	<b>\$10,310,014</b>
<b>Expenditure</b>			
Salaries	\$7,709,719	\$7,763,010	\$7,840,641
Equipment	482,849	410,628	369,565
Travel	1,431,301	1,395,438	976,807
Research maintenance and consumables	1,328,190	1,301,775	1,171,598
Scholarships and prizes	169,268	190,504	192,409
Public outreach and administration	129,245	122,046	97,637
<b>Total Expenditure</b>	<b>\$11,250,572</b>	<b>\$11,183,402</b>	<b>\$10,648,657</b>
<b>Surplus (Deficit)</b>	<b>\$(422,205)</b>	<b>\$(254,870)</b>	<b>\$(338,643)</b>

## FINANCIAL OUTLOOK

As at December 2019, 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 \$157.3m, 29% higher than when the Centre was established in 2014. The ARC Centre of Excellence grant represents 19% of the total funding pool.



## KEY PERFORMANCE INDICATORS

### STANDARD KEY PERFORMANCE INDICATORS FOR ARC CENTRES OF EXCELLENCE

Performance Measure	Target 2019	Outcome 2019
<b>Number of research outputs</b>		
• Journal articles/books/book chapters (p74)	340	<b>411</b>
• Published Data sets	35	<b>43</b>
<b>Quality of research outputs</b> (p73) Publications in journals with Impact Factor >4	100	<b>166</b>
<b>Mean Impact Factor for journals published</b>	4.6	<b>5.7</b>
<b>Citations: total by Centre researchers</b>	30,000	<b>41,036</b>
<b>Centre researchers with &gt;500 annual citations</b>	22	<b>32</b>
<b>Awards and prizes</b> (p8)	30	<b>43</b>
<b>Number of training courses held/offered by the Centre</b> (p42) (over and above the standard courses offered by institutions)	27	<b>32</b>
<b>Number of workshops/conferences held/offered by the Centre</b> (p42)	15	<b>23</b>
<b>Number of additional researchers working on Centre research</b> (p69)		
• Postdoctoral researchers	8	<b>10</b>
• PhD students	25	<b>19</b>
• Masters by research/coursework students	8	<b>13</b>
• Honours students	4	<b>7</b>
<b>Number of postgraduate completions</b> (p42)		
• PhD students	25	<b>27</b>
• Masters by research/coursework students	8	<b>12</b>
• Honours students	4	<b>7</b>
<b>Number of mentoring programs offered by the Centre</b> (p42)	12	<b>16</b>
<b>Number of presentations/briefings</b> (p62)		
• To the public	40	<b>75</b>
• To government/agencies/industry/business/end-users/NGOs (national and international) (in addition to workshops/conferences above)	80	<b>108</b>
<b>Number of new organisations collaborating with, or involved in, the Centre</b>	45	<b>154</b>

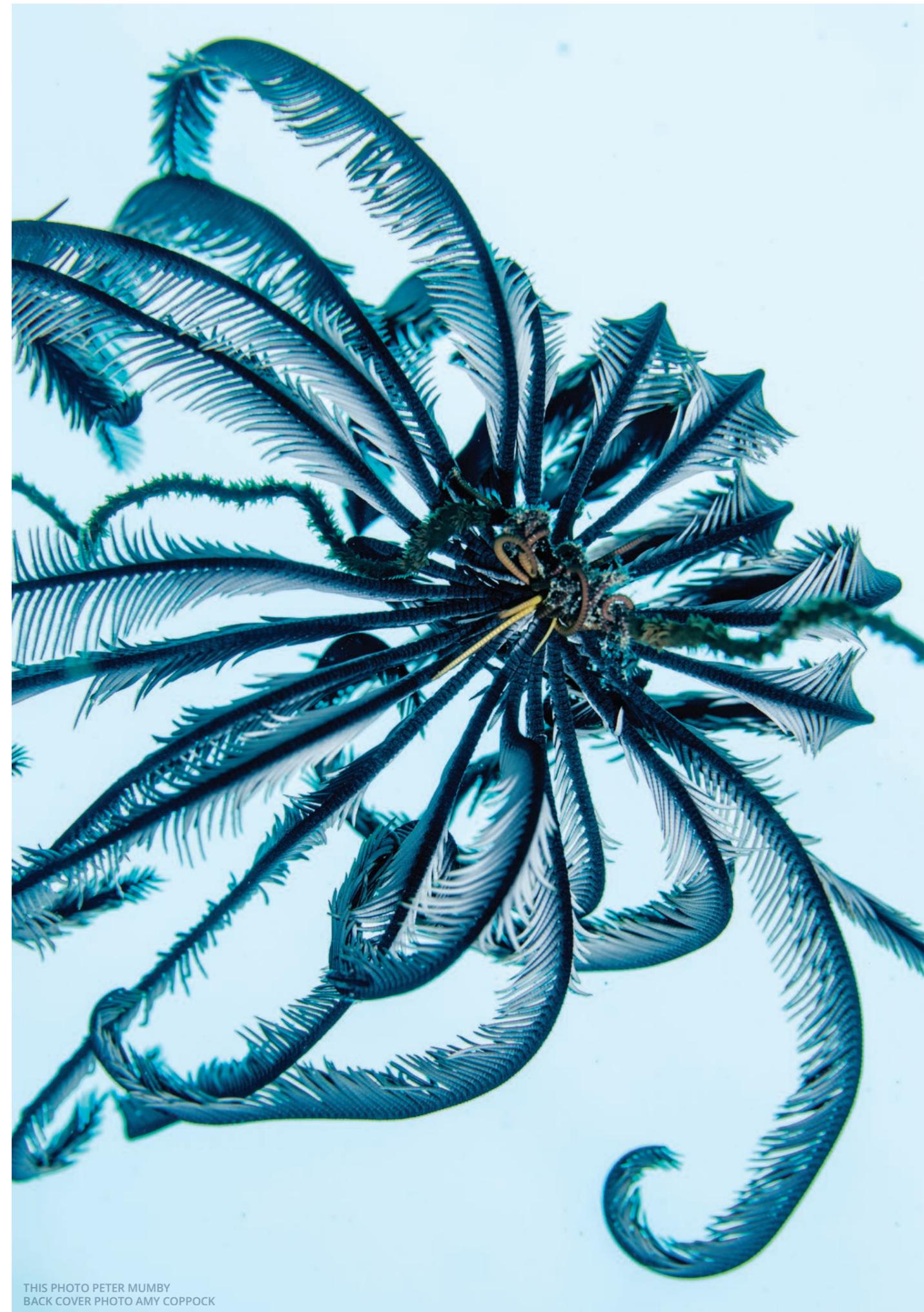
### CENTRE-SPECIFIC KEY PERFORMANCE INDICATORS

Performance Measure	Target 2019	Outcome 2019
<b>Publications</b> (p73) Prestige publications (e.g. Nature, Science, PNAS)	100 over life of Centre	<b>39 (168 to date)</b>
<b>Interdisciplinarity of research</b>		
• No. of journal titles in which Centre of Excellence research published (p73)	105	<b>187</b>
• No. of students with multi-disciplinary supervisory arrangements (p42)	52	<b>52</b>
<b>Centre integration</b>		
• No. of publications with cross-institutional co-authorship	190	<b>313</b>
<b>Global reach</b>		
• No. of countries where Centre undertakes field research	25	<b>28</b>
• No. of international co-authors	320	<b>1,540</b>
• No. of invited talks/papers/keynotes at international meetings	27	<b>42</b>
<b>Media</b> (p62)		
• Commentaries about the Centre's achievements	4,200	<b>5,500</b>
• Articles	26	<b>35</b>
• Centre of Excellence Website hits	7.5m	<b>11.8m</b>
<b>International visitors</b> (p56)	75	<b>79</b>
<b>Gender equity</b>		
• Research Fellow appointments (p69)	50:50	<b>50:50</b>
• Gender equity and diversity mentoring, and training activities: no. of participants and attendances (p42)	25	<b>27</b>

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- Australian Academy of Science
- Australian Centre for International Agricultural Research (ACIAR)
- Australian Government: Department of the Environment and Energy
- Australian Institute of Marine Science (AIMS)
- Australian Coral Reef Society
- Australian Marine Sciences Association
- Australian Museum
- Australian Society for Fish Biology
- Beijing Genomics Institute Australia
- Center for Ocean Solutions, Stanford University, USA
- Centre de Recherches Insulaires et Observatoire de l'Environnement (CRIOBE), French Polynesia
- Centre National de la Recherche Scientifique (CNRS), France
- Charles Darwin University, Australia
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Company of Biologists, UK
- Conservation International
- Coral Reef Research Foundation, Palau
- Deutsche Forschungsgemeinschaft, Germany
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- Musée national d'histoires naturelle, France
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- Museum für Naturkunde, Germany
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- National Oceanic and Atmospheric Administration (NOAA), USA
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- Queensland Museum Network
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- Wildlife Conservation Society, USA
- WorldFish, Malaysia
- World Wildlife Fund
- Yale Peabody Museum, USA



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